Granger Bay

V&A Waterfront

Oceanographic specialist study for the EIA to assess the proposed breakwaters, revetment and mixture of land-use in the Granger Bay precinct, V&A Waterfront, Cape Town

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Prepared for

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Executive Summary

Development of the V&A Waterfront was already proposed in 2018, partially for safety reasons since the shoreline between the Oceana Powerboat Club and the V&A dolos revetment is vulnerable to damage and poses a flooding risk to adjacent areas and partially to reclaim land for mixed use. That development scheme was approved in April 2018. At present, the V&A Waterfront is proposing an alternative development (referred to here as the 2023 development) in which a replacement for the existing unprotected embankment and gravel beach, a permanent rock revetment and two breakwaters will be established to ensure shoreline protection, as well as providing shelter for portions of the site from storm action. This report focuses on the oceanographic impacts, including the potential effects of sea level rise, of these coastal defences, and particularly the two breakwaters.

The port and coastal engineering group, PRDW has conducted numerical modelling of the proposed 2023 development. The modelling comprised two components, namely hydrodynamic modelling and wave modelling. The results of the modelling, namely current speed and direction, flushing of water and seawater temperature in the proposed basin, wave heights and wave induced bottom shear stresses are presented in PRDW (2023). The approach that was followed for this Oceanographic Study was not to conduct modelling, but to infer impacts on the environment from the PRDW report as well as from the 2018 specialist report. As a first step in the approach the PRDW (2023) report was reviewed with particular emphasis on the models upon which the study was based.

It was found that the hydrodynamic model setup, scenarios and results are considered to be robust, and the conclusions are deemed acceptable and may be used in additional analyses for the Environmental Impact Assessment. The model results related to the seawater temperature will need to be interpreted by a marine ecologist to assess the impact on the marine ecology. In addition, the wave model setup, scenarios and results are considered to be robust, and the conclusions are deemed acceptable and may be used in additional analyses for the Environmental Impact Assessment. The model results related to the bottom shear stresses which relates to the deposition and resuspension of fine sediments will need to be interpreted by a marine ecologist to assess the impact on the marine ecology.

The discussion of the baseline conditions in Granger Bay was based on the simulation results from the 2018 baseline report, the Oceanographic study for the 2018 approval and the report for the evaluation of the 2023 proposed development. Water movement within the bay is primarily wind-driven, experiencing minor effects from shelf currents farther offshore and with waves and swell playing an influential role in driving currents in the nearshore. Water movement is further influenced by tides although forcing of this nature is considered minor. In addition, it was determined that (PRDW, 2023):

- The current speeds in Granger Bay due to wind, tides, and ocean currents are very low with speeds generally not exceeding 0.1 m/s.
- The addition of the 2023 development reduces the maximum current speed inside the development from 0.06 m/s in summer and 0.04 m/s in winter to 0.02 m/s.
- The maximum current speeds inside the new development are higher (0.02 m/s) than those inside the Oceana Powerboat Club (0.01 m/s).
- The development does not change the currents significantly beyond 300 m from the development.
- The circulation (calculated as a time-average of the depth-averaged currents) inside the new development comprises twin eddies which will induce flushing of water out of the development.
- The circulation within the development is slightly weaker than the baseline circulation, but stronger than the circulation within the Oceana Powerboat Club.

Offshore waves approach Table Bay mostly from the south-west and west-south-west and then transform, mostly due to refraction, as they move into Table Bay. The wave conditions in the centre of Granger Bay are in a band around northwest (within the angular range from 305° to 345°). Near the entrance to the Granger Bay Marina, the waves have very small heights and there are a small number of waves from the east. The main findings for the present layout of

Granger Bay were that the majority of the long period wave energy inside the Granger Bay Marina originates from the diffracted long period wave component around the head of the Granger Bay Marina breakwater. The gravel beach embayment of the present layout causes a small reflected long period wave component to enter the Granger Bay Marina. It was estimated that some of the reflected free long waves get re-refracted as edge waves and move west along the embayment where these waves reach the existing slipway (currently used by the Oceana Powerboat Club). It was also determined that (PRDW, 2023):

- The wave heights inside the development are generally reduced compared to the baseline layout, but there is significant amplification in the centre of the development due to harbour resonance. This may lead to surging motions in the development area which can cause boats at locations around the amplification area to move horizontally more than what is expected from the surrounding conditions. The amplification may contribute to higher water levels and potential overtopping of the revetments.
- The wave heights inside the development are significantly larger than at the existing slipway (currently used by the Oceana Powerboat Club).
- The wave heights inside the Oceana Powerboat Club are slightly reduced by the development.
- The reflections off the 'East' breakwater of the development generate nodes and anti-nodes, changing the wave height to the north-east of the development by up to 0.5 m for up to 300 m away from the structure. However, the development does not change the wave heights significantly beyond 500 m from the development.

It is anticipated that the effect of sea level rise will not yield additional increases in wave heights at the proposed breakwaters since there is substantial wave height reduction due to refraction around Mouille Point that will continue to limit wave heights in Granger Bay. Identified possible impacts on the oceanographic environment, mostly outside (seawards) of the proposed development are considered as summarised in Table 1.

Table 1: Summary of potential oceanographic impacts.

Impact	Consequence	Probability	Significance	Status	Confidence
Impact 1: Short wave reflections into the greater Table Bay area (mostly off the new 'East' breakwater).	Low	Probable	Low	-ve	High
Impact 2a: Long wave and short wave reflections towards the Granger Bay Marina (mostly off the new 'West' breakwater): Effects on navigation.	Low	Probable	Low	-ve	High
Impact 2b: Long wave and short wave reflections towards the Granger Bay Marina (mostly off the new 'West' breakwater): Effects on vessel berthing and mooring.	Medium	Improbable	Low	-ve	High
Impact 2c: Long wave and short wave reflections towards the Granger Bay Marina (mostly off the new 'West' breakwater): Effects on design parameters of the Granger Bay Marina breakwater.	Low	Improbable	Very Low	-ve	High
Impact 3: Impacts on the users of the new slipway during launching and navigating.	Low	Possible	Very Low	-ve	Medium
Impact 4: Effect on longshore sediment transport on the adjacent coastline.	Not significant	Improbable	Insignificant	-ve	High

The significance of these impacts varies from insignificant to low and these do not change due to possible mitigation measures.

1 Introduction

1.1 Background and brief

Granger Bay is located along the south-western side of Table Bay and is bordered on the east by the main breakwater of the Port of Cape Town and on the western side by Mouille Point. The V&A Waterfront is located on the south-eastern side of Granger Bay with the Oceana Powerboat Club and the Granger Bay Marina on the south-western side as illustrated in Figure 1.

The V&A Waterfront is a place of rich and diverse entertainment and cultural attractions as well as accommodating a broad spectrum of economic opportunities. A large proportion of approved development rights has been utilised to create this built environment, and thus the V&A Waterfront is now seeking to enhance the property and is looking towards the future. This entails determining a long-term development strategy, with the objective of developing the property in a financially and environmentally sustainable way for the benefit of all citizens. As part of this development phase, the Granger Bay precinct is considered for developed.

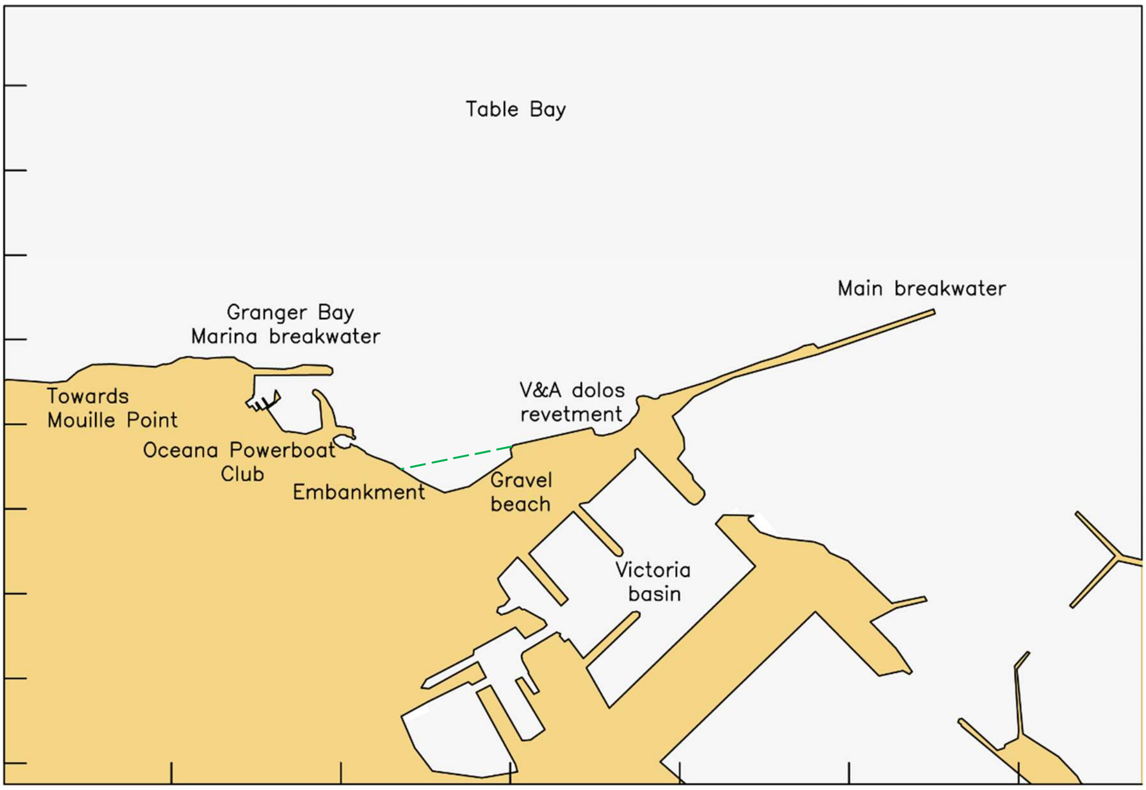


Figure 1: The existing layout of Granger Bay. The dashed green line indicates a dolos breakwater proposed in the 2018 approved development.

Development of the V&A Waterfront was already proposed in 2018, partially for safety reasons since the shoreline between the Oceana Powerboat Club and the V&A dolos revetment is vulnerable to damage and poses a flooding risk to adjacent areas and partially to reclaim land for mixed use. The authorised development scheme approved in April 2018 comprised two main components, namely:

- A new dolos revetment and associated land reclamation; and
- Mixed use (primarily residential with some retail and commercial use) development of Erf 173712, portion of Erf 149294 Cape Town (also referred to as the Granger Bay precinct, located in the V&A Waterfront).

For the 2018 proposal, one of the options was to replace the existing gravel beach and embankment with a permanent dolos revetment. As indicated in Figure 1, the proposed dolos revetment will be an extension of the existing V&A dolos revetment which currently ends at the end of Breakwater Boulevard. The extension will be in a straight line for a length of approximately 310 m in a westerly direction across Granger Bay. In addition, the existing embankment that marks the coastal edge of the Granger Bay precinct will be replaced with a rock or dolos revetment for a length of approximately 160 m. This coastal infrastructure will provide the required protection for reclamation of land and the proposed mixed-use development in the precinct. Authorisation has been granted for this development.

Since then, the V&A Waterfront has taken a visionary approach and is proposing an alternative development scheme as outlined in the next section.

1.2 Study area

The proposed 2023 development scheme for the Granger Bay precinct comprises two main components, namely:

- Replacement of coastal defence structures: associated revetment, breakwaters, and land reclamation.
- Mixed use development packages landward of the coastal defence infrastructure.

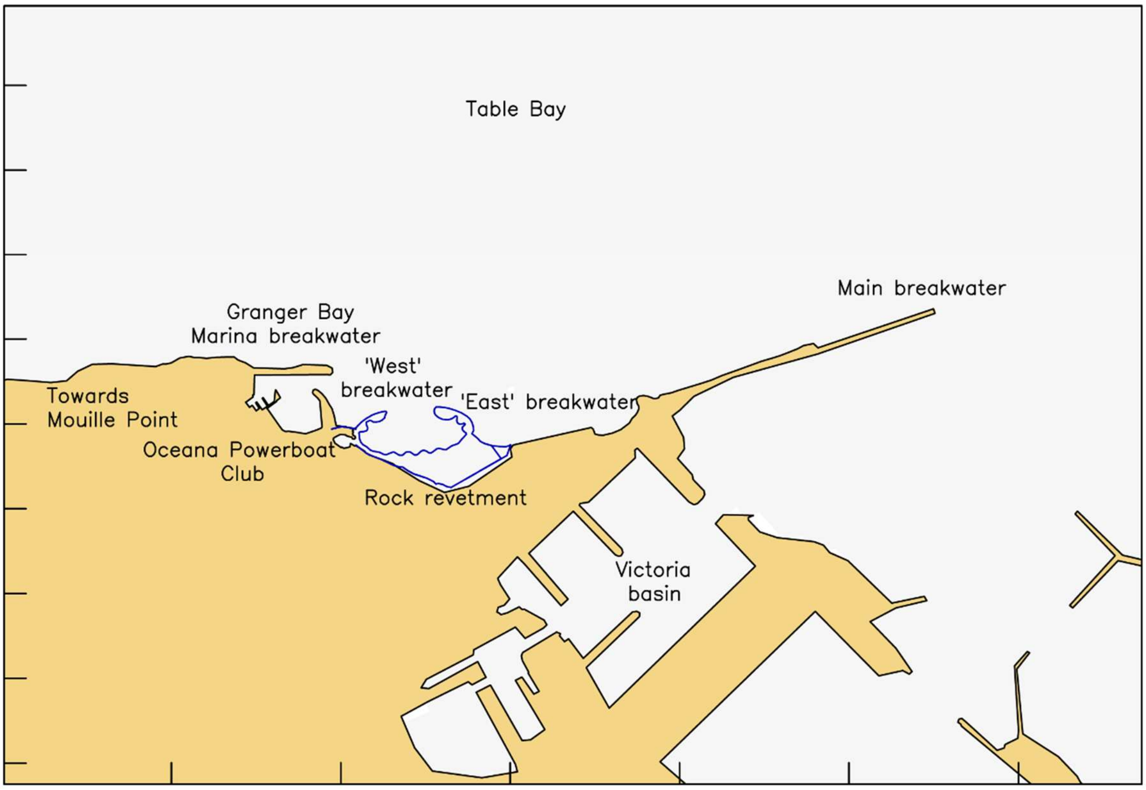


Figure 2: The proposed 2023 development that includes an ''East" breakwater, a "West" breakwater and rock revetment.

As a replacement for the existing unprotected embankment and gravel beach, a permanent rock revetment and two breakwaters will be established to ensure shoreline protection, as well as providing shelter for portions of the site from storm action. As previously mentioned, these improvements are necessary since the existing gravel beach and unprotected embankment are not adequate to provide the necessary shore protection for long term developments and infrastructure development of the site.

This report focuses on the oceanographic impacts of these coastal defence structures and, in particular the two breakwaters. The area seaward of the 100 m setback line from the High-Water Mark is the site to be developed by constructing a coastal amenity zone, a rock revetment and two breakwaters as illustrated in Figure 2. The breakwaters and new rock revetment will protect the public coastal amenity zone of approximately 57 000 m², that will include:

- ±3 ha bay area for water-based activities such as boat launching, leisure craft, sailing, kayaking, swimming, sailing.
- ±1.5 ha coastal park (public amenity) on the land side.

The coastal park will inter alia comprise a slipway, fixed quayside, landscape promenade, tidal pools, pedestrian paths and open areas.

The key changes between the 2018 approved scheme and the proposed 2023 scheme are the reshaping of the proposed rock revetment, the inclusion of two (“East” and “West”) breakwaters and the inclusion of public amenities within shoreline protection infrastructure instead of one breakwater.

1.3 Previous findings and the present approach

The goals of the Oceanographic Studies for the two proposed developments are similar. For the 2018 study, the objectives of the Oceanographic Study were to investigate the possible impacts of the expected changing wave conditions on the coastal (oceanographic) environment due to the different revetments. That investigation comprised numerical modelling studies to assess the potential impacts of the altered wave reflection regime (SU, 2014a).

The main findings of the 2018 study were, for the option where a breakwater is constructed across the bay in line with the V&A breakwater (as illustrated in Figure 1), that there will be relatively small increases in wave heights, approximately less than 15 cm, since reflection occurs in deeper water where the wave heights are larger compared to the existing situation where the waves decrease in height as they propagate to the gravel beach where they reflect. The area affected by these wave height increases is limited to within approximately 300 m from the breakwater.

A range of swell wave conditions associated with long period wave energy was modelled, and it was found that the neighbouring Granger Bay Marina (Waterclub) will not be negatively influenced by the construction of the proposed breakwater and revetment (see Figure 1). The fundamental modes of oscillation of the neighbouring Granger Bay Marina (Waterclub) remain unchanged and not excessively amplified. Similar wave conditions can be expected for the marina. A reduction in surge motions inside the breakwater area of the existing slipway (Oceana Powerboat Club) was predicted.

The port and coastal engineering group, PRDW has conducted numerical modelling of the proposed 2023 development. The modelling comprises two components, namely hydrodynamic modelling and wave modelling. The results of the modelling, which relate to current speed and direction, flushing of water and seawater temperature in the proposed basin, wave heights and wave induced bottom shear stresses are presented in PRDW (2023). The approach that is followed for this Oceanographic Study is not to conduct modelling, but to infer impacts on the environment based on the findings in the PRDW report as well as from the 2018 specialist report.

As a first step in the approach the PRDW (2023) report is reviewed with particular emphasis on the models upon which the study is based. Information was drawn from the 2018 report, but that is not reviewed since it has already been part of the 2018 Environmental Impact Assessment for which authorisation has been granted.

The main objectives of this study are to:

- Describe the existing wave characteristics (baseline description) of the proposed site and greater Table Bay area.
- Identify and assess potential wave impacts resulting from the proposed activity. No additional modelling is required for the assessment, only the evaluation of the report relevant to the 2018 scheme, the new proposal described in the PRDW report and in particular the models upon which the PRDW Wave & Hydrodynamic Modelling Study report (August 2023) is based.
- Recommend mitigation measures to minimize the impacts associated with the proposed development.

- If applicable, identify monitoring measures to ensure the correct implementation and adequacy of recommended mitigation measures.
- Indicate whether the development alternatives are environmentally suitable or unsuitable and identify an environmentally preferred alternative.

2 Methodology

2.1 General approach

The specialist Oceanographic Study for the 2018 proposed development and the evaluation of the changes that the 2023 proposed development may have on the marine environment are based on numerical modelling. The two studies used different numerical modelling suites, but both modelling suites are commercially used and state of the art. The results of the modelling for the 2018 proposal are presented in SU (2014a) and the Environmental Impact Assessment has been completed successfully. These results will therefore not be re-evaluated but drawn on in the present study. No new modelling is thus required for this assessment, since the evaluation of the report (PRDW, 2023) will indicate whether the modelling undertaken was suitable and relevant; and therefore sufficient to evaluate the new 2023 proposed development.

2.2 Evaluation of models

2.2.1 General

The PRDW evaluation is based on the numerical modelling of three-dimensional hydrodynamics and waves. Two different models were used for the modelling, namely the MIKE 3 Flow Flexible Mesh model for the currents and seawater temperature and the MIKE 3 Wave Model FM (M3WFM) for the waves. Both of these models form part of the MIKE 3 suite of models which is a well-established state-of-the art coastal engineering modelling tool.

For both models, the modelling domains are suitable and the computational grid sizes are adequate to capture the physical properties of interest. Important input information for these models is the seabed topography (referred to as bathymetry) and the bathymetry in the models have been obtained from reliable and up-to-date sources. The information needed to drive the two models differ and each model is discussed separately.

2.2.2 Hydrodynamic model

Important information that is required for the hydrodynamic model is wind speed and wind direction. Wind is an important forcing mechanism for currents and influences vertical mixing and upwelling. The spatially and time varying wind fields for the modelling were obtained from the Weather Research and Forecasting (WRF) model from the Climate System Analysis Group at the University of Cape Town. The report shows comparisons between the WRF winds and different measured winds. The comparisons are good, and the wind inputs are deemed appropriate for the hydrodynamic modelling. Additional inputs for the model are seawater temperature and salinity, tidal water levels and tidal currents and atmospheric information such as air temperature, humidity and solar radiation. Different sources were used to obtain the given information such as the HYbrid Coordinate Ocean Model (HYCOM) global ocean circulation model (HYCOM, 2020), DTU10 (Technical University of Denmark) global tidal model (DTU, 2010) and atmospheric information from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 global atmospheric model (ECMWF, 2020). These are all reliable sources and often used sources of information and appropriate for the modelling.

Besides the input information to drive the model, the modelling also needs the specification of model settings and specific scenarios to model. The model settings are appropriate for the modelling, and these types of settings have also been used in other similar models, for example Coleman et al. (2021). Two scenarios were modelled, namely a summer/autumn period and a winter/spring period, each for a duration of six weeks. These should capture the seasonal variations and are deemed appropriate for the modelling.

The results of the hydrodynamic modelling are presented as instantaneous depth-averaged current speeds and velocity vectors during a south-easterly wind event, the instantaneous current speeds and velocity vectors during a north-westerly wind event as well as the maximum (99^{th} percentile) current speeds during the 6-week simulation for summer/autumn and the 6-week simulation for winter/spring. Some of the conclusions, relevant to the Oceanographic Study, drawn by PRDW (2023) by comparing the model results of the baseline model (i.e., with no developments as Granger Bay is at present) to the results from the model with the 2023 development layout are:

- The current speeds in Granger Bay due to wind, tides, and ocean currents are very low with speeds generally not exceeding 0.1 m/s.
- The addition of the 2023 development reduces the maximum current speed inside the development from 0.06 m/s in summer and 0.04 m/s in winter to 0.02 m/s.
- The maximum current speeds inside the new development are higher (0.02 m/s) than those inside the Oceana Powerboat Club (0.01 m/s).
- The development does not change the currents significantly beyond 300 m from the development.

An example of the circulation, that is, instantaneous depth-averaged current speed and current vectors, during a south-easterly wind event is presented in Figure 3 (taken from PRDW (2023)). Within the development area and towards the neighbouring Granger Bay Marine the speeds are low and farther seawards the flow is similar to the present situation (see PRDW (2023)).

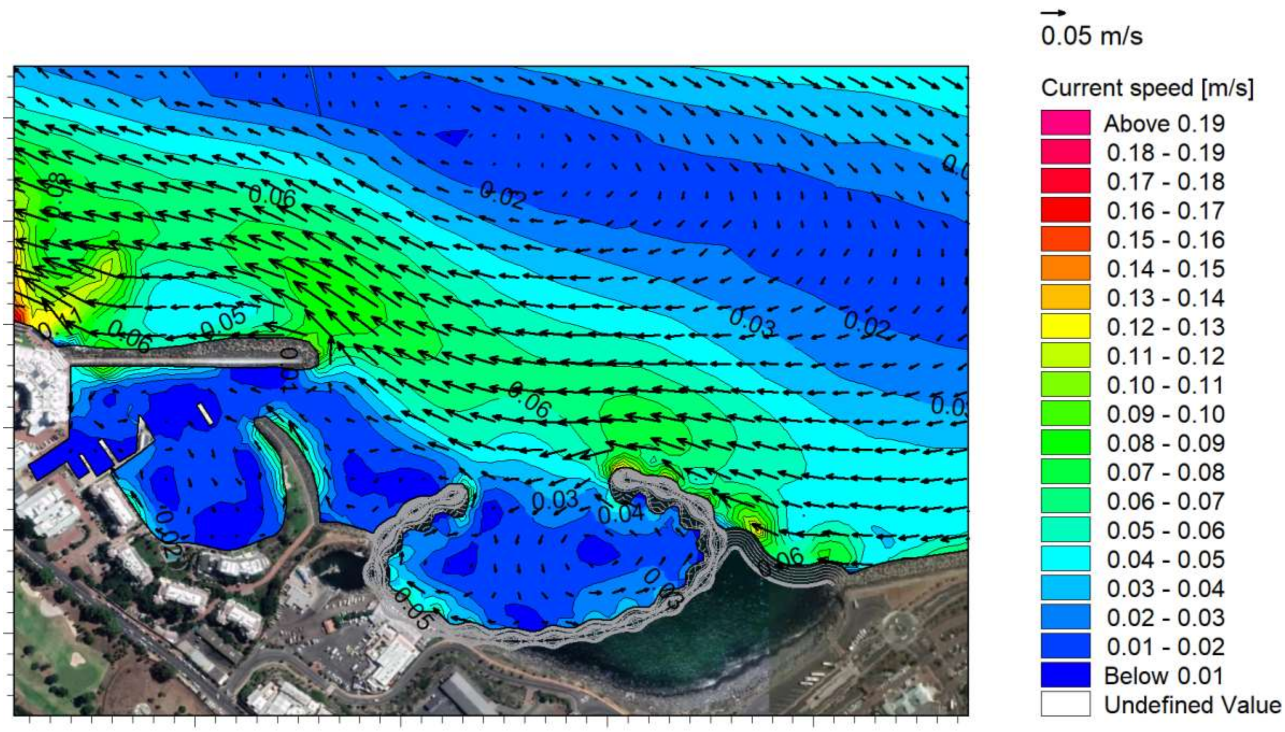


Figure 3: An example of the circulation (instantaneous depth-averaged current speed and velocity vectors) during a south-easterly wind event (PRDW, 2023).

The depth-averaged currents were also vector-averaged to obtain residual currents from which the following conclusions were drawn, amongst others:

- The residual circulation within the development is slightly weaker than the baseline circulation, but stronger than the circulation within the Oceana Powerboat Club.

The model setup, scenarios and results are considered to be robust, and the conclusions are deemed acceptable and may be used in additional analyses for the Environmental Impact Assessment. The model results related to the seawater temperature will need to be interpreted by a marine ecologist to assess the impact on the marine ecology.

2.2.3 Wave transformation model

Offshore waves in deep water, that is where the waves have not been influenced by the sea bottom, transform as they move into shallower coastal areas. Some of the processes that alter the deep-water waves are refraction (causing a change in wave direction due to influences of the sea bottom), diffraction (causing changes in wave direction and wave height as waves bend around seawalls or breakwaters), reflection and depth-induced wave breaking. Since the nearshore sea bottom topography (bathymetry) differs from location to location it is customary to use nearshore wave transformation models to simulate the transformation of offshore waves to the nearshore. There are two main types of nearshore wave transformation models, namely phase-averaged models and phase-resolving models. In phase-averaged models the waves are considered from a statistical point of view where the transformation of a wave energy spectrum is simulated by the model and parameters such as wave height and wave angle are determined from the spectrum. In phase-resolving models, the wave-like water surface elevation is predicted. Phase-resolving models should be used where diffraction is an important transformation process and where so-called long-waves are to be modelled.

The phase-resolving wave transformation model, MIKE 3 Wave Model FM (M3WFM) was used to simulate the wave heights and wave-induced bed shear stresses. An important parameter for the model is the bottom friction. In the modelling, a quadratic friction coefficient formulation was used which is an often-used approach and considered to be appropriate. Different friction coefficients were specified for each type of breakwater armour which is important to accurately account for wave reflections off the structures, and the approach is deemed appropriate for the modelling. The model was qualitatively calibrated by simulating a storm condition that occurred on 13 July 2020. Such qualitative comparisons are valuable, but it would have been more appropriate to calibrate against measurements. However, it is acknowledged that verification measurements are not always available and then the qualitative comparison is adequate since it shows the correct trends at different locations.

The wave model was also used to simulate the bed shear stresses. Bed shear stresses are important since they determine if material will be deposited on, or eroded from, the seabed. In general, waves with their orbital motion of water particles contribute more to bed shear stresses than currents and it is appropriate that the phase-resolving wave model was used to predict the bed shear stresses. An extensive study was conducted to relate the percentages of fine sediments measured during historical sampling campaigns in Table Bay (details not given) to the shear stresses predicted by the model by comparing the percentage fines to the 95th percentile of the modelled shear stresses at different locations across Table Bay. There are often large uncertainties in the determination of bed shear stresses for deposition and erosion and the approach followed is acceptable and quite good.

A return period is a statistical term to indicate an average time or an estimated average time between events. For example, an event with an average 1-year return period implies that the average number of years between events of a certain magnitude is one year. However, a return period is not a guarantee that the event will occur every year and there may be more than one such event in a given year or more than one year may pass before a similar event occurs.

The scenarios that were modelled were the average 1-month return period storm during summer, the average 1-month return period storm during winter and the average 1-year return period storm. These scenarios were determined from a robust statistical method that is referred to as Extreme Value Analysis. From the Extreme Value Analysis the significant wave heights were inferred. These conditions are considered adequate for the wave modelling.

An example of the significant wave heights for the 1-month return period wave in winter is presented in Figure 4 (taken from PRDW (2023)). There are increased wave heights seawards of the breakwaters that may be due to wave reflections. An amplification node where the wave height is higher than the surroundings are visible towards the centre of the development area.

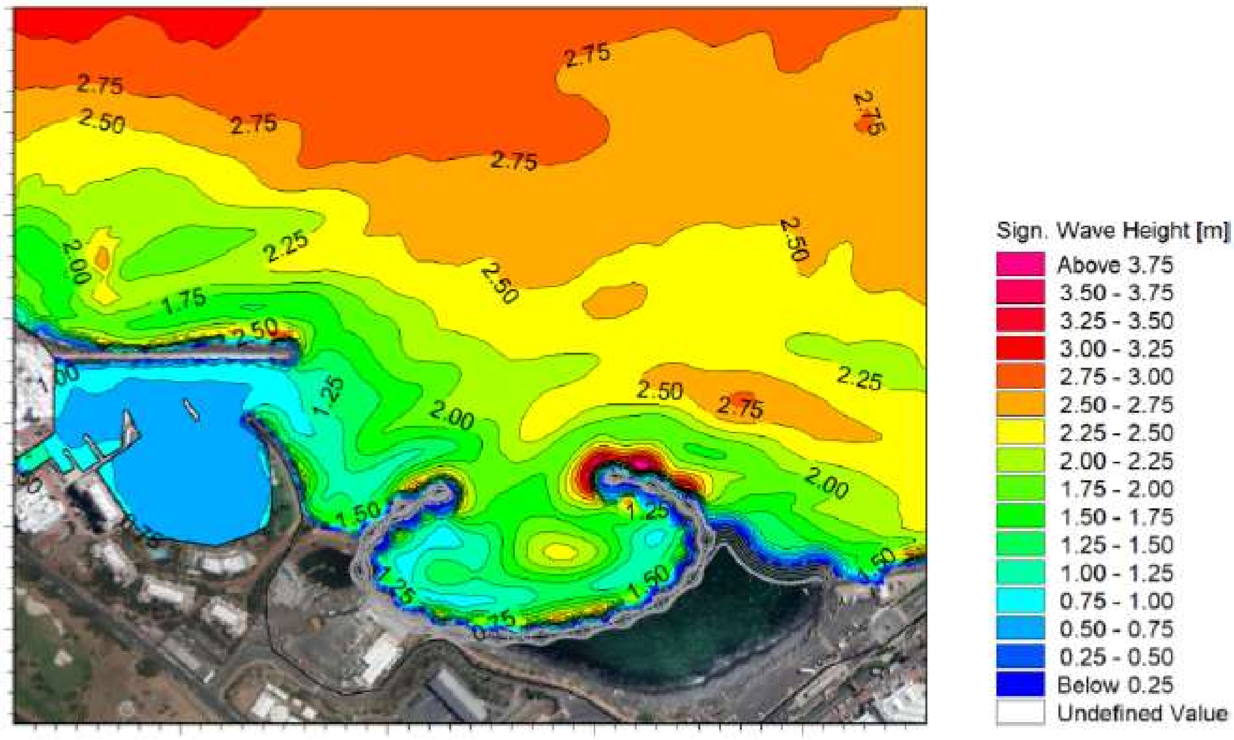


Figure 4: Total significant wave height for the proposed development for the 1-month return period wave in winter (PRDW, 2023).

The results of the wave transformation modelling include the total significant wave height for each of the three conditions for the present-day layout of Granger Bay as well as with the proposed 2023 development. Also reported are the instantaneous water surface elevations for the 1-year return period storm condition. Some of the conclusions, relevant to the Oceanographic Study, drawn by PRDW (2023) by comparing the model results of the baseline model (i.e., with no developments as Granger Bay is at present) to the results from the model with the 2023 development layout are:

- The wave heights inside the development area are generally reduced compared to the baseline layout although there is significant amplification in the centre of the development area due to harbour resonance.
- The wave heights inside the development are significantly larger than those inside the Oceana Powerboat Club.
- The wave heights inside the Oceana Powerboat Club are slightly reduced by the development.
- The reflections off the 'East' breakwater of the development generate nodes and anti-nodes changing the wave height to the north-east of the development by up to 0.5 m for up to 300 m away from the structure. However, the development does not change the wave heights significantly beyond 500 m from the development.

It would have been informative if the process that was followed to determine the peak periods and mean directions of the modelled waves was included in the modelling report (PRDW, 2023). Considering the importance of wave reflections, it would have been informative to also conduct an alternative approach, or sensitivity analysis, in determining wave reflections by considering the porosity of the specific structures (and the slope) and compare the different results to each other. Similarly, it would also have been interesting to investigate if a longer simulation time would have affected the long waves since these kinds of waves generally require a fair duration of simulation to be characterised. However, the model setup, scenarios and results are still considered to be robust, and the conclusions are deemed acceptable and may be used in additional analyses for the Environmental Impact Assessment. The model results related to the bottom shear stresses which relates to the deposition and resuspension of fine sediments will need to be interpreted by a marine ecologist to assess the impact on the marine ecology.

3 Assessment of Wave Conditions in Granger Bay: Baseline Conditions

The baseline wave conditions in Table Bay and Granger Bay were assessed as part of the Environmental Impact Assessment for evaluation of the 2018 proposed development. These baseline conditions are presented in SU (2014b). The conditions in Table Bay and Granger Bay are still valid today and it is not necessary to conduct an additional baseline study. In this chapter some of the results from the previous study are presented since they may aid interpretation of the present results.

3.1 Physical features and oceanography

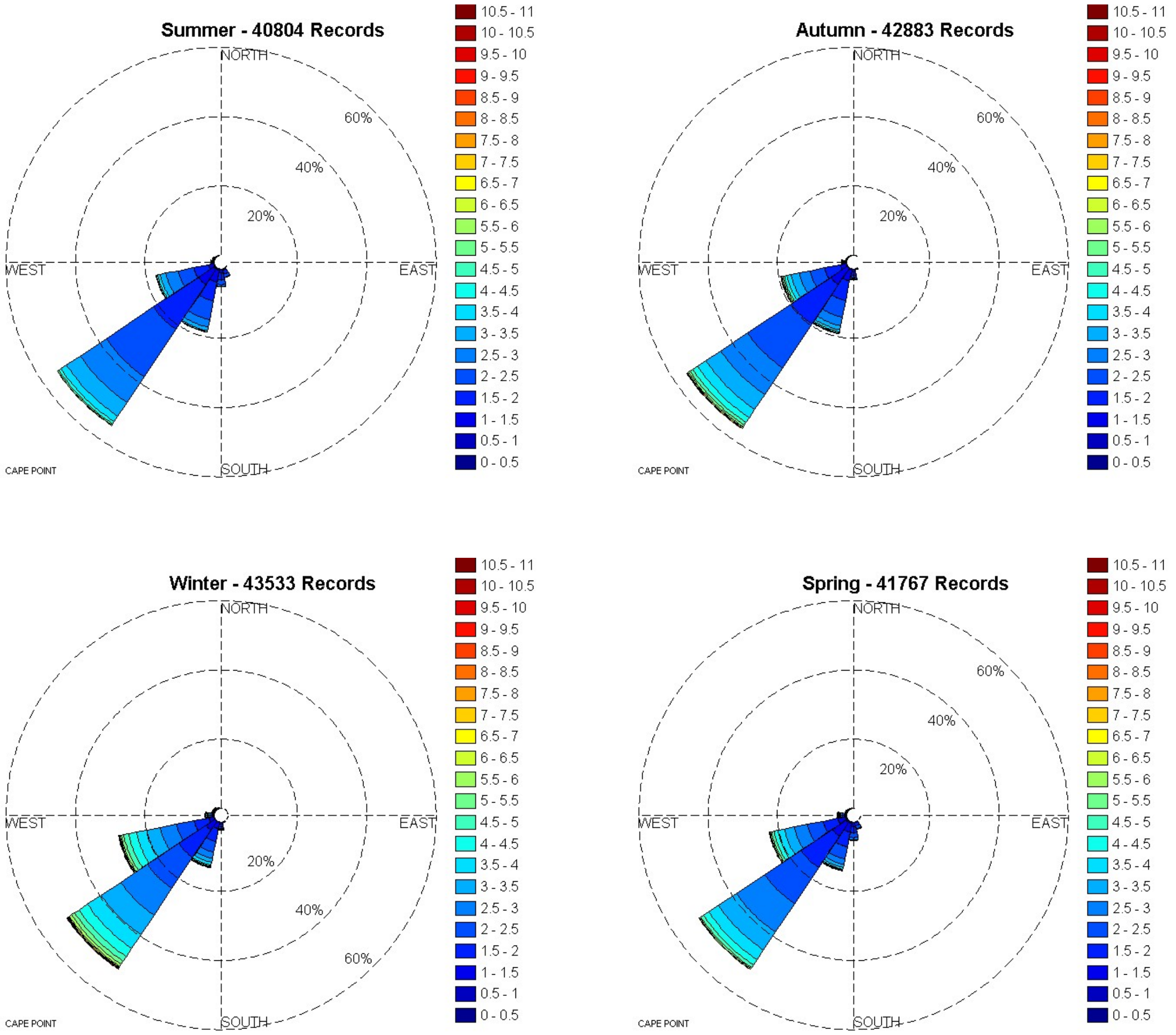
Table Bay is a shallow bay with a surface area of approximately 100 km^2 and depths reaching 35 m in the centre of the bay and increasing to approximately 70 to 80 m outside following a line between Mouille Point and the western shores of Robben Island. The seabed is mainly covered by thin layers of sand but has fairly extensive areas of exposed bedrock (Van Ballegooyen et al., 2006). The shoreline of Table Bay from Blouberg to Mouille Point comprises of 3 km of rocky shore (at Blouberg and at Mouille Point), approximately 13 km sandy beach (between Blouberg and the Port of Cape Town) and 4 km of artificial shore protection and breakwaters comprising the Port of Cape Town.

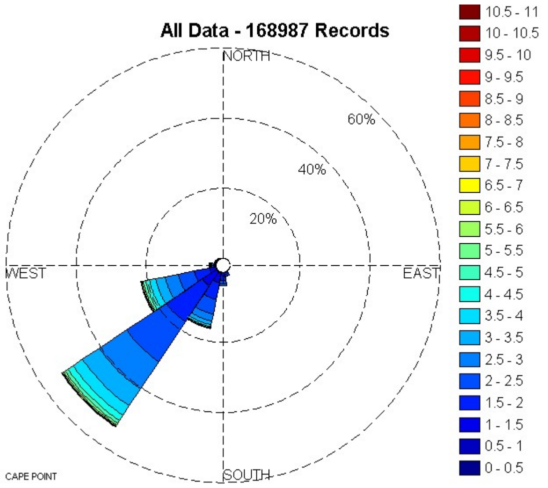
Water movement within the bay is primarily wind-driven, experiencing minor effects from shelf currents farther offshore and with waves and swell playing an influential role in driving currents in the nearshore. Water movement is further influenced by tides although forcing of this nature is considered minor. In summer, wind is predominantly from the south-east resulting in currents that tend to flow northwards that result in a counterclockwise motion in the Table Bay. Conversely, in winter, winds from a north to north-westerly sector predominate and drive water towards the south, producing a slight clockwise motion in the bay.

3.2 Wind-generated waves

Offshore waves approach Table Bay mostly from the south and south-west and then transform, mostly due to refraction, as they move into Table Bay. Directional wave measurements are available from a Directional Waverider buoy, located near Cape Point at a location 34°12'14.40"S, 18°17'12.01"E in 70 m water, about 5.4 km off the coast. These directional wave measurements have been made since 2001, with a 96% good data return. Since conditions are essentially uniform over distances of several kilometres offshore, these conditions are representative of deep-water conditions offshore of Table Bay. Figure 5 shows the seasonal and annual wave roses derived from these measurements for the duration 2001 to 2013 (SU, 2014a and 2014b). These wave roses depict the directional distribution of measured offshore waves as well as the distribution of wave heights. The dominance of south-westerly waves (55% of the time) can be seen, while west-south-westerly waves also occur frequently (25% of the time).

For the 2018 studies (SU, 2014a and 2014b) the nearshore wave conditions in Granger Bay were determined through numerical modelling. An example of wave refraction around Mouille Point is presented in Figure 6 for a storm condition. Two examples showing the refraction into Granger Bay are presented in Figures 7 and 8, illustrating that the southern parts of Table Bay are well protected from southerly to westerly wave conditions which include most of the storm conditions.





Period	2001-01-01 to 2013-02-28
Station	CAPE POINT
Records	168987

Figure 5: Seasonal and annual wave roses near Cape Point for the period January 2001 to February 2013.

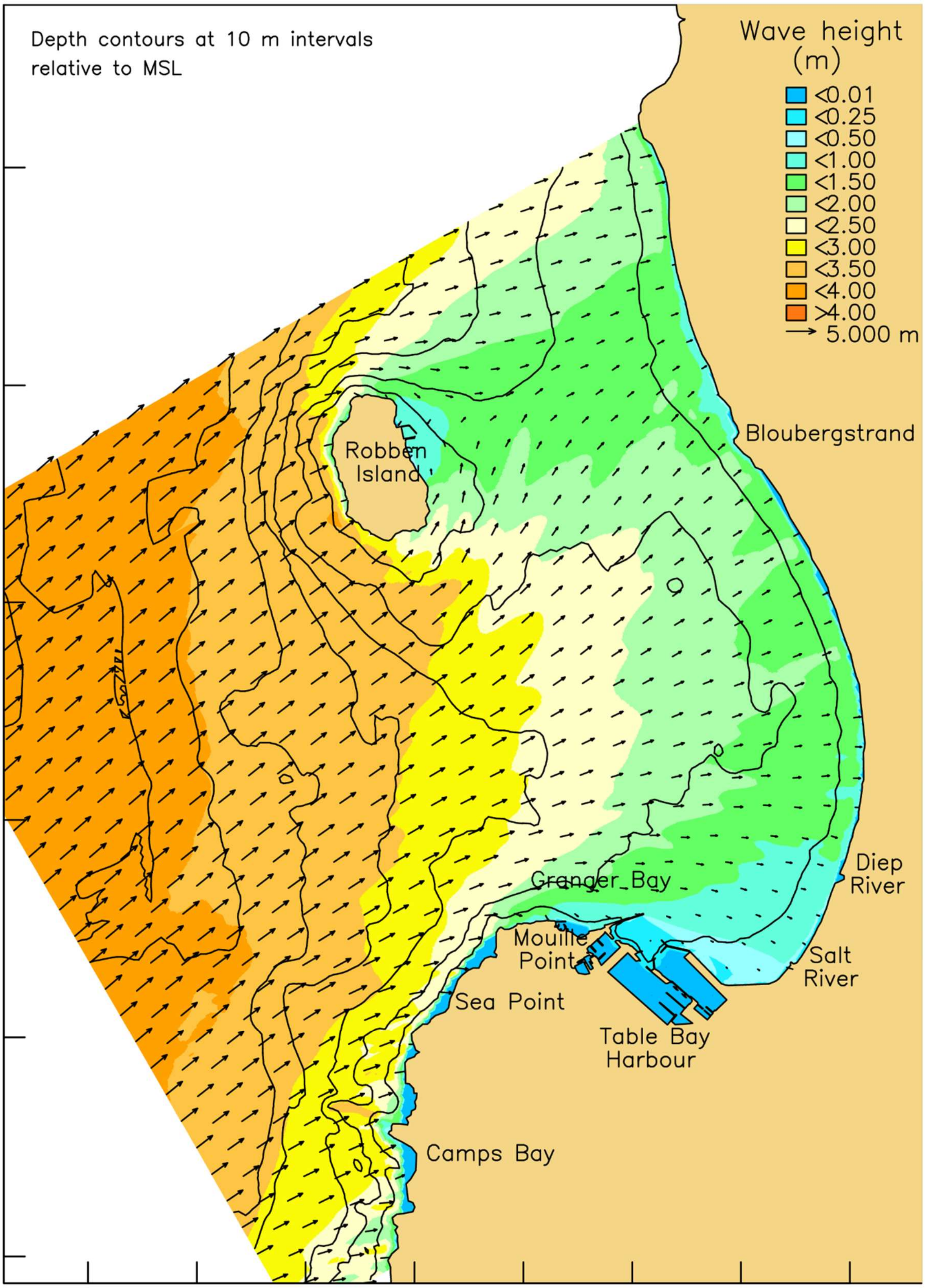


Figure 6: An example of wave refraction into Table Bay showing the significant wave heights and mean wave directions for an offshore condition with Significant wave height = 5 m, Peak wave period = 12.5 s and Mean wave direction = From the southwest.

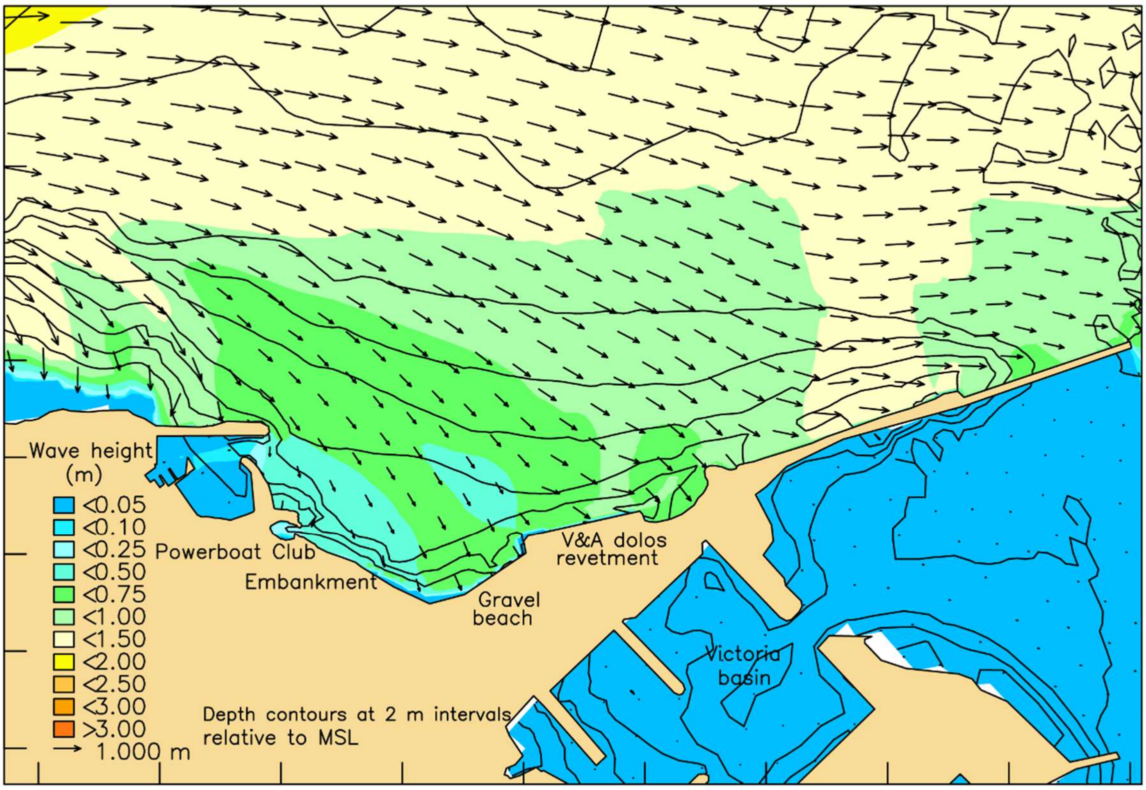


Figure 7: An example of the significant wave heights and mean wave directions in Granger Bay for an offshore condition with Significant wave height = 5 m, Peak wave period = 12.5 s and Mean wave direction = From the southwest. (The same condition as for Figure 4).

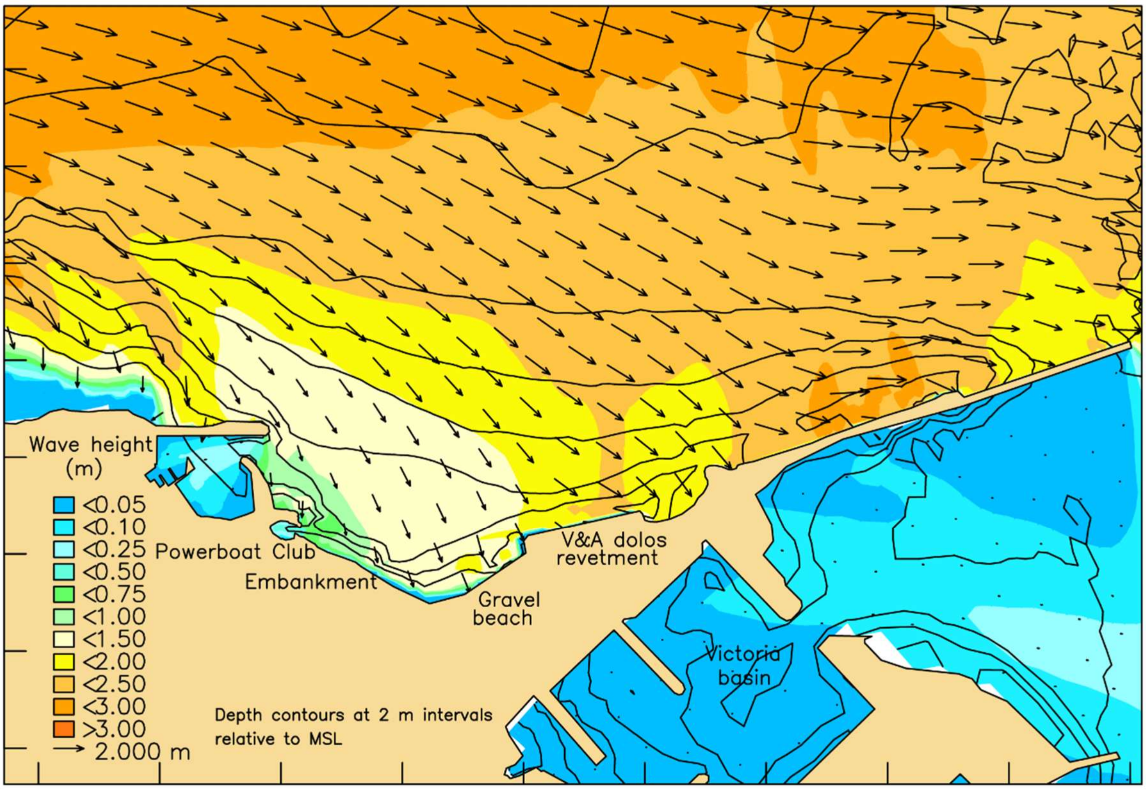


Figure 8: An example of the significant wave heights and mean wave directions in Granger Bay for an offshore condition with Significant wave height = 5 m, Peak wave period = 12.5 s and Mean wave direction = From the west.

In SU (2014a and 2014b), the offshore wave conditions, as shown in Figure 5, were grouped into categories to give 322 conditions according to height, direction and period and these conditions were then transformed into Table Bay with a numerical wave transformation model. The wave heights and directions for two of these simulated conditions are shown in Figures 6 and 7 and Figure 8.

Wave roses from the wave refraction simulations for two locations in Granger Bay are presented in Figure 9. The one location is approximately in the centre of Granger Bay (location A in SU (2014b)) and the other location is at the entrance to the Granger Bay Marina (location D in SU (2014b)).

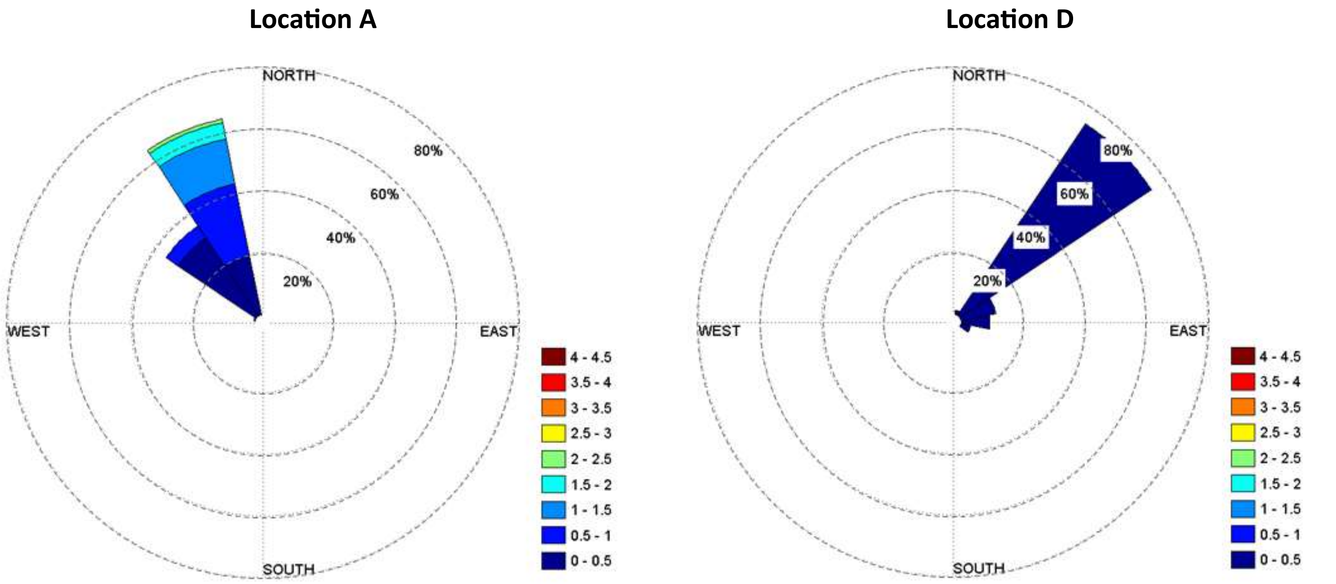


Figure 9: Wave roses (wave heights in metres) showing the angular distribution of significant wave heights at two locations in Granger Bay.

The wave conditions in Figure 9 (left panel) are representative of the waves that arrive in Granger Bay, and they are in a band around northwest (within the angular range from 305° to 345°). At the location near the entrance to the marina (right panel), the waves have very small heights (since most of the wave energy is expended on the severe refraction) and there are a small number of waves from the east which are waves that have reflected from the gravel beach or the V&A revetment towards the Granger Bay Marina.

3.3 Long period waves

Long period waves that travel together with groups of short wind-generated waves, and which are attached to groups of short waves, are referred to as locked waves or bound long waves. Due to refraction of the carrier wave groups, the trajectories of the long waves also curve toward the normal at the coast. Wave breaking causes these long bound waves to be released and the free (released) waves then travel independently and may reflect off the coast since they generally have low steepness values. These free waves are often termed infra-gravity waves or surf beats. Diffraction points, such as breakwater heads, may also destroy the wave groups and reduce the spatial gradients in the radiation stresses. This process also causes the bound long period waves to become free long waves which then travel at their own celerities.

The influence of long waves in Granger Bay was simulated by SU (2014a) where a total of 12 simulations were conducted for the long waves. The offshore swell wave heights used for the simulations were taken as the 1% exceedance value for each of the swell wave peak periods which represent estimates of extreme conditions expected yearly. The wave periods were selected to correspond with the most frequently occurring swell waves of high energy.

The main findings for the present layout of Granger Bay were that the majority of the long period wave energy inside the Granger Bay Marina originates from the diffracted long period wave component around the head of the Granger

Bay Marina breakwater. The gravel beach embayment of the present layout causes a small reflected long period wave component to enter the Granger Bay Marina. Long period wave energy spectra were also calculated which indicated that there is a spread of energy below 0.04 Hz (25 seconds and longer) at the entrance of the Granger Bay Marina. At the centre of the main basin of the Granger Bay Marina the long period wave energy distribution has peaks at more or less 300 seconds, 90 seconds, 23 seconds and 17 seconds. It was estimated that some of the reflected free long waves get re-refracted as edge waves and move west along the embayment where these waves enter the Oceana Powerboat Club. The long period wave energy in the Oceana Powerboat Club has an energy distribution between 60 seconds and 110 seconds with the peak at about 100 seconds.

3.4 Summary

The discussion of the baseline conditions in Granger Bay was based on the simulation results from the 2018 baseline report, the Oceanographic study for the 2018 approval and the report for the evaluation of the 2023 proposed development. Water movement within the bay is primarily wind-driven, experiencing minor effects from shelf currents farther offshore and with waves and swell playing an influential role in driving currents in the nearshore. Water movement is further influenced by tides although forcing of this nature is considered minor. In addition, it was determined that (PRDW, 2023):

- The current speeds in Granger Bay due to wind, tides, and ocean currents are very low with speeds generally not exceeding 0.1 m/s.
- The addition of the 2023 development reduces the maximum current speed inside the development from 0.06 m/s in summer and 0.04 m/s in winter to 0.02 m/s.
- The maximum current speeds inside the new development are higher (0.02 m/s) than those inside the Oceana Powerboat Club (0.01 m/s).
- The development does not change the currents significantly beyond 300 m from the development.
- The circulation (calculated as a time-average of the depth-averaged currents) inside the new development comprises twin eddies which will induce flushing of water out of the development.
- The circulation within the development is slightly weaker than the baseline circulation, but stronger than the circulation within the Oceana Powerboat Club.

Offshore waves approach Table Bay mostly from the south-west and west-south-west and then transform, mostly due to refraction, as they move into Table Bay. The wave conditions in the centre of Granger Bay are in a band around northwest (within the angular range from 305° to 345°). Near the entrance to the Granger Bay Marina, the waves have very small heights and there are a small number of waves from the east. It was also determined that (PRDW, 2023):

- The wave heights inside the development are generally reduced compared to the baseline layout, but there is significant amplification in the centre of the development due to harbour resonance. This may lead to surging motions in the development area which can cause boats at locations around the amplification area to move horizontally more than what is expected from the surrounding conditions. The amplification may contribute to higher water levels and potential overtopping of the revetments.
- The wave heights inside the development are significantly larger than those inside the Oceana Powerboat Club.
- The wave heights inside the Oceana Powerboat Club are slightly reduced by the development.
- The reflections off the 'East' breakwater of the development generate nodes and anti-nodes, changing the wave height to the north-east of the development by up to 0.5 m for up to 300 m away from the structure. However, the development does not change the wave heights significantly beyond 500 m from the development.

It is anticipated that the effect of sea level rise will not yield additional increases in wave heights at the proposed breakwaters since there is substantial wave height reduction due to refraction around Mouille Point that will continue to limit wave heights in Granger Bay.

4 Impact Identification and Assessment

4.1 Introduction

Potential oceanographic impacts associated with the newly proposed 2023 development are assessed in terms of their significance according to the prescribed rating methodology. The assessment matrix was compiled using the 2018 development modelling results (mostly Section 2.3), the baseline description (Chapter 4), the model results from the 2023 assessment (Chapter 3), as well as a general understanding of existing system drivers, impacts and influences.

Only possible impacts on the oceanographic environment, mostly outside (seawards towards the greater Table Bay area) of the new proposed development are considered. The following impacts are evaluated:

- Short wave reflections into the greater Table Bay area (mostly off the 'East' breakwater).
- Long wave and short wave reflections towards the Granger Bay Marina (mostly off the offshore side of the 'West' breakwater).
    - Effects on navigation;
    - Effects on vessel berthing and mooring;
    - Effects on design parameters of the Granger Bay Marina breakwater;
- Impacts on the new slipway (Oceana Powerboat Club) users during launching and navigation.
- Effect on longshore sediment transport on the adjacent coastline.

4.2 Short and long wave reflections into Table Bay

Short period, wind-generated waves as well as long period waves will reflect off the new 'East' and 'West' breakwaters, as is shown in Figure 4, and can alter wave conditions for up to 500 m from the breakwaters. The changes in total wave heights are considered to be small and should be around 15 cm. The reflected waves will not travel more than 500 m into Table Bay and will not reach the Bloubergstrand beach or Milnerton beach. There are limited mitigation options to reduce the intensity or probability of this impact. The impact remains of Low significance even without mitigation.

Table 2: Impact 1- Impact of reflected short and long period waves on Table Bay.

	Extent	**Intensity**	**Duration**	**Consequence**	**Probability**	**Significance**	**Status**	**Confidence**
Without mitigation	Local 1	Low 1	Long-term 3	Low 5	Probable	Low	-ve	High
Mitigation measures: Not required due to the low significance of the impact.								

4.3 Short and long wave reflections towards the Granger Bay Marina

4.3.1 Short wave reflections

The short period, wind-generated waves that reflect towards the Granger Bay Marina (mostly from the offshore side of the new proposed 'West' breakwater) as partially shown in Figure 4 will arrive perpendicularly to the direction in which boats enter or exit the Granger Bay Marina. It is possible that boats moving into or out of the marina will experience short waves with low wave heights from the side that may influence navigation. There are limited mitigation options to reduce the intensity or probability of this impact. The impact remains of Low significance even without mitigation.

Table 3: Impact 2a - Impact on navigation to and from the Granger Bay Marina.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Long-term 3	Low 5	Probable	Low	-ve	High
Mitigation measures: Not required due to the low significance of the impact.								

4.3.2 Long wave reflections

The long period waves that reflect from the offshore side of the new proposed breakwater towards the Granger Bay Marina (mostly from the offshore side of the new 'West' breakwater) will enter the Granger Bay Marina and may cause seiches or water level surges in that marina. During the 1970s the Granger Bay harbour (prior to being the Granger Bay Marina) was prone to harbour resonance (Gerber, 1986). It is possible (but improbable) that the new proposed breakwaters and the Granger Bay Marina breakwater will form a wave guide for long waves and possibly cause resonance in the Granger Bay Marina. Should accentuated long wave action present in the Granger Bay Marina after the Granger Bay Precinct development (new breakwaters), wave mitigation measures can potentially be implemented.

Table 4: Impact 2b - Impact on berthing and mooring in the Granger Bay Marina.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Medium 2	Long-term 3	Medium 6	Improbable	Low	-ve	High
With mitigation	Local 1	Low 1	Long-term 3	Low 5	Improbable	Very low	-ve	High

4.3.3 Effect of wave reflections on existing Granger Bay Marina breakwater

The waves that reflect from the offshore side of the new proposed breakwaters onto the Granger Bay Marina breakwater (mostly from the offshore side of the new 'West' breakwater) can lead to increased wave heights at the Granger Bay Marine breakwater. During storm conditions the increased wave heights may exceed the design criteria of the Granger Bay Marina breakwater or cause increased damage to the breakwater. Mitigation can include regular monitoring of the condition of the existing Granger Bay breakwater with rehabilitation when necessary. The impact is considered of Very Low significance and there are mitigation methods available.

Table 5: Impact 2c - Impact on the Granger Bay Marina breakwater.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Long-term 3	Low 5	Improbable	Very Low	-ve	High
With mitigation	Regional 1	Low 1	Long-term 3	Low 5	Improbable	Very low	-ve	High

4.4 Impacts on the new slipway within the new proposed bay

Total wave heights will be reduced at the new slipway and lead to more favourable launch conditions. Users navigating towards, and from, the exit of the new proposed bay (opening between the new 'East' and new 'West' breakwaters) will encounter a circulating eddy current as well as a tidal current. Although the tidal currents are small, they will increase in magnitude in the opening to the development which may give stronger currents than expected. User may also experience higher than normal wave heights near the centre of the new development due to resonance. There are limited physical mitigation options available, but users can be made aware of the possible effects that they may encounter.

Table 6: Impact 3 - Impact on the users of the new slipway during launching and navigation.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	Local 1	Low 1	Long-term 3	Low 5	Possible	Very Low	-ve	Medium
With mitigation	Regional 1	Low 1	Long-term 3	Low 5	Improbable	Very low	-ve	Medium

4.5 Longshore sediment transport

The coastline around the development area is a rocky coast and it is anticipated that no changes will occur in the sediment transport regime due to the proposed revetment and breakwaters except for longer-term mud accumulation that is predicted within parts of the Granger Bay Marina. Therefore, no impacts on coastal process will be considered except the changes in wave regime.

There are limited mitigation options available to reduce the intensity or probability of this impact, and therefore the impact remains of Low significance with mitigation.

Table 7: Impact 4 - Impact on the longshore sediment transport along the adjacent coastline.

	Extent	Intensity	Duration	Consequence	Probability	Significance	Status	Confidence
Without mitigation	None 0	None 0	None 0	Not significant 0	Improbable	Insignificant	-ve	High
Mitigation measures: Not required due to the insignificance of the impact.								

5 Summary and Conclusions

Development of the V&A Waterfront was already proposed in 2018, partially for safety reasons since the shoreline between the Oceana Powerboat Club and the V&A dolos revetment is vulnerable to damage and poses a flooding risk to adjacent areas and partially to reclaim land for mixed use. This development scheme was approved in April 2018. At present, the V&A Waterfront is proposing an alternative development (referred to as the 2023 development) in which a replacement for the existing unprotected embankment and gravel beach, a permanent rock revetment and two breakwaters will be established to ensure shoreline protection, as well as providing shelter for portions of the site from storm action. This report focuses on the oceanographic impacts of these coastal defence structures and, in particular, the two breakwaters.

The port and coastal engineering group, PRDW has conducted numerical modelling of the proposed 2023 development. The modelling comprised two components, namely hydrodynamic modelling and wave modelling. The results of the modelling, namely current speed and direction, flushing of water and seawater temperature in the proposed basin, wave heights and wave induced bottom shear stresses are presented in PRDW (2023). The approach that was followed for this Oceanographic Study was not to conduct modelling, but to infer impacts on the environment from the PRDW report as well as from the 2018 specialist report. As a first step in the approach the PRDW (2023) report was reviewed with particular emphasis on the models upon which the study was based.

It was found that the hydrodynamic model setup, scenarios and results are considered to be robust and the conclusions are deemed acceptable and may be used in additional analyses for the Environmental Impact Assessment. The model results related to the seawater temperature will need to be interpreted by a marine ecologist to assess the impact on the marine ecology. In addition, the wave model setup, scenarios and results are considered to be robust, and the conclusions are deemed acceptable and may be used in additional analyses for the Environmental Impact Assessment. The model results related to the bottom shear stresses which relates to the deposition and resuspension of fine sediments will need to be interpreted by a marine ecologist to assess the impact on the marine ecology.

The discussion of the baseline conditions in Granger Bay was based on the simulation results from the 2018 baseline report, the Oceanographic study for the 2018 approval and the report for the evaluation of the 2023 proposed development. Water movement within the bay is primarily wind-driven, experiencing minor effects from shelf currents farther offshore and with waves and swell playing an influential role in driving currents in the nearshore. Water movement is further influenced by tides although forcing of this nature is considered minor. In addition, it was determined that (PRDW, 2023):

- The current speeds in Granger Bay due to wind, tides, and ocean currents are very low with speeds generally not exceeding 0.1 m/s.
- The addition of the 2023 development reduces the maximum current speed inside the development from 0.06 m/s in summer and 0.04 m/s in winter to 0.02 m/s.
- The maximum current speeds inside the new development are higher (0.02 m/s) than those inside the Oceana Powerboat Club (0.01 m/s).
- The development does not change the currents significantly beyond 300 m from the development.
- The circulation (calculated as a time-average of the depth-averaged currents) inside the new development comprises twin eddies which will induce flushing of water out of the development.
- The circulation within the development is slightly weaker than the baseline circulation, but stronger than the circulation within the Oceana Powerboat Club.

Offshore waves approach Table Bay mostly from the south-west and west-south-west and then transform, mostly due to refraction, as they move into Table Bay. The wave conditions in the centre of Granger Bay are in a band around northwest (within the angular range from 305° to 345°). Near the entrance to the Granger Bay Marina, the waves have very small heights and there are a small number of waves from the east. The main findings for the present layout of Granger Bay (baseline condition) were that the majority of the long period wave energy inside the Granger Bay Marina originates from the diffracted long period wave component around the head of the Granger Bay Marina breakwater. The gravel beach embayment of the present layout causes a small reflected long period wave component to enter the Granger Bay Marina. It was estimated that some of the reflected free long waves get re-refracted as edge waves and move west along the embayment where these waves enter the Oceana Powerboat Club. It was determined that for the proposed development (PRDW, 2023):

- The wave heights inside the development are generally reduced compared to the baseline layout, but there is significant amplification in the centre of the development due to harbour resonance. This may lead to surging motions in the development area which can cause boats at locations around the amplification area to move horizontally more than what is expected from the surrounding conditions. The amplification may contribute to higher water levels and potential overtopping of the revetments.
- The wave heights inside the development are significantly larger than those inside the Oceana Powerboat Club.
- The wave heights inside the Oceana Powerboat Club are slightly reduced by the development.
- The reflections off the 'East' breakwater of the development generate nodes and anti-nodes, changing the wave height to the north-east of the development by up to 0.5 m for up to 300 m away from the structure. However, the development does not change the wave heights significantly beyond 500 m from the development.

From the wave and hydrodynamic modelling study it may be deduced that the reflected waves will not affect the surf break Thermopylae since the reflected waves that may refract around the Granger Bay Marina breakwater will not reach the surf break which is located more than 500 m from the prosed developments. With regards to the Granger Bay Marina (Waterclub), wave reflections will occur off the western breakwater, but wave height comparisons with and without the development show a slight reduction in wave heights within the Granger Bay Marina due to the development. Both wave heights and currents within the marina are slightly smaller with the development and scour around structures is expected to be reduced. Considering that the proposed land reclamation and breakwaters are not expected to impact on total wave heights at distances of more than 500 metres from the development, the proposed development is not expected to impact on longshore sediment transport or coastal dynamics on the eastern shoreline of Table Bay (specifically the Bloubergstrand and Milnerton regions). Changes in sediment transport due to the proposed development are not expected except for longer-term mud accumulation that is predicted within the entire inner area of the Granger Bay Marina, except for the entrance and some localised areas of scour.

Only possible impacts on the oceanographic environment, mostly outside (seawards) of the proposed development are considered. The impacts that were evaluated are:

- Short wave reflections into the greater Table Bay area (mostly off the 'East' breakwater);
- Long wave and short wave reflections towards the Granger Bay marine (mostly off the 'West' breakwater);
  - Effects on navigation;
  - Effects on vessel berthing and mooring;
  - Effects on design parameters of the Granger Bay Marina breakwater;
- Impacts on the Oceana Powerboat Club users during launching and navigation.
- Effect on longshore sediment transport on the adjacent coastline.

The significance of these impacts varies from insignificant to low.

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