REPORT

Tonkin+Taylor

CentrePort Harbour Deepening Project

Assessment of potential effects on beach systems along east coast of Wellington Harbour

Prepared for
CentrePort Ltd

Prepared by
Tonkin & Taylor Ltd

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Executive summary

CentrePort Ltd (CentrePort) is investigating the deepening of the Wellington Harbour entrance shipping channel and the approach to, and berth at, the Thorndon Container Wharf (together called “the Project”). The purpose of the Project is to enable larger ships to access CentrePort, thereby maintaining CentrePort’s existing container service and providing for its future growth.

The purpose of this report is to assess the effect of the changes in wave height and direction on coastal processes along the eastern shores of the Wellington Harbour entrance from Pencarrow Head to Eastbourne.

There has been significant accretion along the shoreline from Pencarrow Head to Eastbourne over the last 100 to 150 years, which has covered the original sandy beach environment with gravels. At Rona Bay the advance was in the order of 50 to 70 m between 1904 and 2005 (Gibb, 2005). This accretion has been attributed to a pulse of gravels infilling the embayment between the Orongorongo River and Pencarrow Head from around 1941 and arriving along the Eastbourne shoreline in around 1985/86 and Days Bay in around 2008. The littoral system is still establishing along this area and has not reached equilibrium; the northern sections of the coastline are in transition from sandy to mixed sand gravel systems, particularly at Days and Rona Bays.

For the existing situation, there is a reduction in wave energy from the open coast (i.e., Pencarrow) northwards. The predicted changes in the average wave heights after dredging at the northern end of Eastbourne to Lowry Bay have no effect in terms of coastal process effects, because the existing average wave height of 0.2 m is not sufficient to initiate movement of coarse sands and gravels that form the majority of the beach material at these locations.

The results of this analysis showed that the dredging will not change the trend of gradual accretion within the bays and gravels moving further to the north, but the rate of change is likely to reduce (i.e. slower rates of deposition and alongshore sediment transport) apart from the shoreline immediately to the south of Camp Bay that might experience slightly greater rates of accretion.

Therefore any adjustment in the coastline as a result of the channel dredging programme is likely to be within the natural range of beach profile fluctuation experience on this coast. The main change will be in the rate of longshore transport with a general reduction in the rate of change likely to be observed. This will result in slower net changes in coastal processes.

1 Purpose

As an international port, CentrePort, situated in Wellington Harbour, is critical to the economy of central New Zealand (a region that includes the lower half of the North Island and the top of the South Island and that contributes 27% of national GDP). It is important this region maintains strong international connections to ensure it remains competitive and can grow.

While Wellington Harbour is a naturally deep water harbour, the current harbour entrance shipping channel, berth and berth approach depths restrict ships with draughts over 11.6m. The overall Project Aim is to enable CentrePort to deepen the shipping channel in the Wellington harbour and berth at, the Thorndon Container Wharf (together called “the Project”) in order to meet the long term needs of its customers.

The purpose of the Project is to enable larger ships to access CentrePort, thereby maintaining CentrePort’s existing container service and providing for its future growth. Globally, container ships are increasing in size and most major New Zealand ports are preparing for their potential arrival. Based on navigation modelling and channel optimization studies, the proposed entrance channel depth required for the 14.5 m laden draft design vessel varies from 16.5 m to 17.2 m below Chart Datum based on a sloped channel descending to the south. However a staged approach to the channel deepening is being sought due to the uncertainty of timing when the maximum drafts will be required.

CentrePort commissioned MetOcean Solutions Ltd (MSL) to complete detailed studies of the oceanographic and sediment processes operating in this area to support and inform the Project. These studies included modelling the existing hydrodynamic (tide and wave) and sediment processes operating within the entrance to the harbour and within the harbour itself, evaluating the changes to these processes as a result of the Project. The hydrodynamic modelling carried out by MSL (2015) identified that there is an increase in wave energy along the western shorelines to the entrance of Wellington Harbour as a result of increased wave refraction resulting from the dredged channel and an associated decrease in energy along the coast on the eastern shoreline. These changes have the potential to change alongshore drift and the associated patterns of accretion and erosion along both the western and eastern shorelines. Tonkin + Taylor (T+T) calculated the alongshore drift using nearshore wave climate information provided by MSL for the existing situation and the post dredged channel situation and compared the differences in shoreline evolution using the numerical model UNIBEST.

An evaluation of the effects on coastal processes of Seatoun Beach and the beaches at Worser and Scorching Bay has been reported under separate cover (T+T 2016). The purpose of this report is to assess the effect of the changes in wave height and direction on coastal processes along the eastern shores of Wellington Harbour from Pencarrow Head to Eastbourne on the east coast (refer Figure 1-1).

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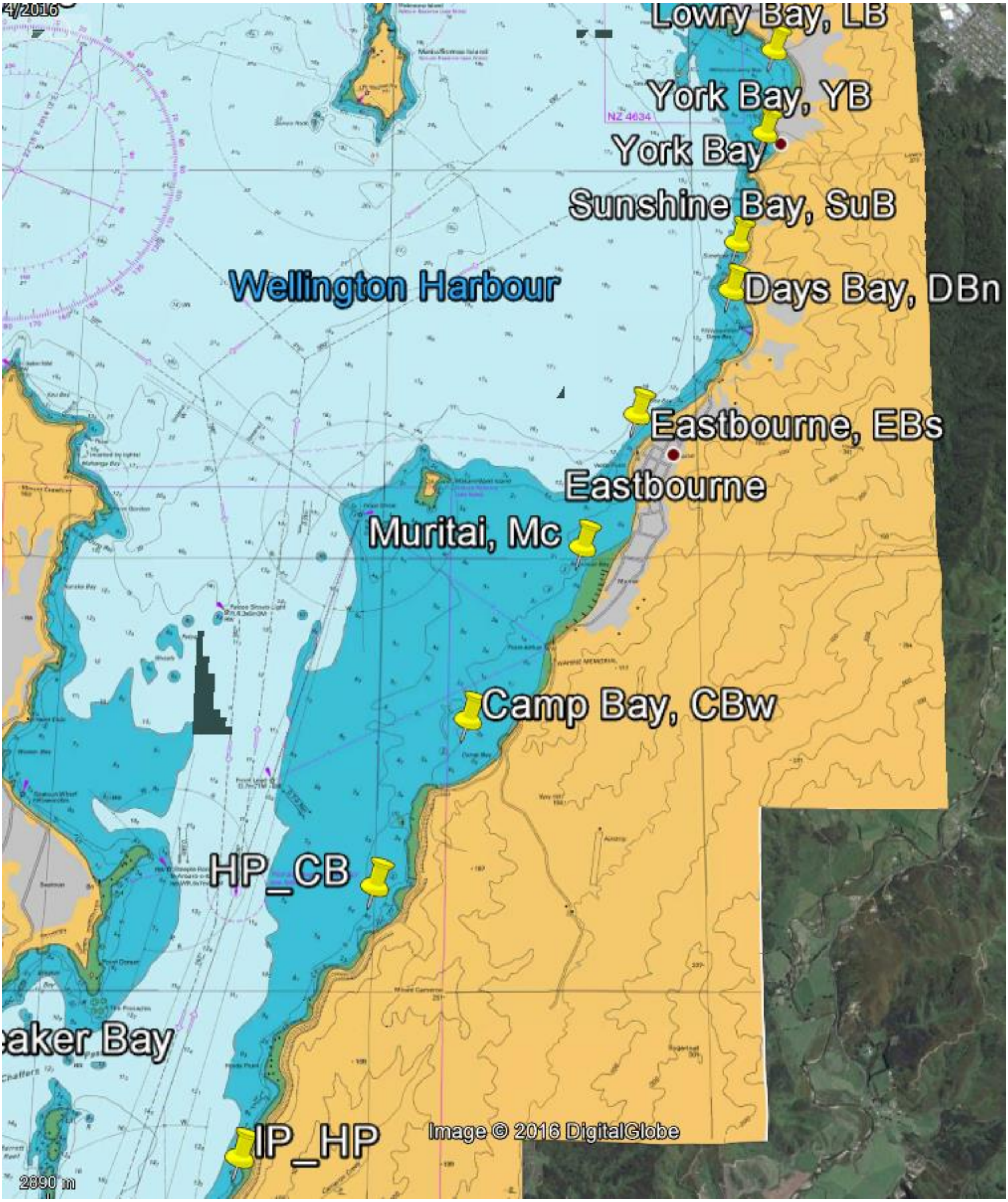


Figure 1-1 Entrance to Wellington Harbour showing embayments and wave output points along the eastern shores (Source: Google Earth and LINZ Chart NZ4633)

2 Setting

2.1 Physical setting

The Wellington Harbour entrance is an 8.5 km long, northward extension of the inner shelf that connects with the 20 – 30 m deep harbour basin (refer Figure 1-1). It is flanked by hills formed of greywacke rock with mixed sand and gravel beaches along the eastern shores and beaches transitioning from gravels to sand from south to north along the Miramar Peninsula.

The entrance channel runs along the centre of the entrance with an irregular pinnacle-studded western flank and a shallow (< 5 m) eastern platform that reaches a maximum width off Eastbourne (Carter & Lewis, 1995). The east coast consists of a series of embayed beaches separated by rocky headlands. The coastal plains and beaches that are situated along the east coast comprise sand and gravels derived from the Orongorongo River. Sands and gravels are transported along the coast by wave driven longshore transport, while finer sands are transported sub-tidally into the harbour entrance forming the shallow flood shoals between Camp Bay and Eastbourne (refer Figure 2-1).

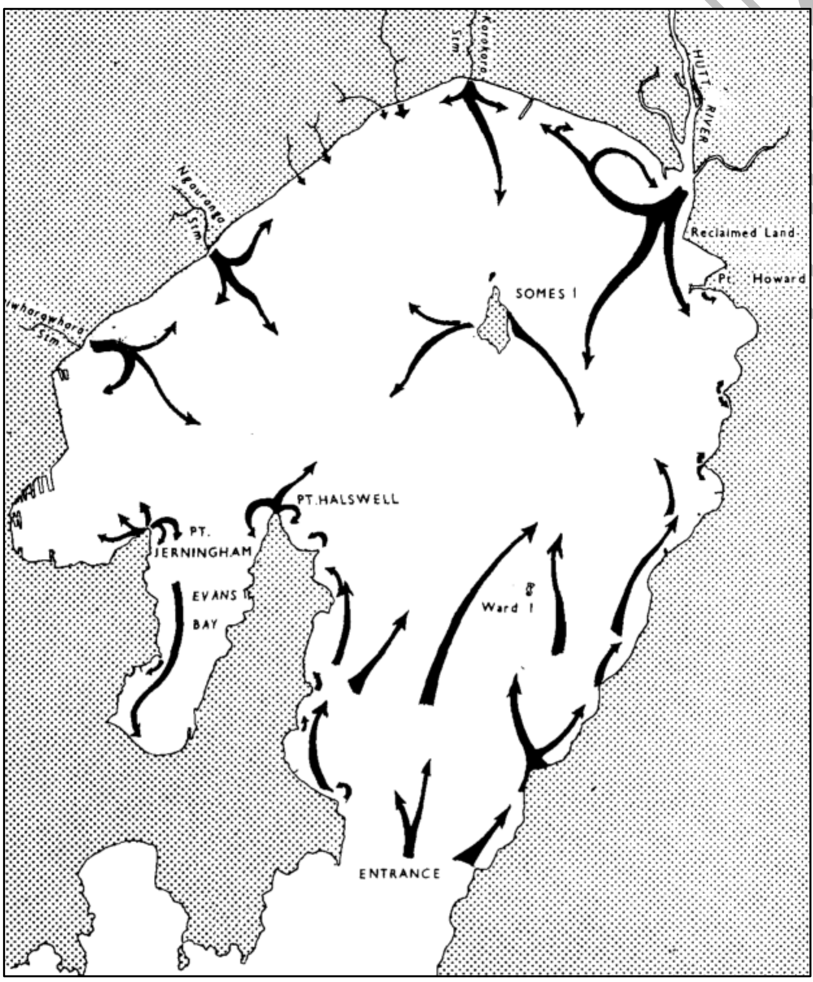


Figure 2-1 Supply and transport directions of sediment in Wellington Harbour (Source: van der Linden, 1967)

There has been significant accretion along the shoreline from Pencarrow Head to Eastbourne over the last 100 to 150 years covering the original sandy beach environment with gravels, with 50 to 70 m of accretion recorded at Rona Bay from 1904 to 2005 (Gibb, 2005). This has been attributed to a pulse of gravels infilling the embayment between the river and Pencarrow Head from around 1941 and arriving along the Eastbourne shoreline in around 1985/86 and Days Bay in around 2008 (see Figure 2-2).

This pulse of gravel is attributed to the 1855 Wairarapa Earthquake and land use changes. The earthquake is thought to have provided material through uplift of nearshore sediments and increased sediment yields from rivers through landslips etc. in the river catchments (Dahm, 2009). It is expected that this supply is largely exhausted, with the present day input of sediment from the Orongorongo River estimated to be around 22,000 m^3/year (Matthews, 1980).

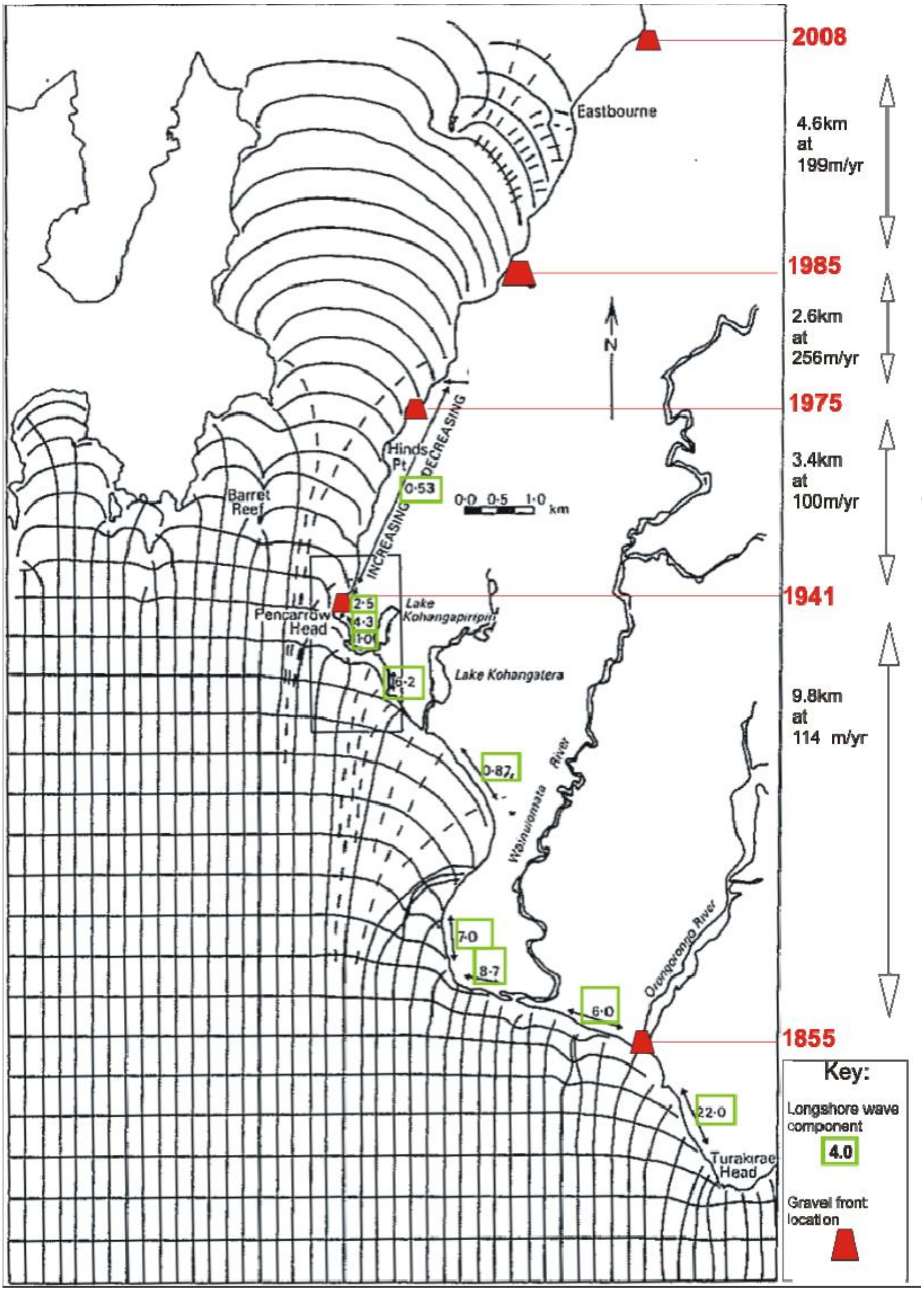


Figure 2-2 Location of the northern extent of the gravel front through time showing the relative migration rates of gravel in relation to wave refraction and the reduction in alongshore transport (Source: Olson, 2009)

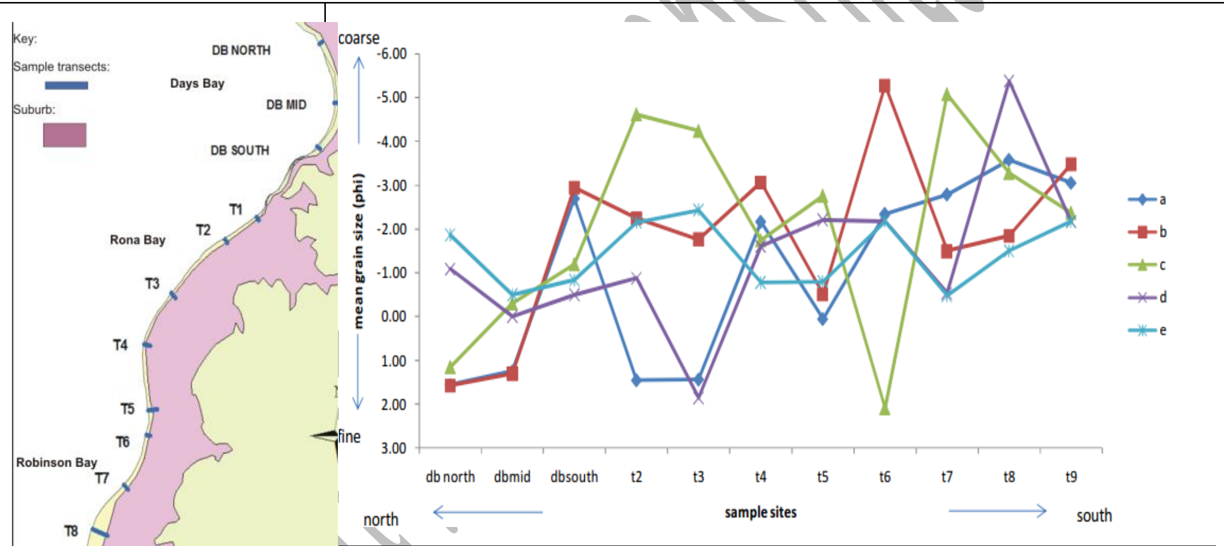
Days Bay currently represents the northward limit of the littoral drift system that transports gravel along the entire Eastbourne coastline, from the harbour mouth (Olson, 2009). This gravel front has been migrating progressively northward since the 1855 earthquake and has now only just reached the Days Bay embayment. Gravels are transported primarily in the intertidal zone, while sand can move sub-tidally, down to the limit of wave action on the sea bed. This means that sand-sized sediment was able to bypass the rocky headlands and therefore accumulate in Days Bay, while gravel-size material had to infill the various embayments to the south before it could be transported into the next bay. This likely explains the initial presence of sand in Days Bay, being deposited before the gravels.

The littoral system is still establishing along this area and has not reached equilibrium as the northern sections of the coastline are in transition from sandy to mixed sand gravel systems, particularly at Days and Rona Bays (Olson, 2009).

2.2 Beach and sediment properties

Beaches in this area tend to be reasonably steep, between 6 and 11 degrees which is equivalent to 5(H):1(V) to 10(H):1(V) (Matthews, 1980). Sediments in this system are classed as mixed sand gravels, with predominantly gravels and cobble size sediments at Pencarrow Head to a mix of sand and gravels, with the proportion of sand increasing towards Days Bay.

The measured longshore variation in grain size from Muritai to Days Bay (Figure 2-3, from Olson 2009) shows a general trend of sediment size reduction from T9 at the south to Days Bay in the north, but there is still a wide range of grain sizes recorded. In the swash zone ("e" on Figure 2-3), sediments increase from around 4 mm in the south to around 2 mm in the north, but there are larger gravels on the upper part of the beach (zones a to c).



Phi (Φ)	-6	-5	-4	-3	-2	-1	0	1	2
mm	64	32	16	8	4	2	1	0.5	0.25

Figure 2-3 Location of sediment sample transects and results of grading analysis measured in phi (Φ), with "a" to "e" representing samples located from the most landward (a) to the most seaward (e) extent of the transect (Source: Olson, 2009). [Note: sediment size is presented in terms of phi (Φ) which is a scale based on the Udden-Wentworth system of universal size grading where size grades are separated by factors of two based on a grain size centre of 1.0 mm (to convert, mm = $2^{-\Phi}$); see table, inset]

2.3 Reported wave height changes

Detailed modelling of the effects of channel deepening on the waves is reported in MSL (2015), particularly in Section 5.2.2. MSL modelled wave climate change for two channel depth options which provided 98% (optimised channel depth) and 100% operability by the design ship for wave and currents. The assessment of different channel depths also allowed an assessment to be made whether a shallower channel made any difference to the nearshore wave energy.

Comparisons of wave height were made at several locations as shown in Figure 2-4, including at Seaview Wharf, off Point Howard (P4), Robinson Bay (P2) and Camp Bay (P2) along the east coast of Wellington Harbour and at Barrett's Reef at the entrance to Breaker Bay (P7). A comparison of the wave heights from existing to the 98% and 100% operability conditions is shown in Figure 2-4.

These plots show no change in wave climate at Seaview Wharf and a reduction in wave energy at Robinson Bay and Camp Bay. This suggests that there will be little change in existing coastal processes observed in the vicinity of Seaview Wharf, but further consideration of the extent and effect of a reduced wave climate is required along the coastline in the vicinity of Robinson Bay and Camp Bay.

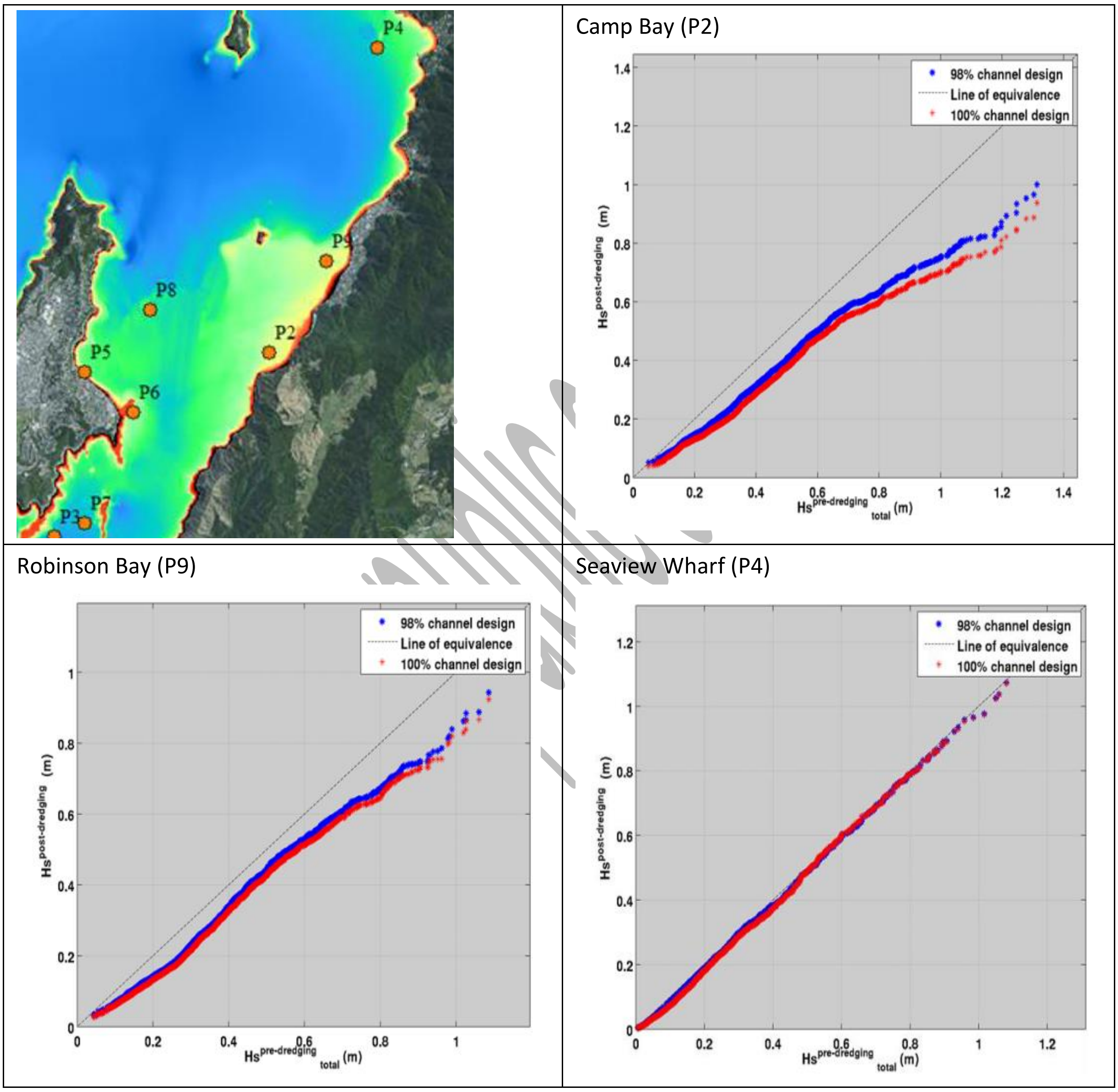


Figure 2-4 Quantile-quantile plots of total significant wave height (H_s) at P2, P4, and P9 (Source: MSL, 2016)

3 Assessment of potential impact on shoreline change

This section presents the methodology and results of identifying the extent of possible changes and the effect of a reduced wave climate. The first step involved an assessment of the modelled changes in wave climate between the existing and post-dredge situations. The assessment considers whether the observed changes in wave height and direction make a material difference on alongshore sediment transport rate and then whether the difference in transport rate has a material effect on the variation in shoreline position currently experienced. Where there are changes in wave height and direction that have a material effect on the shoreline position that is greater than the existing variability in shoreline position, this affect is considered significant. Where changes are within the expected variability in shoreline position, the effects are not significant.

3.1 Wave data

To provide a more detailed assessment of wave height along the shoreline, nearshore wave data for a representative year were provided by MSL at 15 locations along the shoreline at around the 5 m depth contour (see Figure 1-1) for the existing situation and for the situation after dredging for the 14.5 m draught vessel option. The wave roses at each location are shown in Appendix A. A summary of the mean and maximum wave height for the existing situation and with the dredged channel is shown in Table 3-1.

Table 3-1 Changes in mean and maximum wave heights

Location	Output point ref.	Coast angle (degrees wrt N)	Existing situation		With dredged channel		Change (%)	
			Mean wave height (m)	Max wave height (m)	Mean wave height (m)	Max wave height (m)	Mean wave	Max wave
Lake Kohangapiripiri Beach	LK	126	1.1	3.1	1.1	3.0	0.0%	-3.2%
Pencarrow Head Beach	PH	130	0.7	2.4	0.7	2.4	0.0%	0.0%
Pencarrow to Inconstant Point	PH_IP	8	0.5	2.8	0.5	2.9	0.0%	3.6%
Inconstant Point to Hinds Point	IP_HP	39	0.5	2.6	0.6	2.8	20.0%	7.7%
Hinds Point to Camp Bay	HP_CB	6	0.4	1.9	0.4	1.7	0.0%	-10.5%
Camp Bay	CBw	49	0.4	1.4	0.3	1.1	-25.0%	-21.4%
	Cbe	10	0.4	1.2	0.3	1.1	-25.0%	-8.3%
Muritai, Robinson Bay	Ms	13	0.4	1.4	0.3	1.2	-25.0%	-14.3%
	Mc	23	0.3	1.2	0.3	1.1	0.0%	-8.3%
	Mn	172	0.2	1.0	0.3	1.1	50.0%	10.0%
Eastbourne, Rona Bay	Ebs	45	0.3	1.1	0.2	1.0	-33.3%	-9.1%
	Ebn	54	0.2	0.9	0.2	0.9	0.0%	0.0%
Days Bay	DBn	157	0.2	1.1	0.2	1.1	0.0%	0.0%

Location	Output point ref.	Coast angle (degrees wrt N)	Existing situation		With dredged channel		Change (%)	
			Mean wave height (m)	Max wave height (m)	Mean wave height (m)	Max wave height (m)	Mean wave	Max wave
Sunshine Bay	SuB	46	0.2	0.8	0.2	0.8	0.0%	0.0%
York Bay	YB	178	0.2	0.9	0.1	0.9	-50.0%	0.0%
Lowry Bay	LB	1	0.2	1.2	0.1	1.1	-50.0%	-8.3%
Note: Green shading indicates areas where absolute change in wave height is less than or equal to 0.1 m.								

3.2 Changes in wave height and direction

For the existing situation there is a reduction in wave energy from the open coast northwards, with the average wave height of 0.2 m north of Eastbourne. The results in Table 3-1 show that at most locations the absolute change as a result of the dredged channel, in both the average and maximum wave height values, is less than 0.1 m and the largest change is at Camp Bay for the maximum wave, where the is an 0.3 m reduction in maximum wave height.

There is no change to the average wave heights and only a small reduction in maximum wave height (3.2%) at the open coast to the entrance to the harbour (from Lake Kohangapiripiri Beach to Hinds Point) as a result of the dredging. There is a general reduction in both average and maximum wave height at Camp Bay to Eastbourne, although there are some areas where no significant reduction in either average or maximum wave height is observed (e.g. Muritai, Mc and Eastbourne, Ebn to Sunshine Bay), or even increases (e.g. Muritai, Mn).

The report on regionally significant surf breaks for Greater Wellington Regional Council (eCoast, 2015) identified that there are numerous left hand point breaks along the Eastbourne coast, with the best known being Pipes in Camp Bay. The report also noted that historic breaks along the coast has have been affected by gravel accretion. MSL (Report P0214-03, 2015) identified that the reduction in wave energy, particularly at Camp Bay, will reduce wave heights by around 25%. This reduction in wave height could reduce the potential surfable time from 29% to 6%.

The measured changes in the average wave height at the northern end of Eastbourne to Lowry Bay are insignificant in terms of coastal process effects as the existing average wave height of 0.2 m is not sufficient to cause movement of coarse sands and gravels that form the beaches at these locations.

Based on the wave rose plots (Appendix A) there is no change in wave direction that is likely to result in variations to existing alongshore sediment transport trends along the western shoreline from Pencarrow Head until Muritai (Mn). However, variations both in wave height and direction can affect alongshore sediment transport rates at these locations and this is assessed in the next section.

4 Sediment transport modelling

The numerical model UNIBEST (version 7.1) was used to assess the shoreline evolution of this coastal stretch. UNIBEST is a shoreline evolution package developed by Deltares (formerly Delft Hydraulics), a coastal research institute based in the Netherlands. UNIBEST is an engineering tool that can be applied for simulating the response of the nearshore zone of the shoreline where effects of wave breaking and wave driven longshore currents occur. The model is best suited to situations where gradients in longshore sediment transport capacity are responsible for the imbalance in sediment supply to, and transport from, the considered area so is appropriate at this location to consider potential changes resulting from changes in the annual wave climate. Modelling provides a means of assessing effects of the net long-term trends, rather than short term fluctuations such as seasonal effects and storm induced changes that typically are more cross-shore than longshore dominated. Actual shoreline positions can be dominated by these short-term fluctuations, so the results presented in this section should not be used as an accurate prediction of future shoreline position.

The UNIBEST_LT module was used in this assessment. Due to the low average wave heights offshore to the north of Days Bay, no change in wave height at Seaview Wharf (refer Figure 2-4), and this location being identified as the limit of northward sediment transport from the harbour entrance (Olson, 2009), sediment transport analysis was focussed along the shoreline to the south of Days Bay.

4.1 Sediment transport (UNIBEST_LT)

UNIBEST_LT is designed to compute tide and wave-induced longshore currents and sediment transport on any beach of arbitrary profile. Surf zone hydrodynamics are computed by a built-in random wave propagation and decay model based on the formulation of Battjes and Stive (1984).

The model transforms offshore wave data to the coast, taking into account the principal processes of wave energy changes due to refraction, shoaling and dissipation by wave breaking and bottom friction. In the model, the longshore current distribution across the beach profile is derived from the momentum equation alongshore (momentum has a direction and a magnitude and changes in momentum affect sediment transport), taking into account bottom friction and the gradient of radiation stress (the flux of momentum carried by waves that causes nearshore currents when waves break in the nearshore). A semi-analytical description of the wave induced, depth-mean averaged longshore current is used. This is derived through the breaking wave dissipation and using a linearized version of the bottom friction term for wave and current combined.

Sediment transport is calculated based on the physically fundamental concepts that the transport has a threshold of motion and there is a maximum capacity that a flow can carry. Sediment transport is assumed to respond to the local wave conditions in an instantaneous, quasi-steady way.

The transport analysis was carried out for the gravel sized sediment as this is the material that is transported along the intertidal zone, with sand transport typically occurring in the sub-tidal zone (Olson, 2009).

4.2 Longshore transport assessment

The alongshore transport analysis was carried out for the gravel sized sediment as this is the material that is transported along the intertidal zone. The coast angle, equilibrium coast angle and longshore transport capacity for the existing situation and with the proposed channel deepening are shown at each profile in Table 4-1. The coast angle is the angle (with respect to north) of a shore-normal beach profile at each location. The equilibrium coast angle shows the amount of shoreline rotation from the shore-normal beach profile orientation that is required to reduce alongshore transport rates of change to zero (i.e. no longshore transport). The transport capacity is the theoretical alongshore drift based on the grain size, wave height, period and duration. A negative transport is from north to south (i.e. towards the harbour entrance), while a positive transport is from south to north (i.e. towards Days Bay).

Potentially significant changes between existing and proposed coast angles and transport rates are the important matters to consider in this process. As the waves are grouped in direction "bins" of 22.58 (i.e. northerly waves are defined as coming from between 348.758 and 11.258), changes between the existing situation and with the dredged channel of less than 4.58 are, in reality, not likely to produce observable differences in coastal process behaviour at specific locations. Changes of this magnitude therefore can be considered to have no effects on long term coastal process trends.

Table 4-1 Net longshore gravel transport capacity and equilibrium coast angles at selected locations along the coast

Location	Output point ref.	Existing situation			With dredged channel	
		Coast angle (8 wrt N)	Difference between equilibrium coast angle and actual	Net transport capacity (m^3/yr)	Difference between equilibrium coast angle and actual	Net transport capacity (m^3/yr)
Inconstant Point to Hinds Point	IP_HP	39	39.0	70,000	39.0	76,000
Hinds Point to Camp Bay	HP_CB	6	-17.3	59,000	-17.0	40,000
Camp Bay	CBw	49	71.4	31,000	71.2	12,000
Muritai	Mc	20	42.1	28,000	42.3	12,000
Eastbourne	Ebs	25	56.3	10,000	62.6	8,000
Days Bay	DBn	151	14.2	7,000	14.6	7,000

Notes:

1. Green cells indicate changes in coast angle less than 4.58 and therefore change will be difficult to discern. Blue cells indicate changes greater than 4.58 where changes more likely to be noticeable.

This table shows:

- There is a slight increase in the frequency of waves of between 0.5 m and 0.8 m at the output point between Inconstant Point to Hinds Point that results in an increase in transport capacity with the dredged channel from 70,000 m^3/yr to 76,000 m^3/yr
- There is a reduction in net transport capacity from Inconstant Point to Days Bay both for the existing situation and with the dredged channel. This is due to the reduced wave energy propagating into the harbour and supports the findings of earlier studies summarised by Olson (2009).
- There is no change in equilibrium coast angle at any of the wave output points from the existing situation and with the dredged channel that is likely to change existing coastal process trends apart from at Eastbourne. At this location the change in coast angle means the shoreline is wanting to be more aligned to the south-west due to the greater wave energy from the south-west. However the 6.3 degree change in coast angle at this location is offset by lower rates of alongshore transport and therefore any changes are likely to be within the existing variability present at this location.

- Where the net transport capacity decreases from location to location this shows an area of potential accretion. For the existing situation the results show that there is around 11,000m^3/yr deposited from Inconstant Point to Hinds Point (i.e. 70,000 m^3/yr – 59,000 m^3/yr) and some 28,000 m^3/yr deposited from Hinds Point to Camp Bay (i.e. 59,000 m^3/yr – 28,000 m^3/yr). There is some 3,000 m^3/yr deposited between Camp Bay and Muritai, 18,000 m^3/yr deposited from Muritai to Eastbourne and 3,000 m^3/yr transported from Eastbourne to Days Bay.
- With the dredged channel there is a higher net transport along Inconstant Point to Hinds Point (IP_HP), but greater deposition from IP_HP to the coastal stretch from Hinds Point to Camp Bay (26,000 m^3/yr compared to 11,000 m^3/yr for the existing situation) but also a similar level of deposition from HP_CB and Camp Bay as experienced in the present day (28,000 m^3/yr). There is no change in transport gradient from Camp Bay to Muritai (both 12,000 m^3/yr meaning no deposition) and a reduced rate of change (4,000 m^3/yr) from Muritai to Eastbourne and 1,000 m^3/yr from Eastbourne to Days Bay.
- These results show that the dredging will not change the trend of gradual accretion within the bays and gravels moving further to the north, but the rate of change is likely to reduce (i.e. slower rates of deposition and alongshore sediment transport) apart from the shoreline immediately to the south of Camp Bay that might experience slightly greater rates of accretion. However, it is noted that supply is limited to around 22,000 m^3/yr, so effectively transport capacities greater than 22,000 m^3/yr mean that it is likely that all sediment entering the harbour at Pencarrow Head are likely to be rapidly transported northward and that dredging will not change this process.
- This means that there will not be any adjustment in the coastline as a result of the channel dredging programme. The main change will therefore be in the rate of longshore transport movement, which is predicted to be slower than currently experienced from Hinds Point to Eastbourne.

5 Summary and conclusions

The purpose of this report is to assess the effect of the changes in wave height and direction on coastal processes along the eastern shores of Wellington Harbour from Pencarrow Head to Eastbourne.

There has been significant accretion along the shoreline from Pencarrow Head to Eastbourne over the last 100 to 150 years, which has covered the original sandy beach environment with gravels. At Rona Bay the advance was in the order of 50 to 70 m between 1904 and 2005 (Gibb, 2005). This accretion has been attributed to a pulse of gravels infilling the embayment between the Orongorongo River and Pencarrow Head from around 1941 and arriving along the Eastbourne shoreline in around 1985/86 and Days Bay in around 2008. The littoral system is still establishing along this area and has not reached equilibrium; the northern sections of the coastline are in transition from sandy to mixed sand gravel systems, particularly at Days and Rona Bays.

For the existing situation, there is a reduction in wave energy from the open coast (i.e., Pencarrow) northwards. The predicted changes in the average wave heights after dredging at the northern end of Eastbourne to Lowry Bay have no effect in terms of coastal process effects, because the existing average wave height of 0.2 m is not sufficient to initiate movement of coarse sands and gravels that form the majority of the beach material at these locations.

The results of this analysis showed that the dredging will not change the trend of gradual accretion within the bays and gravels moving further to the north, but the rate of change is likely to reduce (i.e. slower rates of deposition and alongshore sediment transport) apart from the shoreline immediately to the south of Camp Bay that might experience slightly greater rates of accretion.

Therefore any adjustment in the coastline as a result of the channel dredging programme is likely to be within the natural range of beach profile fluctuation experience on this coast. The main change will be in the rate of longshore transport with a general reduction in the rate of change likely to be observed. This will result in slower net changes in coastal processes

6 Applicability

This report has been prepared for the benefit of CentrePort Ltd with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Tonkin & Taylor Ltd

Report prepared by: Authorised for Tonkin & Taylor Ltd by:

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Richard Reinen-Hamill Penny Kneebone

Coastal Engineer Project Director

RRH
https://extranet.buddlefindlay.com/sites/centreport/reports for consultation/beaches - eastern (eastbourne) .docx

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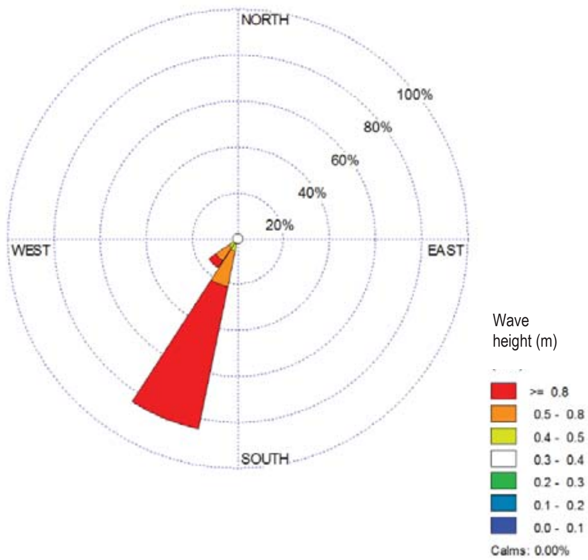
Appendix A: Wave roses at selected output points

Location	Ref.	Lat	Long	Coast angle (w.r.t. N)
Lake Kohangapiripiri Beach	LK	-41.367075°	174.854501°	126
Pencarrow Head Beach	PH	-41.361652°	174.848799°	130
Pencarrow Head to Inconstant Point	PH_IP	-41.353174°	174.850564°	8
Inconstant Point to Hinds Point	IP_HP	-41.346907°	174.853405°	39
Hinds Point to Camp Bay	HP_CB	-41.327323°	174.865974°	6
Camp Bay	CBw	-41.314611°	174.875196°	49
	Cbe	-41.309060°	174.880912°	10
Muritai, Robinson Bay	Ms	-41.303714°	174.883715°	13
	Mc	-41.300861°	174.887068°	20
	Mn	-41.297251°	174.889783°	172
Eastbourne, Rona Bay	Ebs	-41.289867°	174.892980°	44
	Ebn	-41.286155°	174.898880°	54
Days Bay	DBn	-41.279180°	174.903419°	157
Sunshine Bay	SuB	-41.274980°	174.904207°	46
York Bay	YB	-41.265120°	174.907566°	178
Lowry Bay	LB	-41.257482°	174.908883°	1

[Please refer to PDF version for diagrams]

Existing



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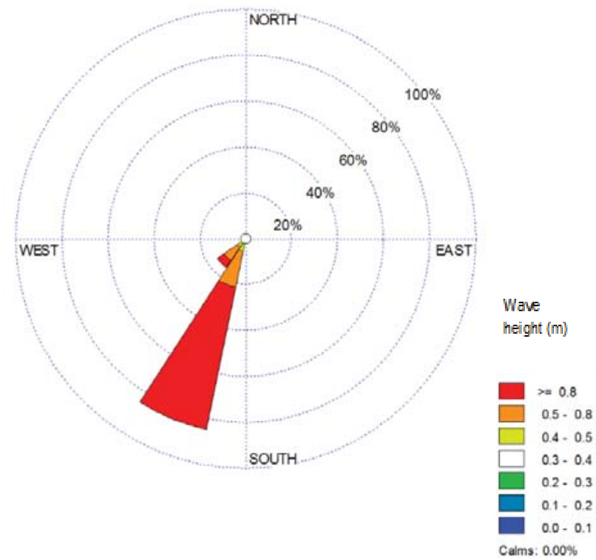
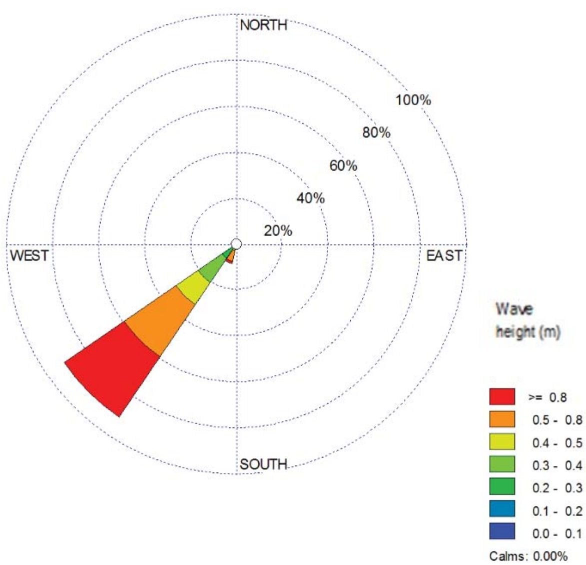


Lake Kohangapiripiri Beach (LK)

Existing



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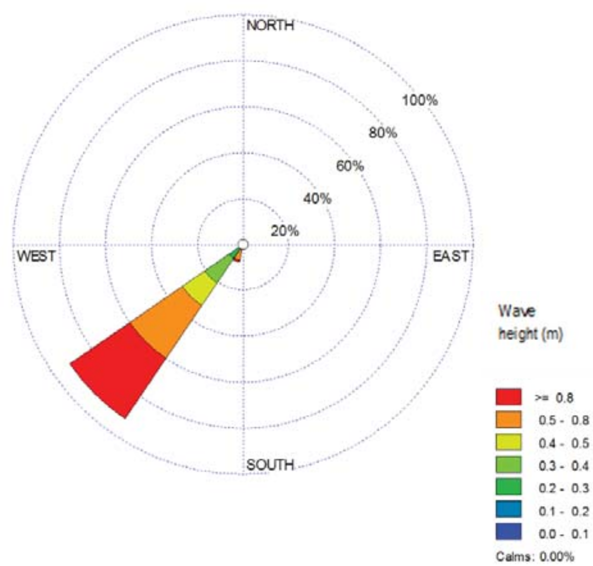
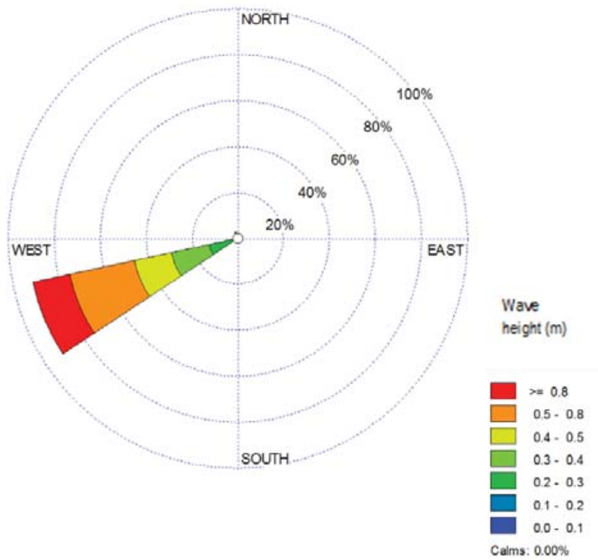
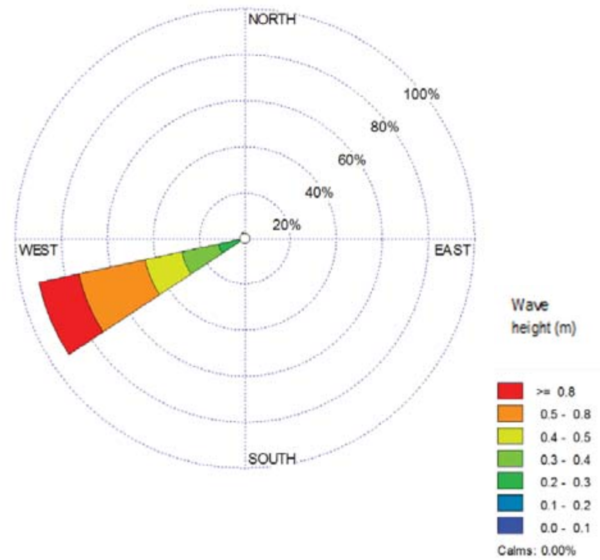


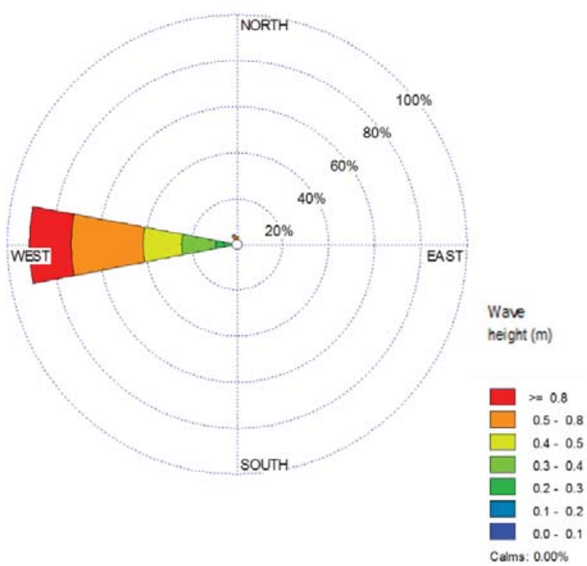
Pencarrow Head Beach (PH)

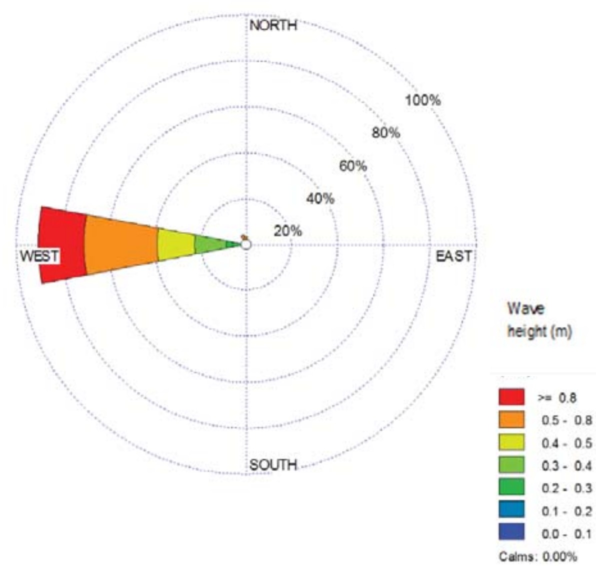




Pencarrow Head to Inconstant Point (PH_IP)

Existing	**Dredged**





Inconstant Point to Hinds Point (IP_HP)

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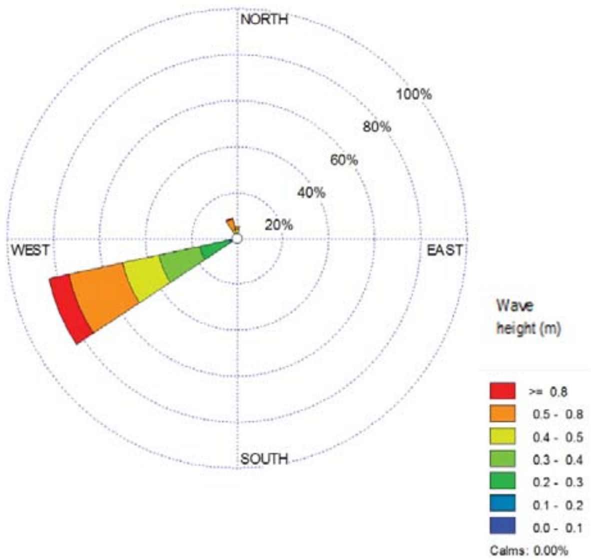
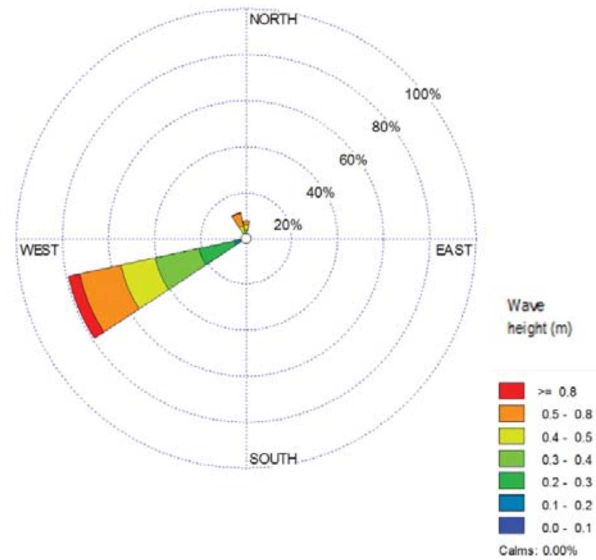
<tr><td>
</td><td>
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<tr><td colspan="2">Hinds Point to Camp Bay (HP_CB)</td></tr>
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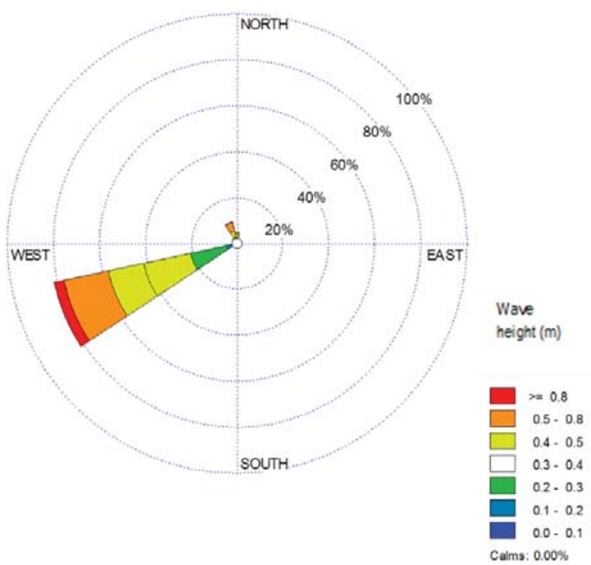
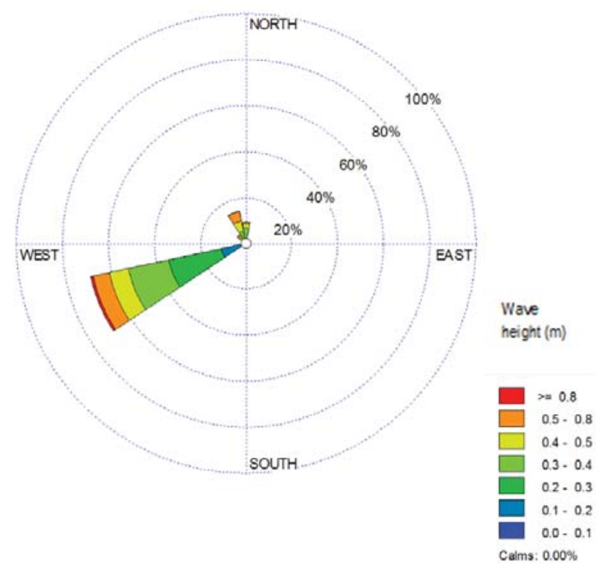
<tr><td>
</td><td>
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<tr><td colspan="2">Camp Bay (CBw)</td></tr>
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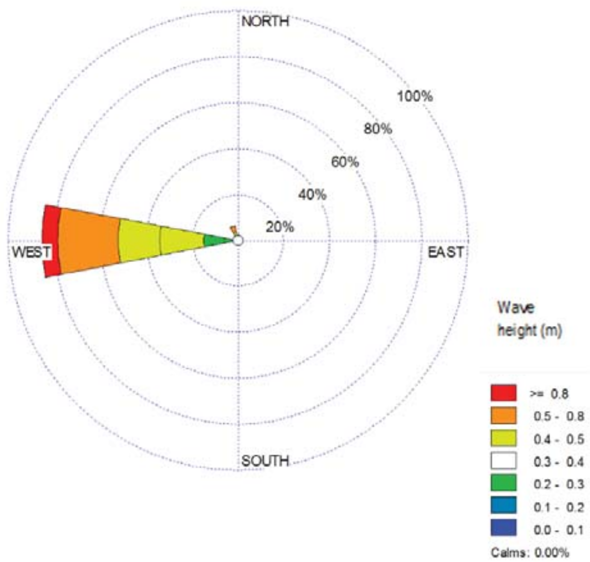
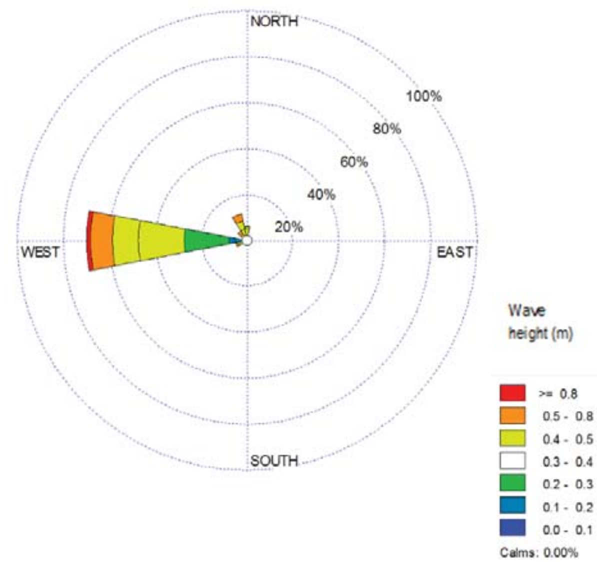
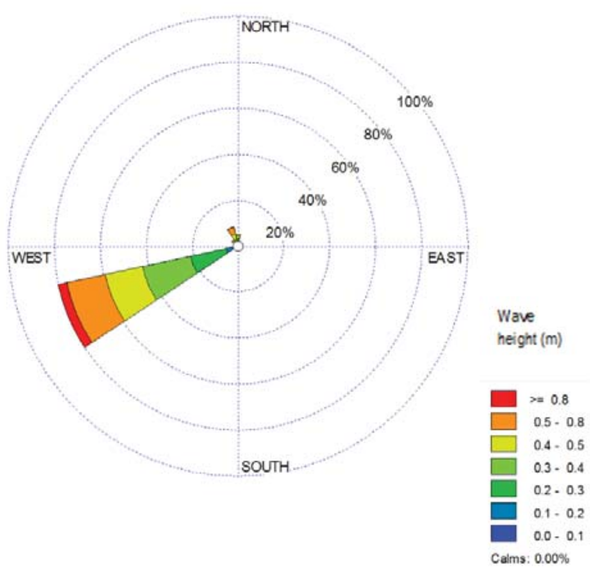
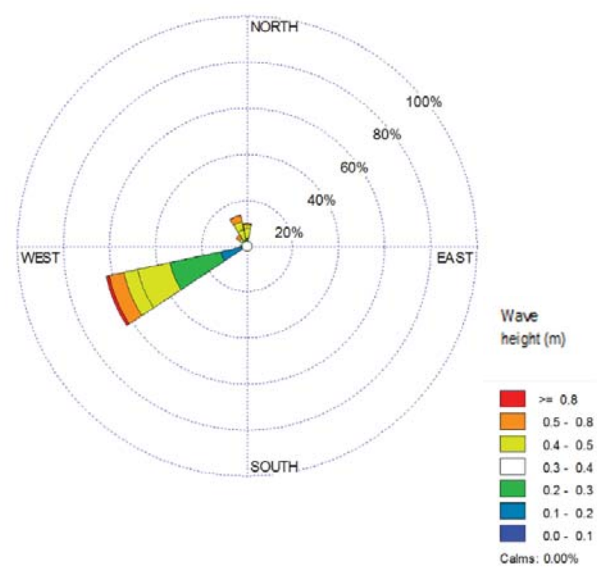




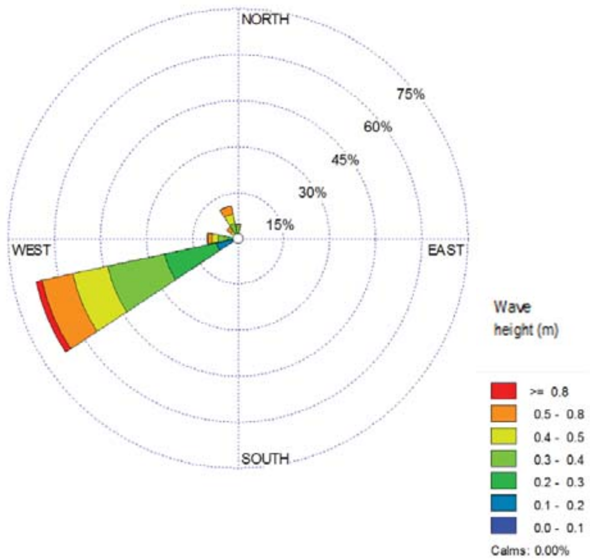
Camp Bay (Cbe)

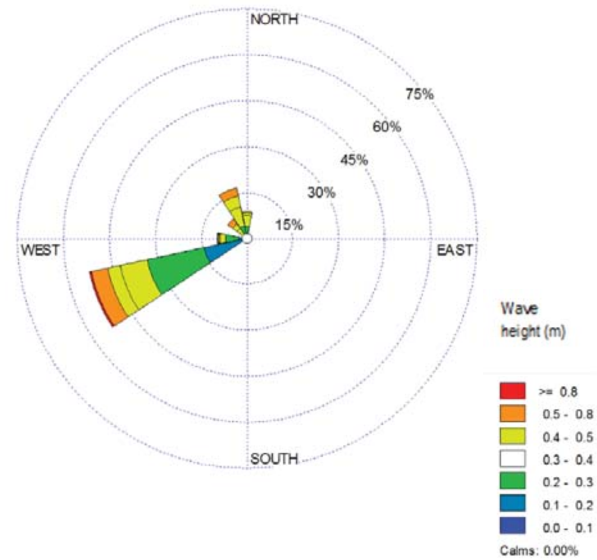
Existing	**Dredged**





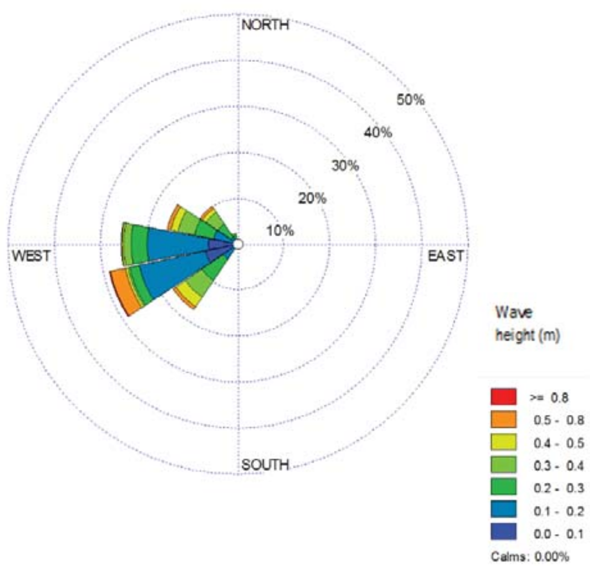
Muritai, Robinson Bay (Ms)

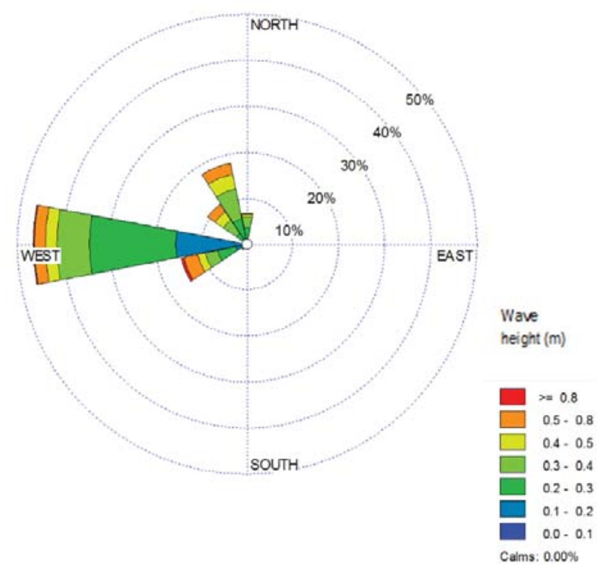




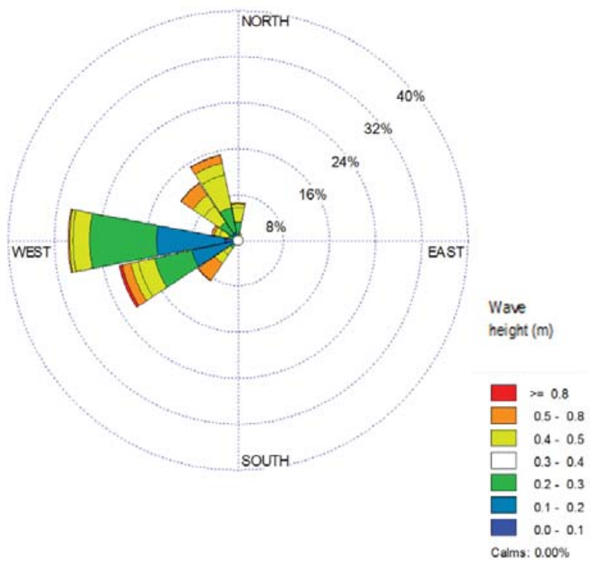
Muritai, Robinson Bay (Mc)

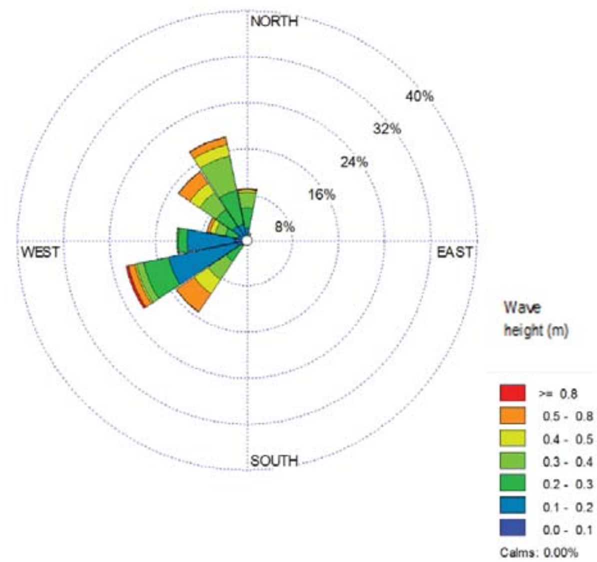
Existing	**Dredged**





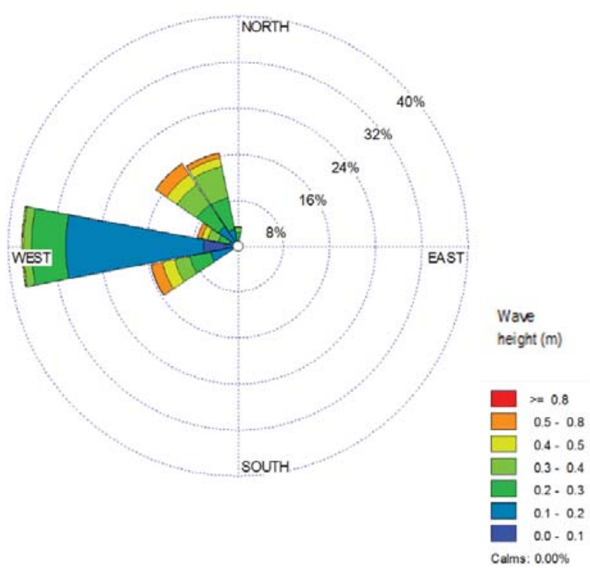
Muritai, Robinson Bay (Mn)

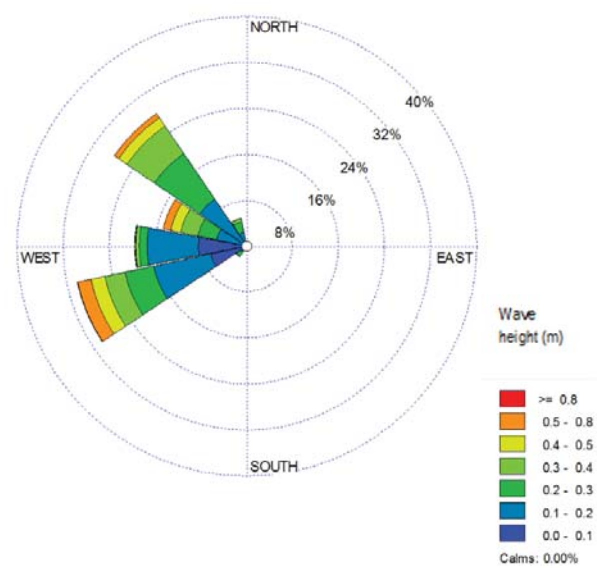




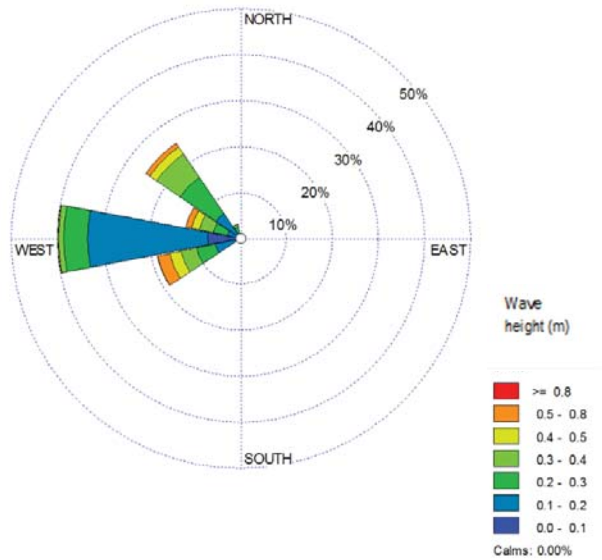
Eastbourne, Rona Bay (Ebs)

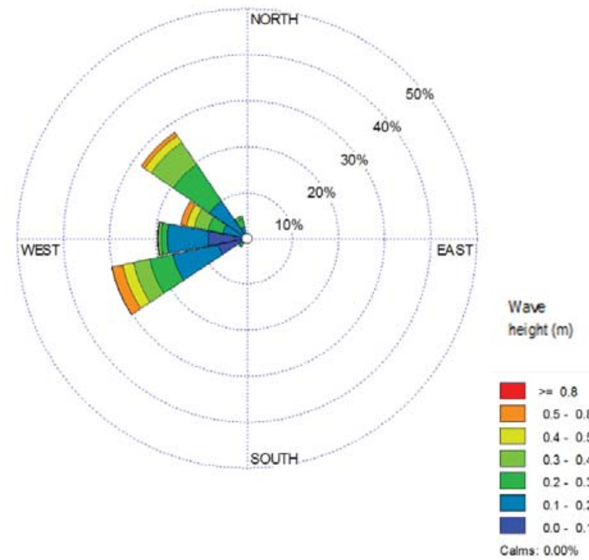
Existing	**Dredged**





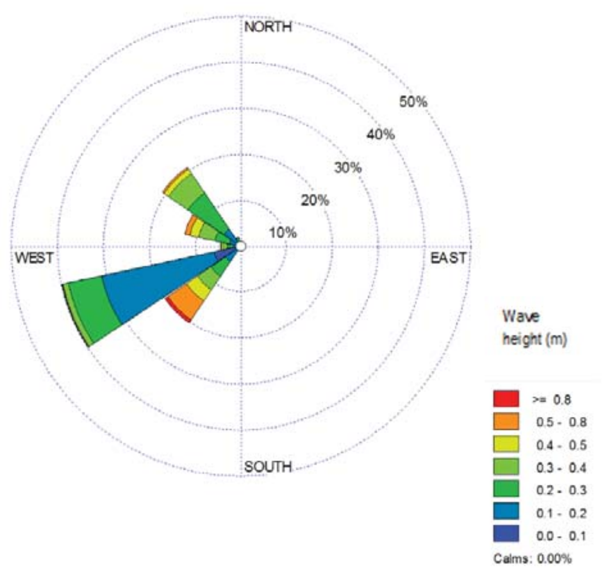
Eastbourne, Rona Bay (EBn)

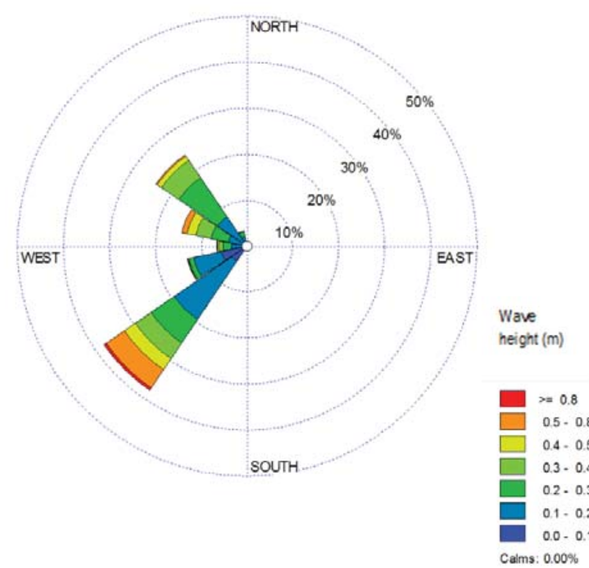




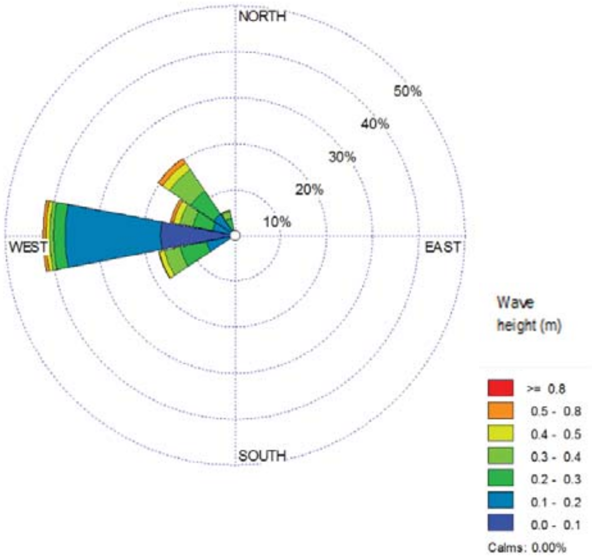
Days Bay (DBs)

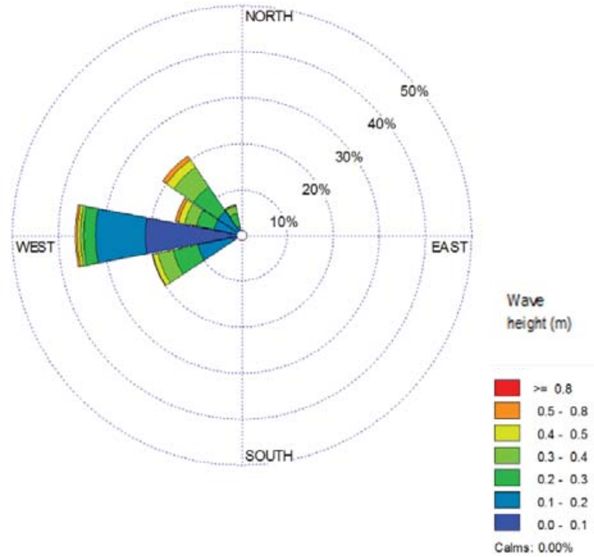
Existing	**Dredged**





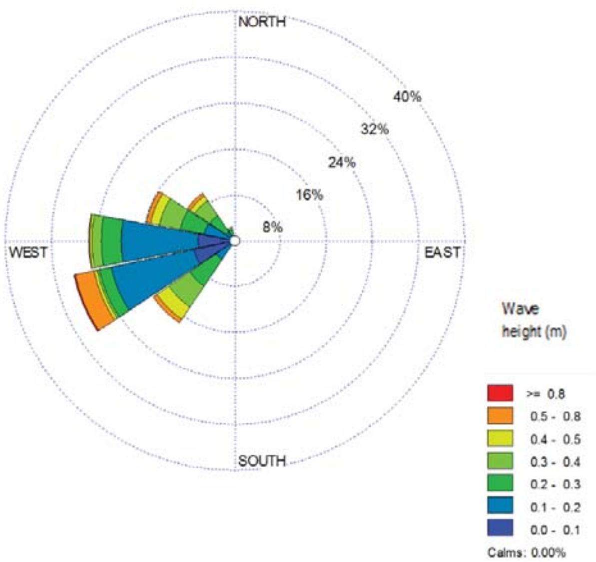
Days Bay (DBn)

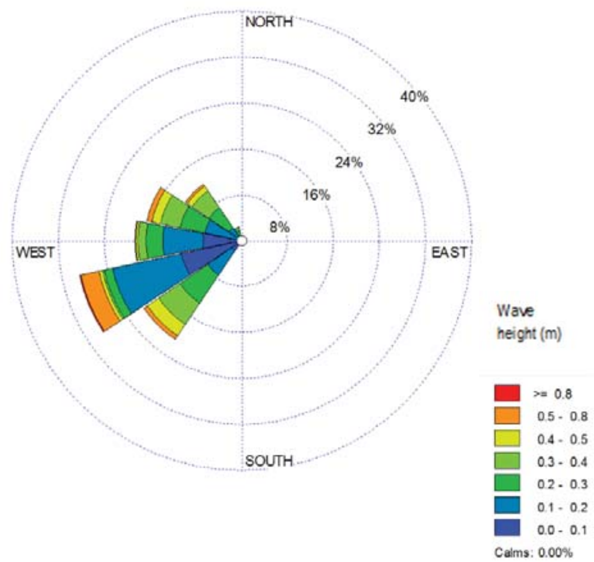




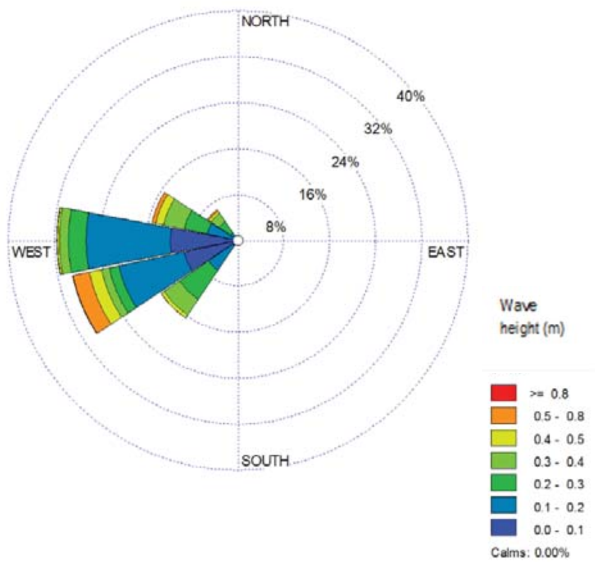
Sunshine Bay (SuB)

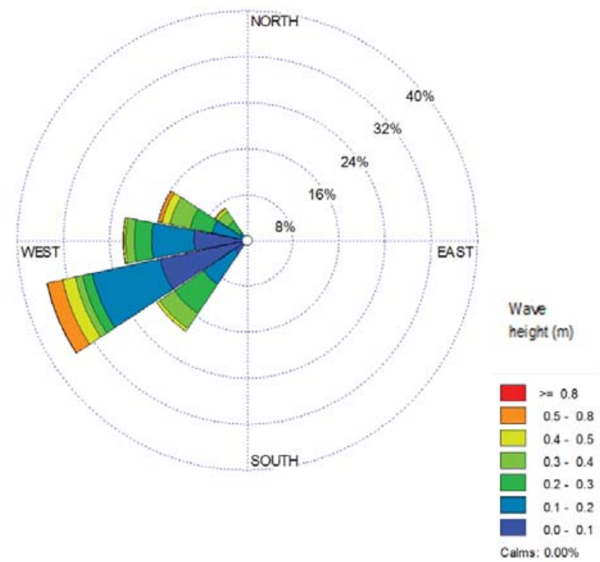
Existing	**Dredged**





Mahina Bay (MhB)





York Bay (YB)

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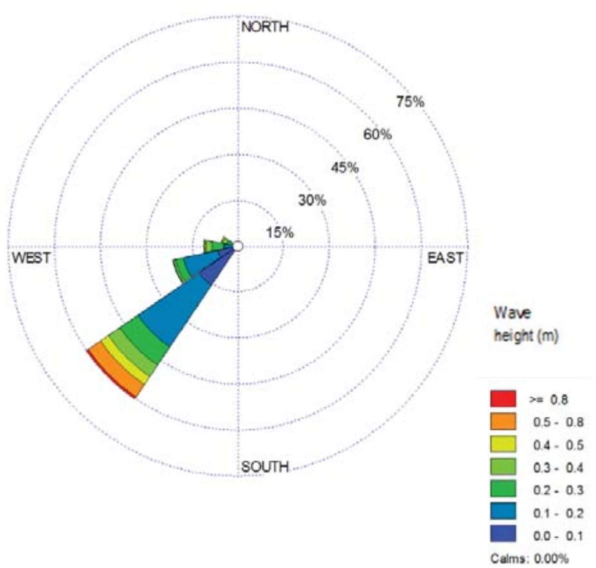
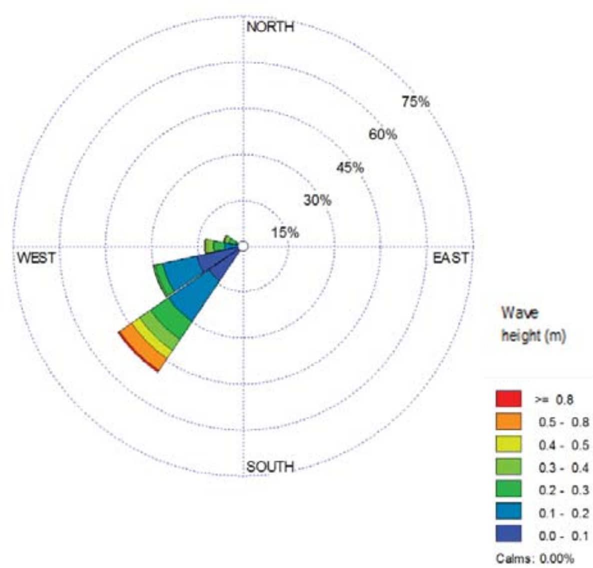
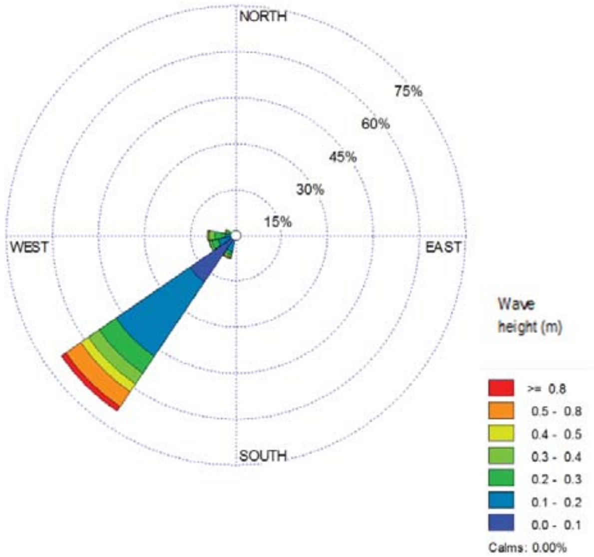
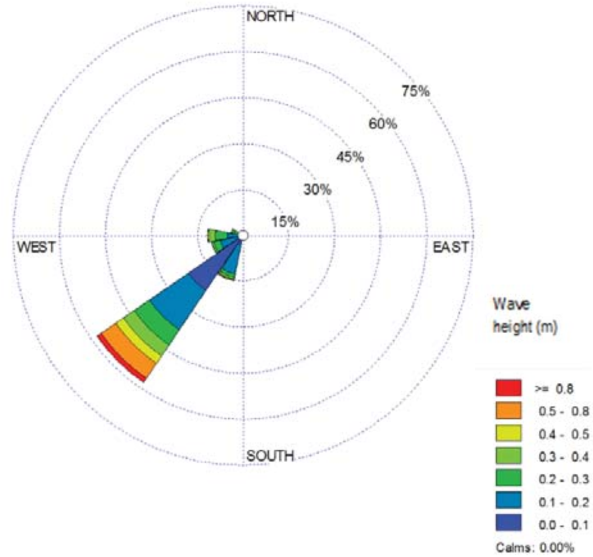




Lowry Bay (LB)





Sorrento Bay (SoB)

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