Stranraer Marina Expansion

RPS Wave Modelling for Proposed Marina Expansion

Briefing Note 2C

1. Introduction

RPS has undertaken wave modelling of the proposed Stranraer Marina Expansion project to establish the wave climate in the proposed harbour basin for storm return periods of 1 in 1, 10, 50, 100 and 200 years. The 1 in 1, 10 and 50 year storms have been used to establish the performance of the proposed layout of pontoon berths while the higher return period storms are used to provide design information for the structural elements of the proposed scheme. The modelling has been undertaken using RPS's in-house coastal process models which are based in the DHI Mike modelling system.

The wave climate approaching the harbour has been established by modelling the storms approaching Loch Ryan and then simulating how these waves are transformed through Loch Ryan to the approaches to Stranraer. The marina expansion project in Stranraer harbour, Loch Ryan, is exposed to waves generated during storms from the WNW to the NE. The extent of the wave model used for the simulation of the waves approaching Loch Ryan and the bathymetry of the model of Loch Ryan itself are shown in Figure 1.1.

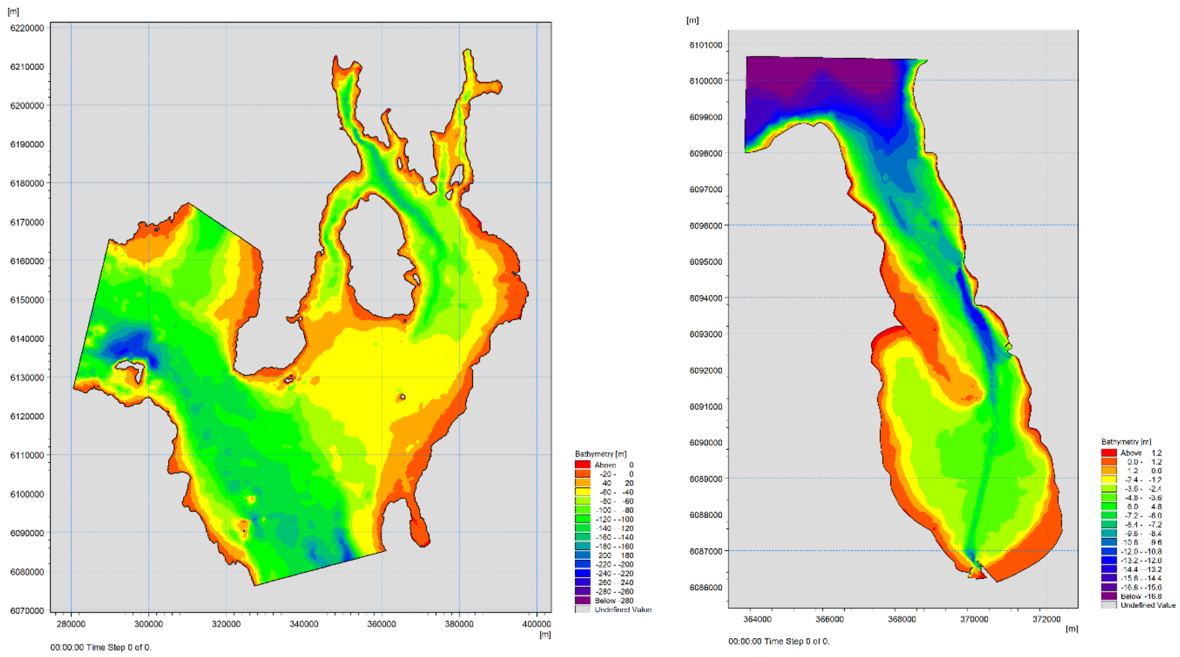

Figure 1.1 Wave model bathymetries used in simulation of waves approaching Stranraer

The simulations were undertaken for every 15° direction from 285° to 45° N at Mean High Water Spring Tides as the wave penetration into the proposed marina basin was expected to be most pronounced at high tide water levels. The wave climate along the boundary of the detailed harbour model was extracted from the results of the simulation of the storm waves in the Loch Ryan model. It was found that the storm waves approaching the marina basin had relatively short wave lengths with peak wave periods in the range 3.3 to 4.5 seconds.

2. Validation of Stranraer Harbour Model

The validation of the wave model was undertaken by analysing and simulating a significant storm event that occurred on 7th December 2024 and comparing the wave climate with video clips taken in Stranraer during the morning of the 7th December 2024.

2.1 Storm wind data

The storm wind data in Loch Ryan for the event was obtained from the Global AT CFSR data base for a point at 5.051326°W 54.93134°N. The wind speed and direction from 5.00am to 16.00pm is shown in Table 2.1. It will be seen from this table that the wind speeds during the daylight hours were reasonably constant being between 23 to 24 m/s from directions 337° to 340° N. The predicted tidal levels for Stranraer are also given in Table 2.1. It should be noted that the storm direction of around 340°N is within the most arduous sector for storm wave height penetration into Stranraer harbour.

Table 2.1 Hourly wind data for the storm on morning of 7 December 2024

Time	Ws m/s	Wd °N	Tide level m CD
07/12/2024 05:00:00	24.93	330.89	2.57
07/12/2024 06:00:00	25.47	332.58	2.18
07/12/2024 07:00:00	25.33	336.69	1.68
07/12/2024 08:00:00	25.68	338.36	1.21
07/12/2024 09:00:00	24.06	337.62	0.98
07/12/2024 10:00:00	23.68	339.35	1.07
07/12/2024 11:00:00	23.15	340.41	1.41
07/12/2024 12:00:00	22.89	340.47	1.87
07/12/2024 13:00:00	21.83	337.94	2.36
07/12/2024 14:00:00	23.24	337.96	2.79
07/12/2024 15:00:00	23.73	337.64	3.08
07/12/2024 16:00:00	23.24	336.68	3.12

The return period for the event on the 7 December has been established by analysing 25 years of hourly wind data for the period January 2000 to March 2025 for Loch Ryan for the critical NW to N sector. The Extreme Value Analysis was undertaken using the DHI EVA toolbox and the output from the peak over threshold analysis of the data is shown in Figure 2.1 below. It will be seen from this figure that there is a very good statistical fit of the extreme value distribution to the wind data. This analysis shows that a 1 in 10 year return period event would have a wind speed of 23.5 m/s which almost exactly matches that which occurred during the morning of the 7th December 2024. Thus, it is concluded that the storm which is seen in the video clips taken on the 7th December is a 1 in 10 year return period event.

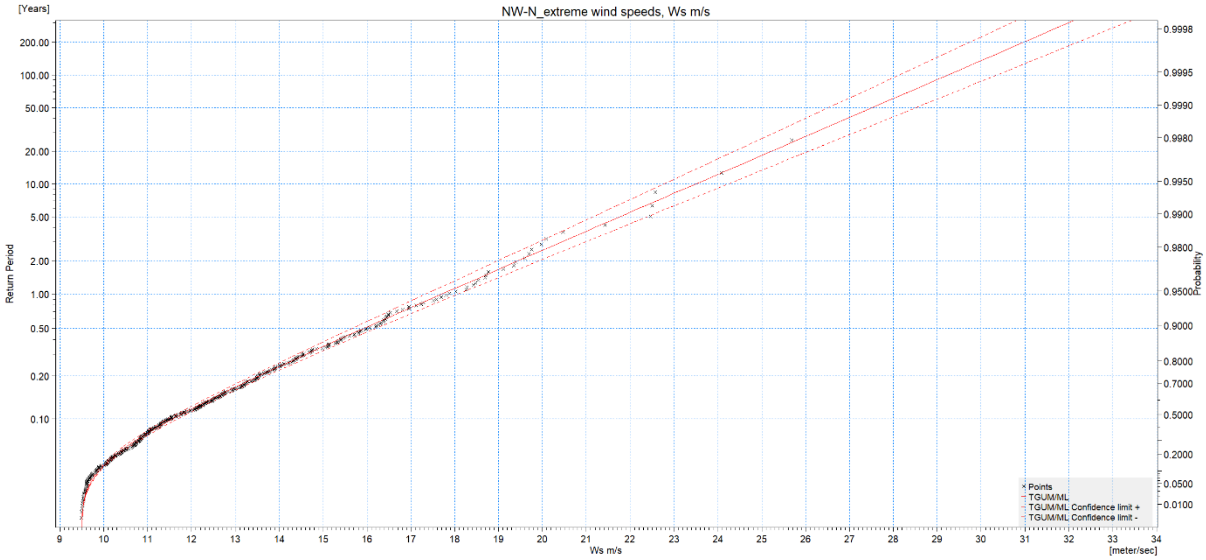

Figure 2.1 Extreme Value Analysis of 25 years of hourly wind speeds from the NW-N sector

2.2 Harbour wave model simulation

The video clips are not accurately time stamped but are thought to be taken during mid morning of the 7th of December. Looking at the light in the video it appears that the sun is quite high for a December morning thus it considered that a time of about 11.30am is likely to be appropriate, when the predicted tidal level will have been about 1.75m CD. Thus, the simulations have been undertaken based on the wind and water level data at that time. As the wind speeds and directions were relatively stable during this morning, the actual time of the simulation is not too critical. The simulations were undertaken using the existing model of Stranraer harbour area and the model bathymetry of the harbour basin is shown in Figure 2.2.

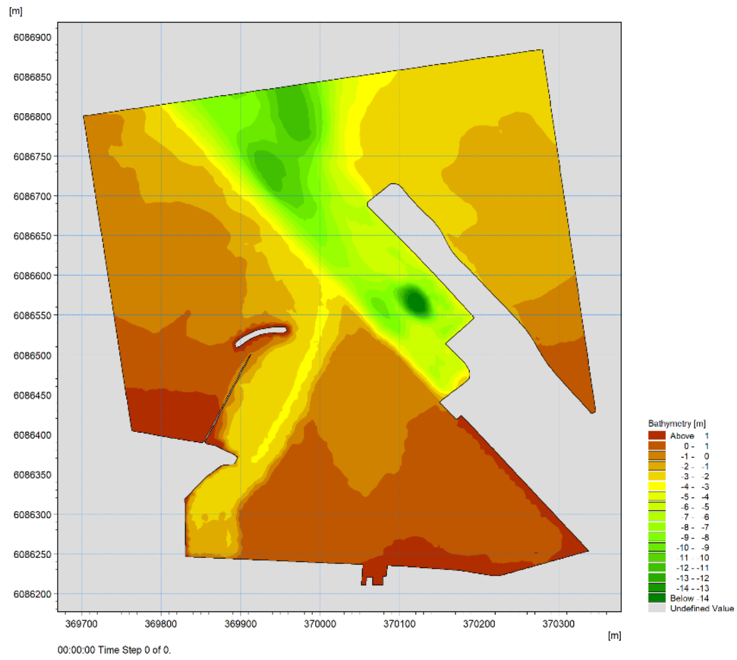

Figure 2.2 Existing Stranraer harbour model bathymetry

As explained in Section 1, the boundary data for the harbour model was taken from the results of the simulations of the storm in the whole of Loch Ryan and its adjoining sea areas.

The wave heights and mean wave directions during the December 7th storm predicted by the model are shown in Figure 2.3. The spectral peak wave periods during the storm were about 4.00s with the mean energy wave period of 3.63s.

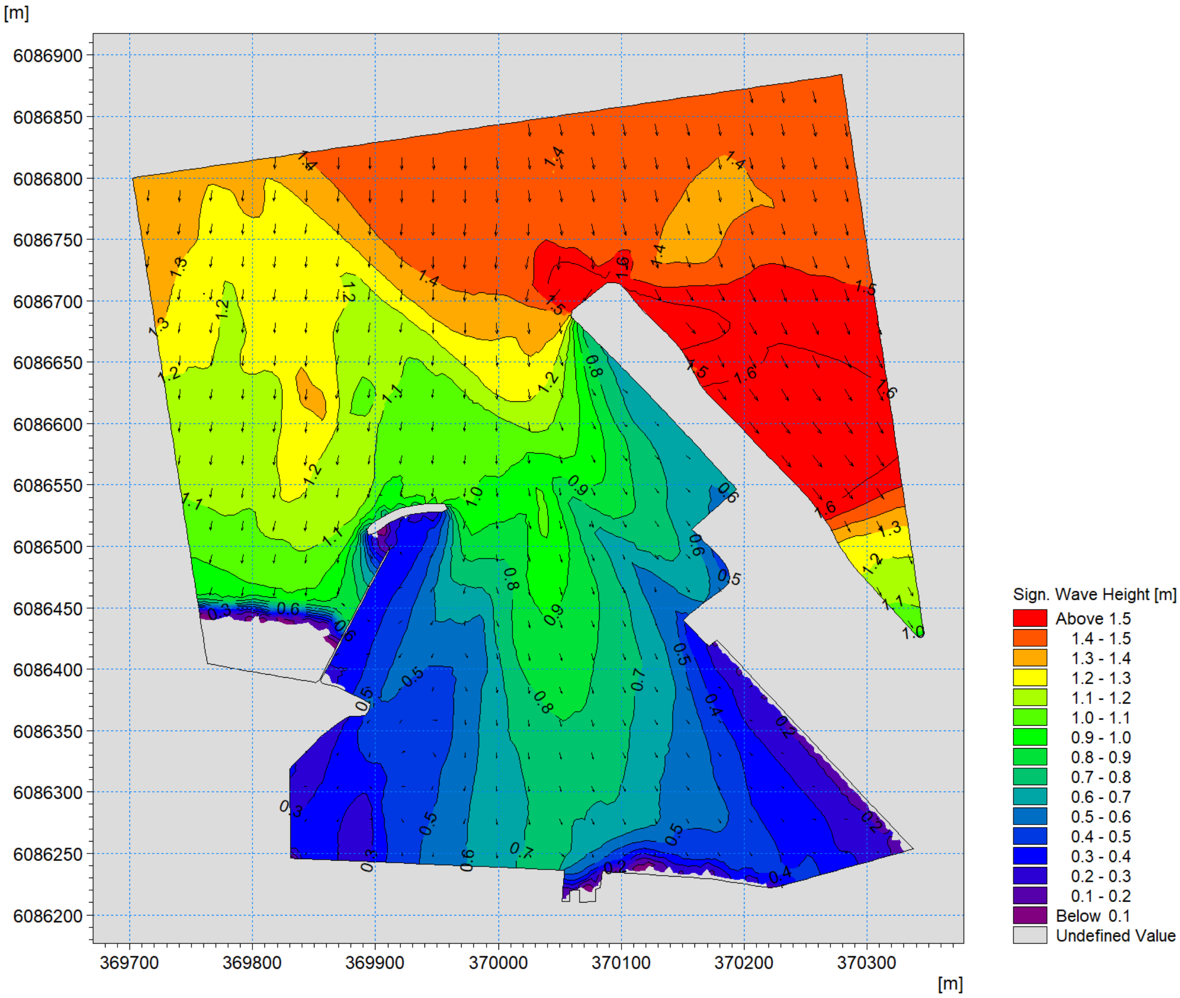

Figure 2.3 Significant wave heights and mean wave direction of waves in Stranraer harbour during the storm of the morning of 7th December 2024

As will be seen from Figure 2.3, waves with significant wave heights of 0.9m to 1.0m enter the harbour to the east of the mole breakwater and the waves in the existing pontoon area have a significant height of about 0.5m.

Stills taken from the video clips are shown in Figures 2.4 and 2.5 which give an idea of the conditions on the 7th December. However, the visual of the actual video give a better idea of the conditions during the storm. Examination of the video shows that generally the wave heights given by the model are similar to or very slightly higher than those seen in the video. Thus, the model is considered fit for purpose.

Figure 2.4 Storm waves entering Stranraer harbour 7th December 2024.

Figure 2.5 Wave disturbance in the existing marina berth 7th December 2024

The significant wave heights and mean wave directions around the proposed harbour during this storm event are shown in Figure 2.6.

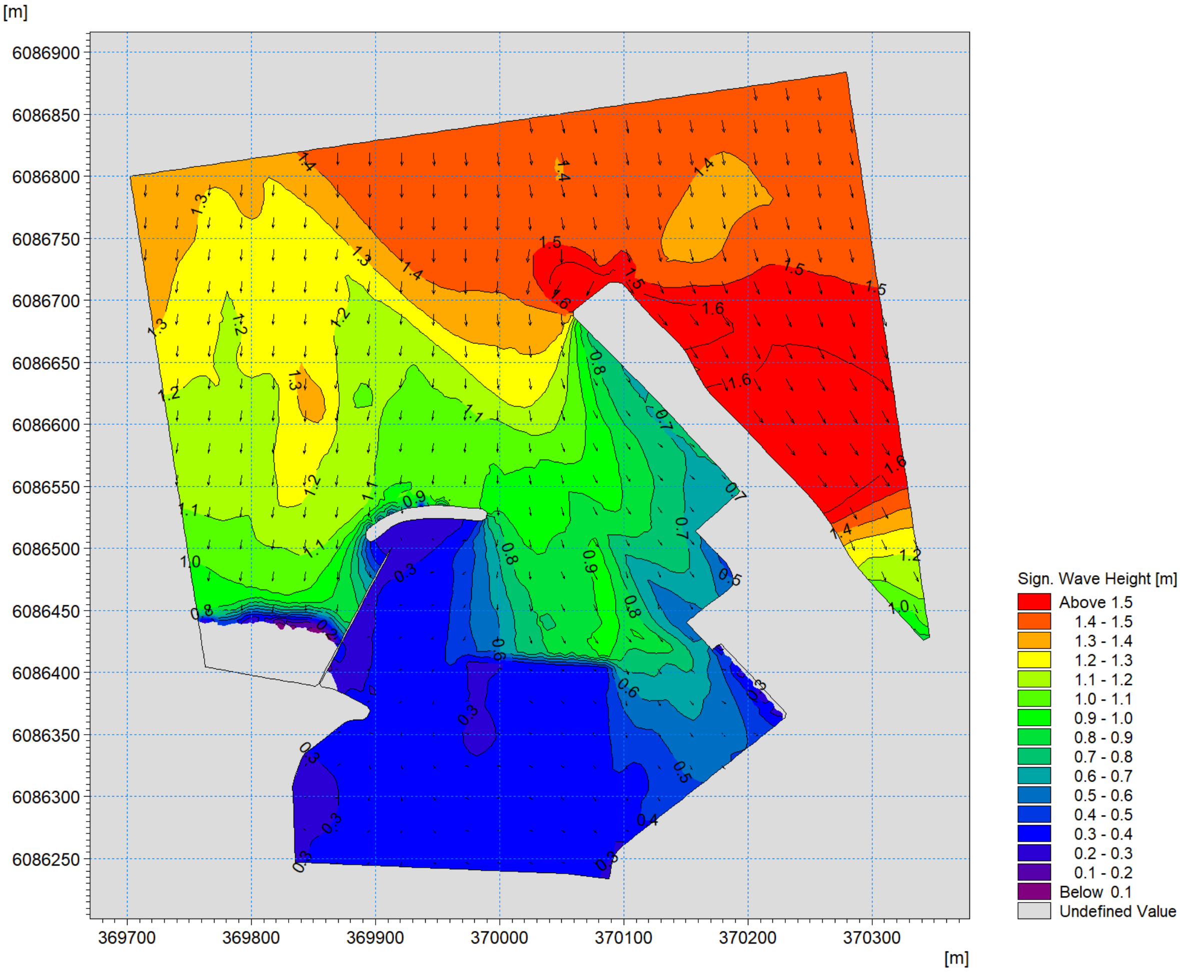

Figure 2.6 Significant wave heights and mean wave direction of waves in the proposed Stranraer harbour during the storm of the morning of 7th December 2024

3. Simulation of Extreme Storms in the Existing Stranraer Harbour

The wave climate in the existing harbour was simulated for storm directions between 285° and 45° for storms with 1 in 1, 10, 50 and 200 years return period at a MHWS tide level. It was found that storms from 345° produced the largest waves within the existing harbour area. The significant wave heights around the existing harbour are shown in Figures 3.1 to 3.4. The spectral peak wave periods ranged between 3.40s to 3.60s for the 1 in 1 year storms, between 3.70s to 4.00s for the 1 in 10 year storms, between 3.90s to 4.20s for the 1 in 50 year storms and between 4.15s to 4.35s for the 1 in 200 year storms.

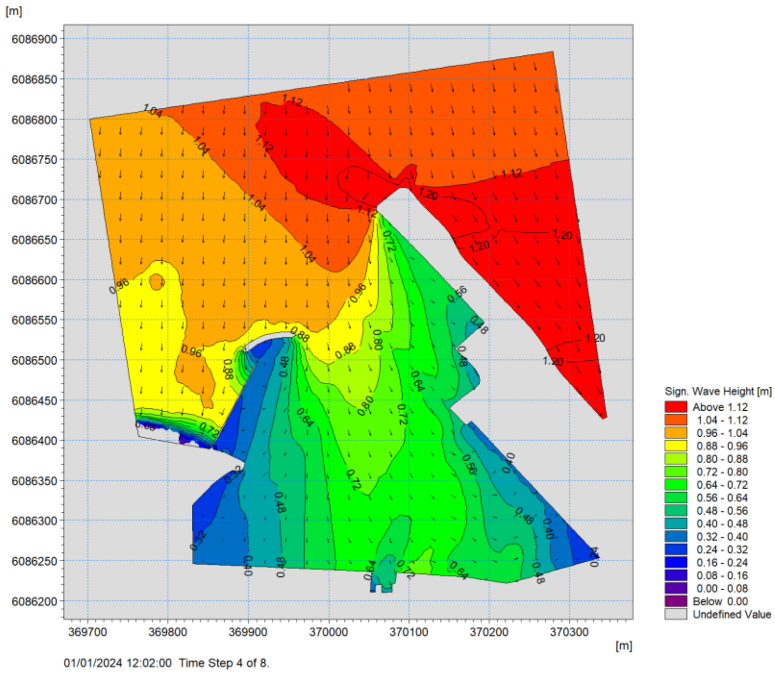

Figure 3.1 Significant wave heights and MWD 1 in 1 year storm at MHWS from 345°

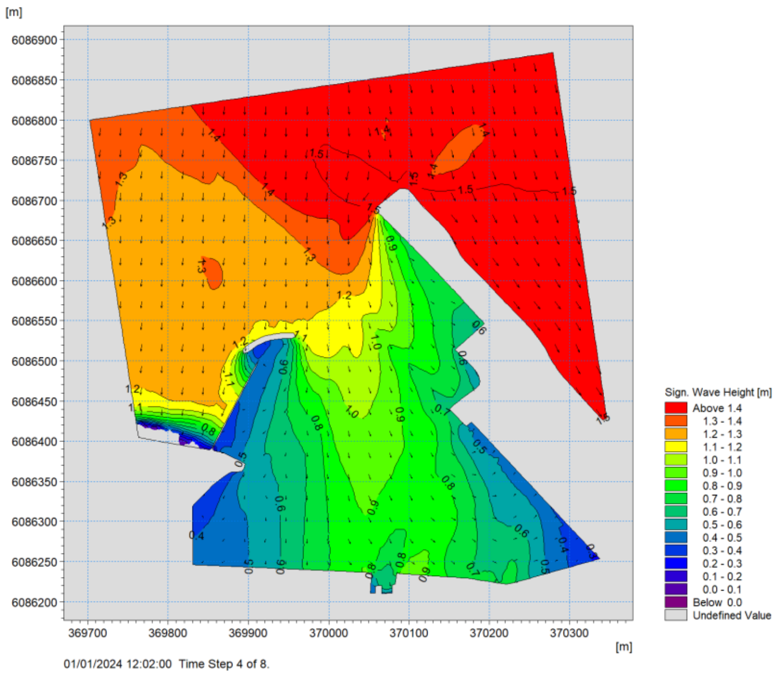

Figure 3.2 Significant wave heights and MWD 1 in 10 year storm at MHWS from 345°

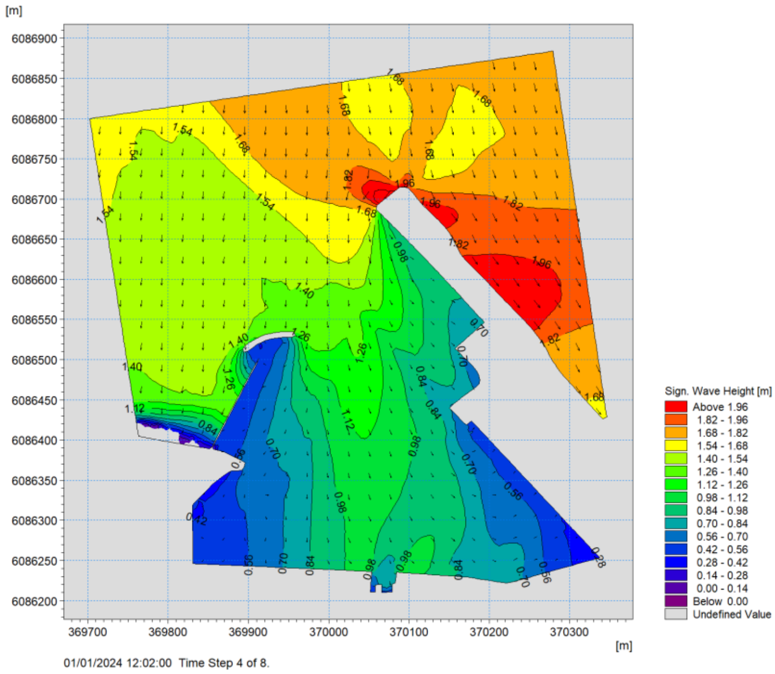

Figure 3.3 Significant wave heights and MWD 1 in 50 year storm at MHWS from 345°

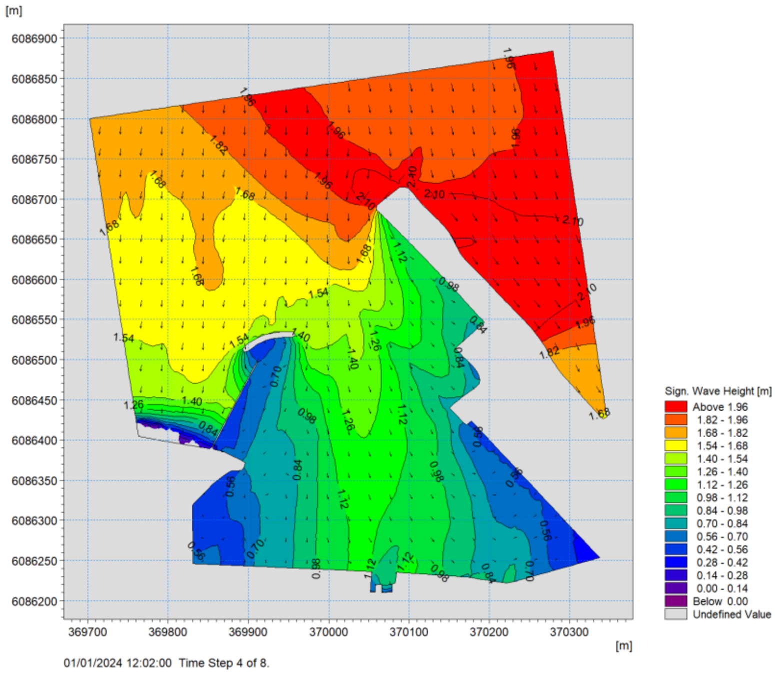

Figure 3.4 Significant wave heights and MWD 1 in 200 year storm at MHWS from 345°

It will be seen from Figures 3.1 to 3.4 that, except for the area of the existing pontoons berths, the wave climate in Stranraer Harbour is too energetic to allow the development of an extended marina without the provision of additional breakwaters.

4. Development of the Extended Stranraer Marina Layout

Following the simulations of the wave disturbance, reported in the previous RPS briefing notes, Fairhurst have developed the harbour layout to include an eastward extension of the existing rubble mound breakwater, and a 120m long by 5m wide floating breakwater as part of the superyacht berth in the harbour. In addition, the dredged depths were changed significantly and a new wall constructed along the southern boundary of the dredged harbour basin. The proposed revised layout for the Stranraer Marina expansion project is shown in Figure 4.1.

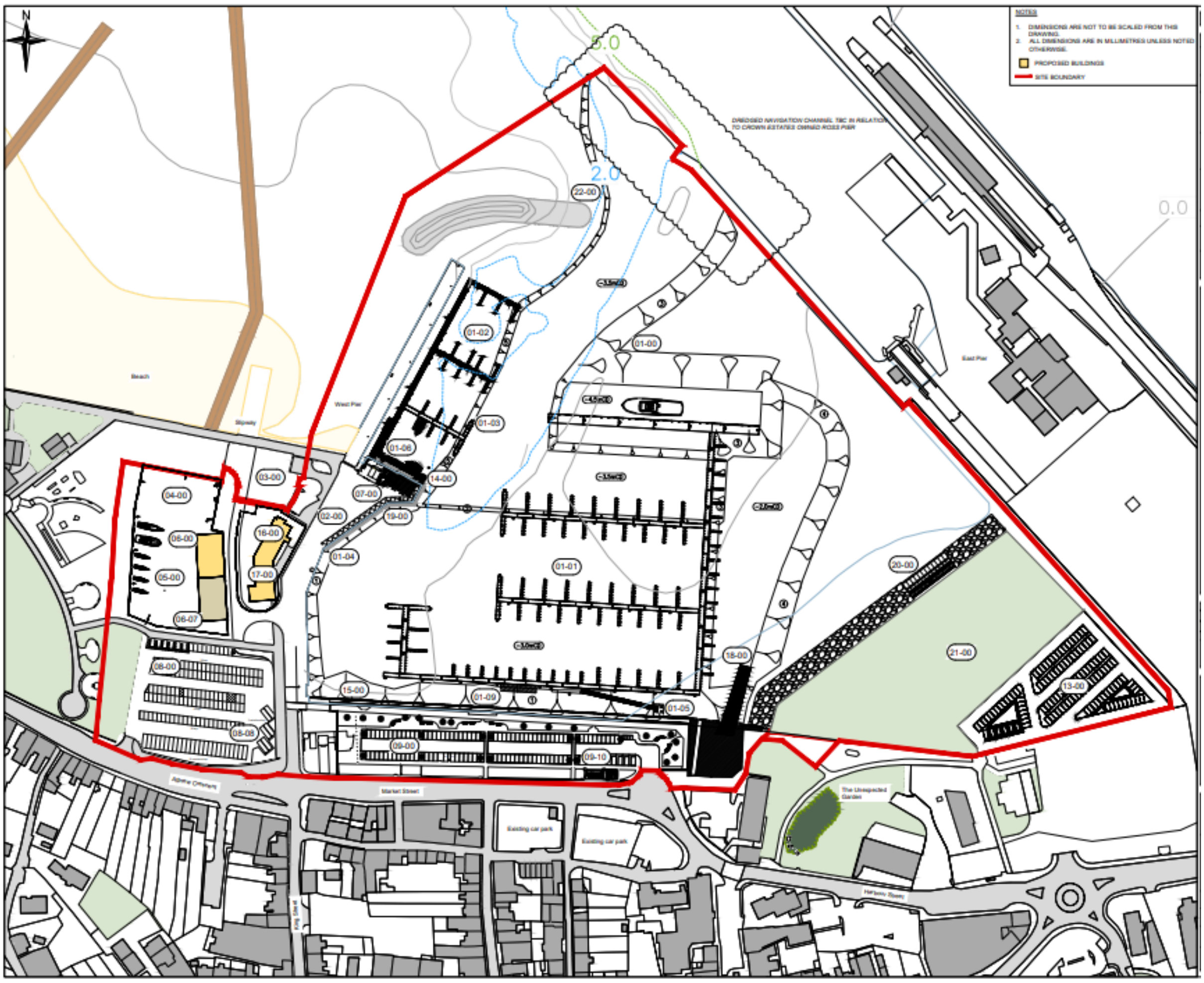

Figure 4.1 Layout for the proposed revised Stranraer Marina Expansion Project

The model bathymetry of the amended revised scheme is shown in Figure 4.2.

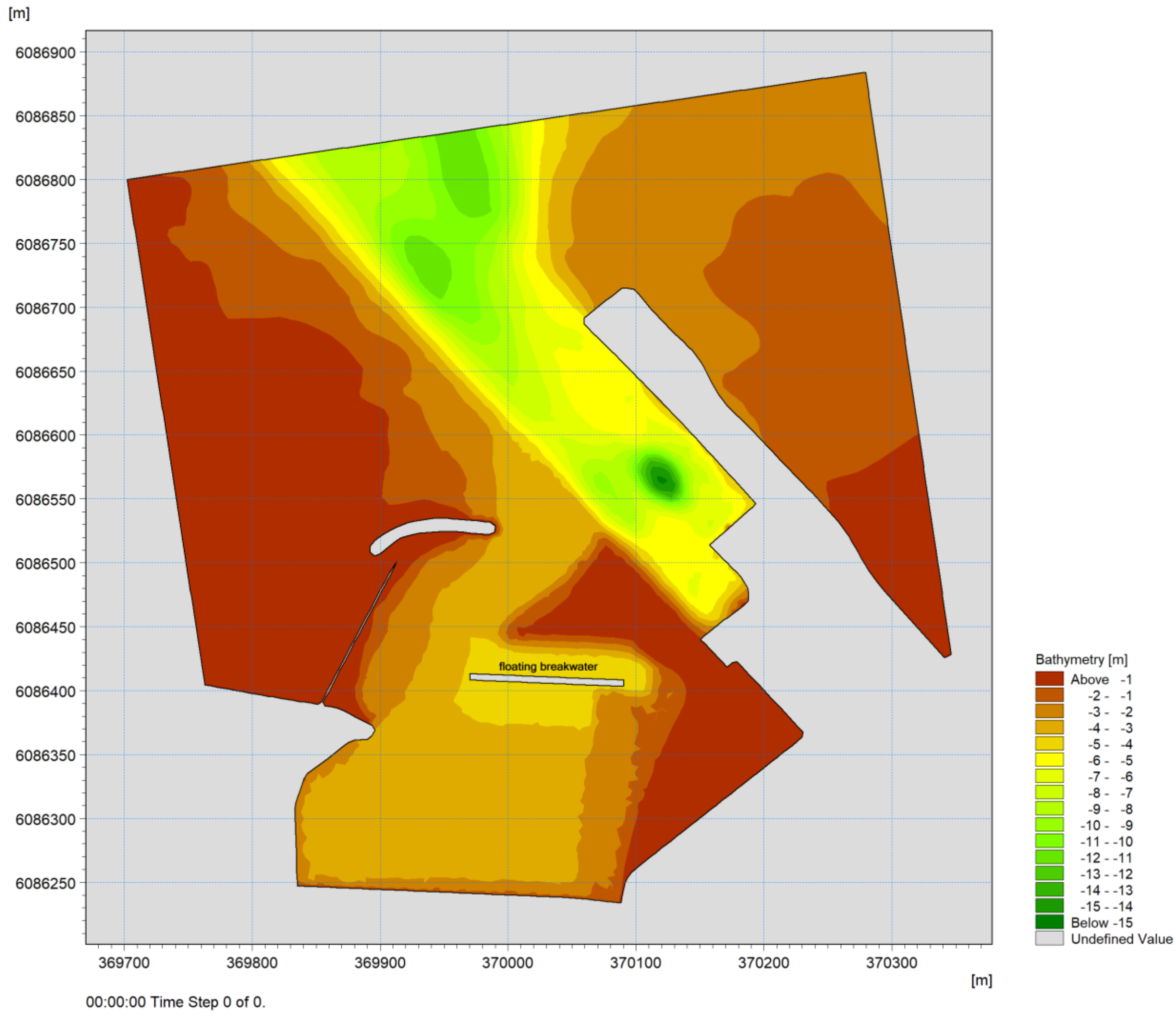

Figure 4.2 Model bathymetry of the amended revised scheme including floating breakwater

The wave heights around the basin were simulated with the special version of the Mike 21 SW model, which includes diffraction and reflective boundaries as well as transmissive and reflective structures. In the model the vertical walls were assumed to be 90% reflective while the rock armoured breakwaters and revetments were assumed to reflect 40% of the wave energy. The transmission and reflection characteristics of the floating breakwater, in the model, were calculated using the wave heights and wave lengths together with the performance curves for a Marintek K 5300 breakwater.

5. Wave climate in the amended revised scheme

The wave climate in the proposed scheme was simulated for storm directions between 285° and 45° for storms with 1 in 1, 10 and 50 years return period at MHWS. It was found that storms from 345° and 360° produced the largest waves within the proposed marina basin. The significant wave heights around the amended revised marina extension layout are shown in Figures 5.1 to 5.3. The spectral peak wave periods ranged between 3.50s to 3.60s for the 1 in 1 year storms, between 3.80s to 4.00s for the 1 in 10 year storms and between 4.05s to 4.20s for the 1 in 50 year storms.

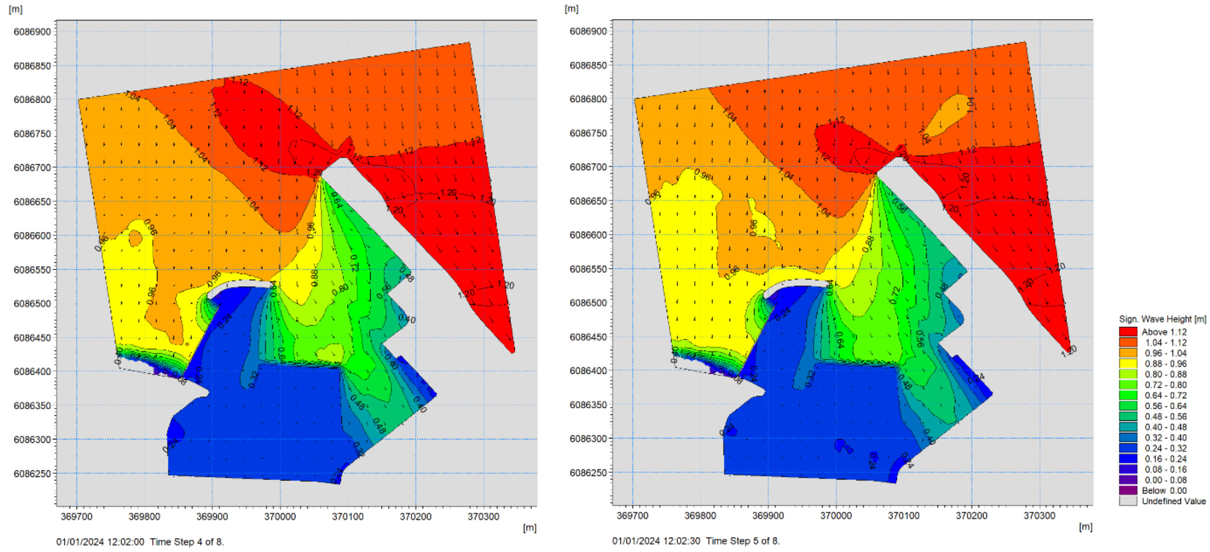

Figure 5.1 Significant wave heights 1 in 1 year storm at MHWS from 345° (left) and 360° (right)

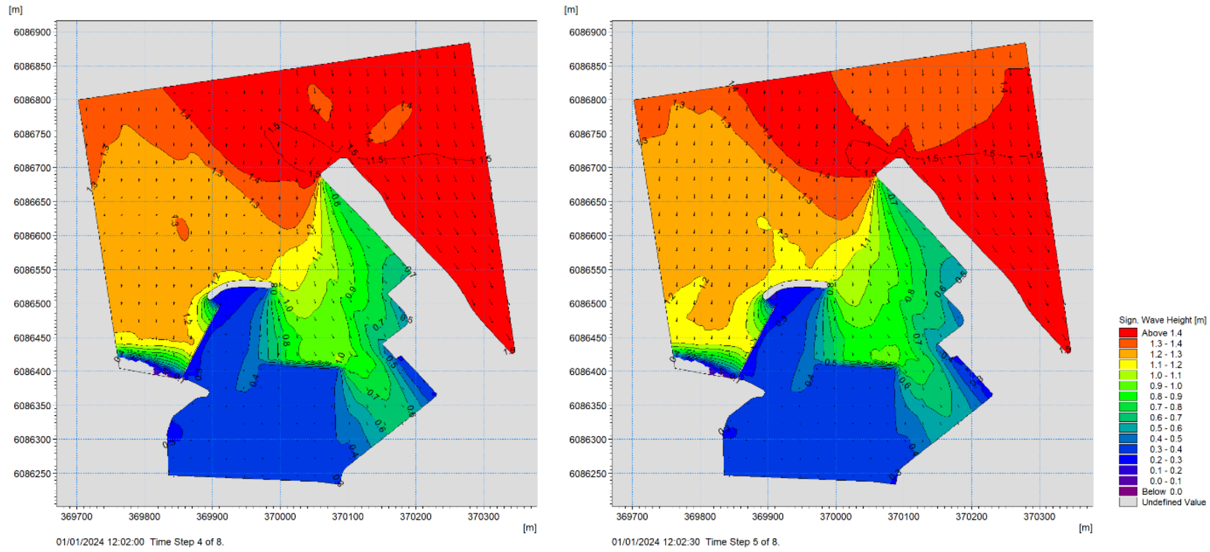

Figure 5.2 Significant wave heights 1 in 10 year storm at MHWS from 345° (left) and 360° (right)

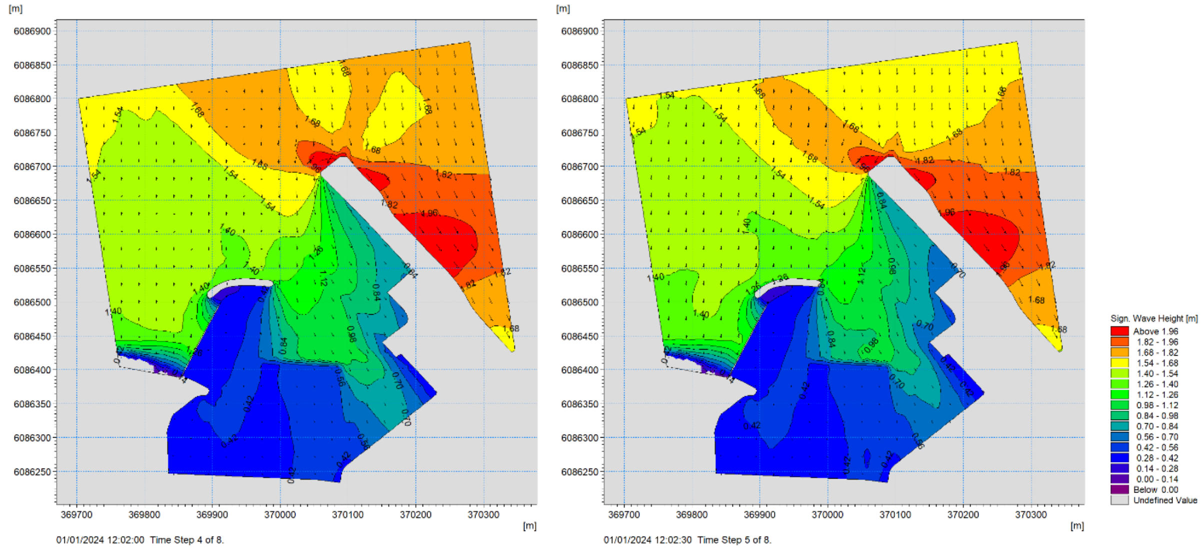

Figure 5.3 Significant wave heights 1 in 50 year storm at MHWS from 345° (left) and 360° (right)

The model simulations have been undertaken assuming that the 5m wide breakwater will perform similarly to a Marintec K 5300 breakwater. The resulting significant wave heights in the marina basin are predicted to be up to 0.30m, up to 0.40m and up to 0.48m during a 1 in 1, 10 and 50 year return period storms respectively. These significant wave heights indicate that the scheme including a 5m wide floating breakwater would provide acceptable wave heights at the all the proposed pontoon berths.

Modelling was also completed for 1 in 200 year return period storms at MHWS both with and without the floating breakwater in place as it is likely that the design of the harbour structures will need to take account of a future condition when the floating breakwater may not be in place. Figures 5.4 to 5.6 show the significant wave heights and mean wave directions for 1 in 200 year storm at MHWS from 315°, 345° and 360°. The spectral peak wave periods were 4.20s to 4.36s, 4.20s to 4.38s and 4.20s to 4.35s for the 315°, 345° and 360° directions respectively.

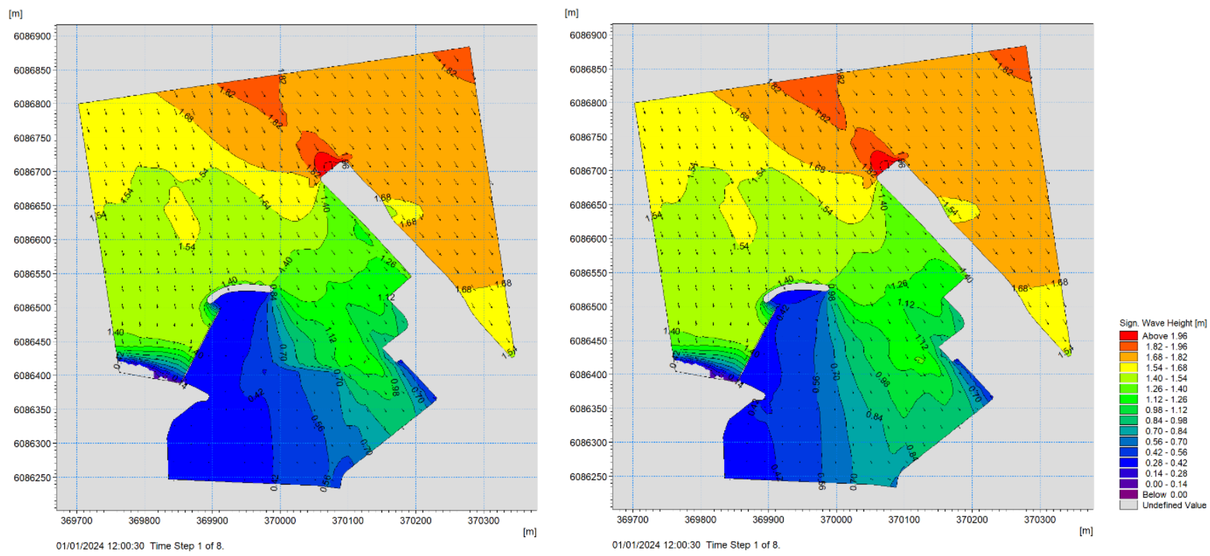

Figure 5.4 Significant wave heights in harbour with floating breakwater (left) and without floating breakwater (right) – 1 in 200 year return period storm at MHWS from 315°

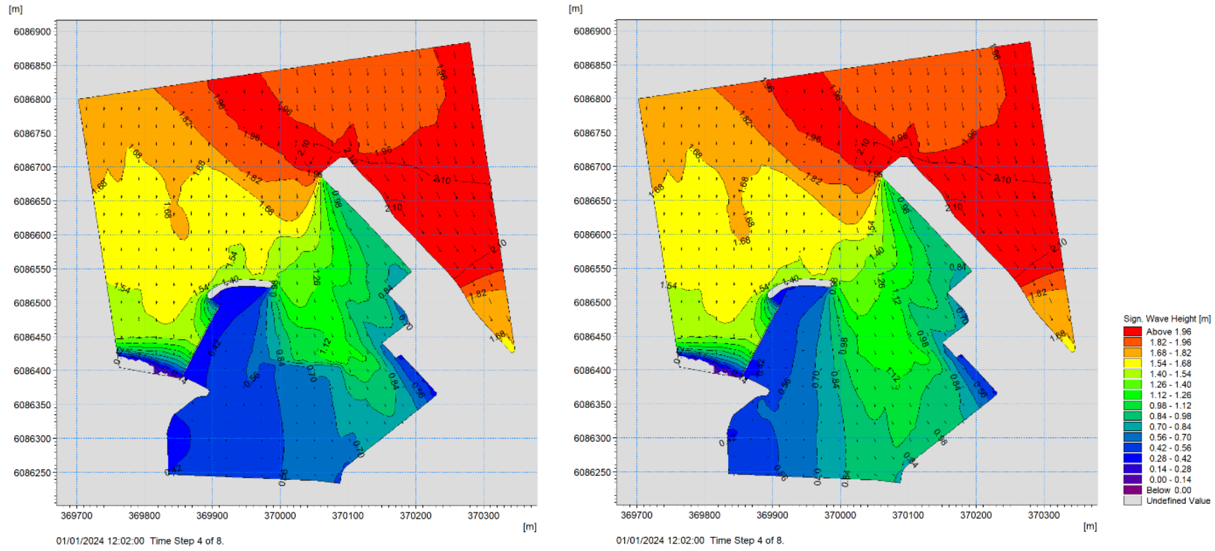

Figure 5.5 Significant wave heights in harbour with floating breakwater (left) and without floating breakwater (right) – 1 in 200 year return period storm at MHWS from 345°

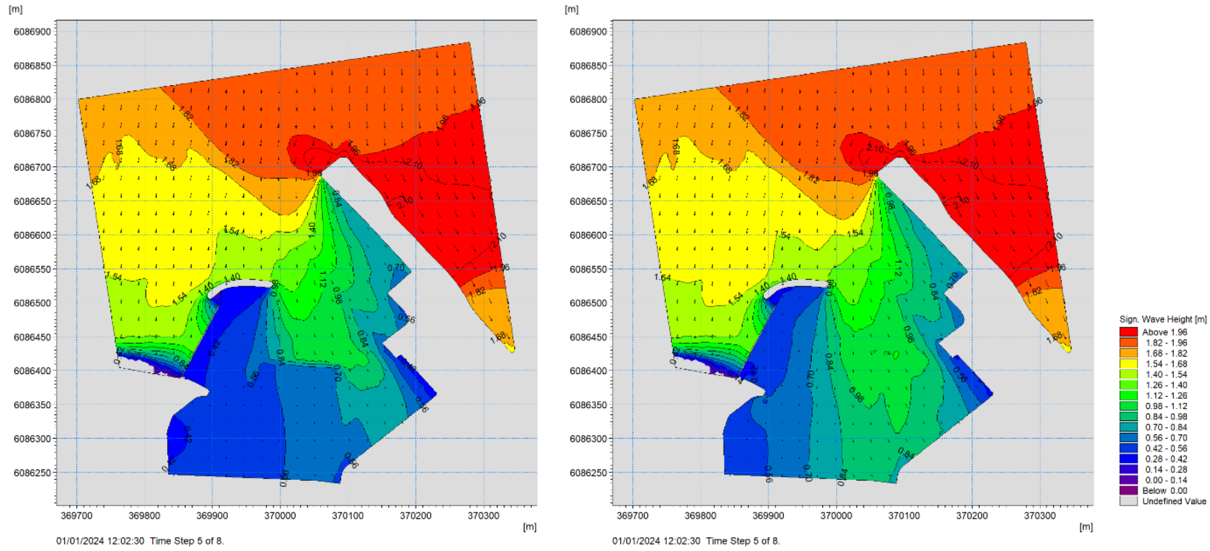

Figure 5.6 Significant wave heights in harbour with floating breakwater (left) and without floating breakwater (right) – 1 in 200 year return period storm at MHWS from 360°

6. Modelling response to issues raised at the Public Consultation

During the public consultations comments were made to Fairhurst about waves coming through the gap between the mole breakwater and the north end of the West Pier during strong westerly winds at high tide. The gap between the structures is shown in the Google Earth picture Figure 6.1.

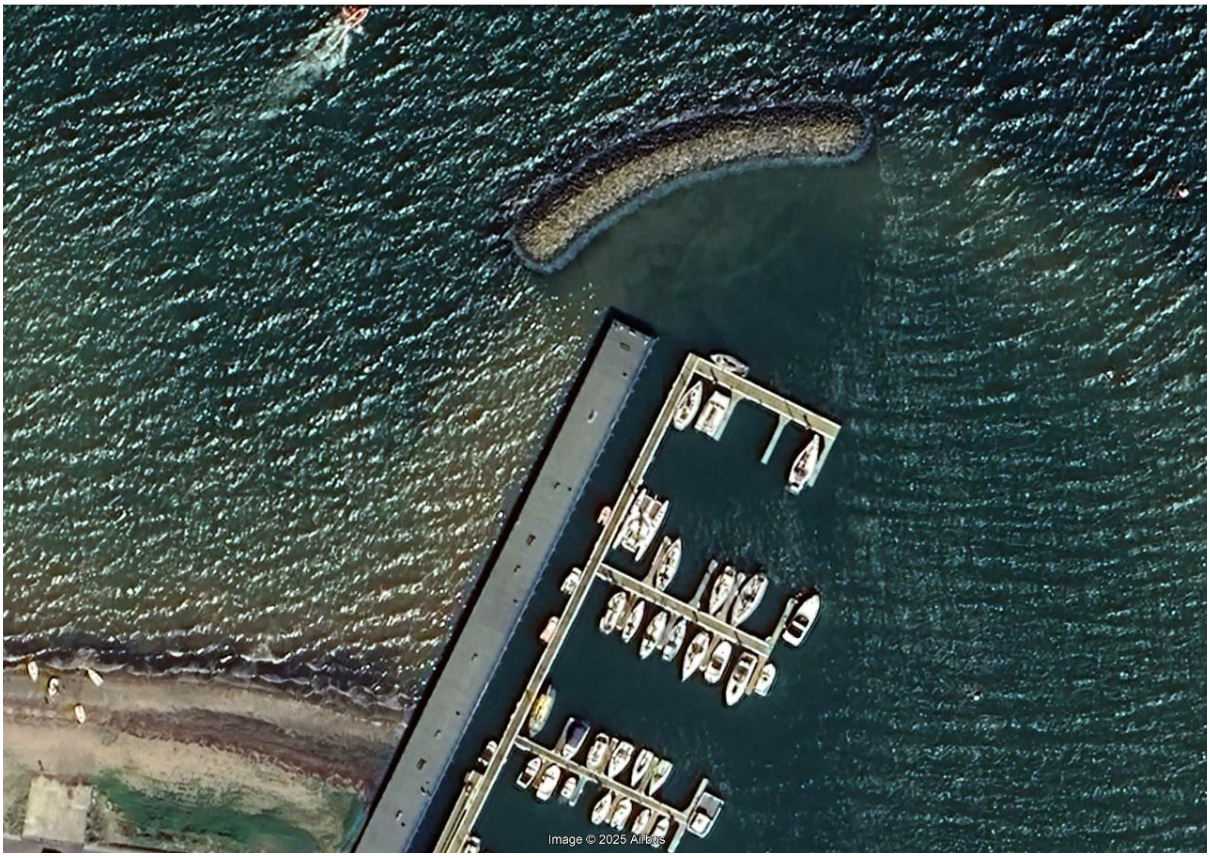

Figure 6.1 Gap between the mole breakwater and the northern end of West Pier.

As a result of the sloping end to the mole breakwater, the gap will be most pronounced at time of high tides. RPS has therefore undertaken simulations of a 1 in 50 year return period storm from the west coincident with a tidal height of 3.7m CD (HAT).

Figure 6.2 shows the significant wave heights and spectral peak wave periods around the harbour during a 1 in 50 year return period storm from the west. An enlarged view of the wave heights passing through the gap is shown in Figure 6.3. It will be seen from these diagrams that the waves passing through the gap between the southwestern tip of the existing mole breakwater and the northern end of the West Pier are expected to have a significant wave height of about 0.33m with a wave period of about 2.5 seconds during a 1 in 50 year westerly storm. These waves do not contribute much wave energy in terms of the overall wave climate in the harbour, but they may make the berths at the northern end of the existing marina a little uncomfortable as they will tend to roll the boats as moored boats will be beam on to these waves. However, as the wave climate is well within what is considered acceptable for marinas, additional works to mitigate these waves are not considered to be necessary.

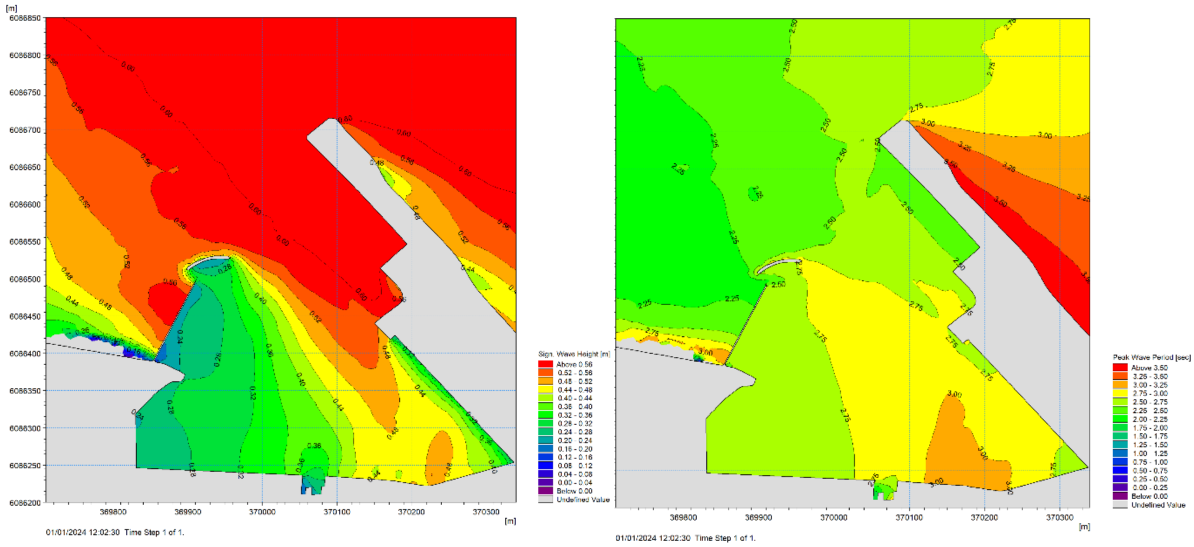

Figure 6.2 **Significant wave height (left) and spectral peak wave period (right) in Stranraer Harbour during 1 in 50 year storm from 270° at HAT.**

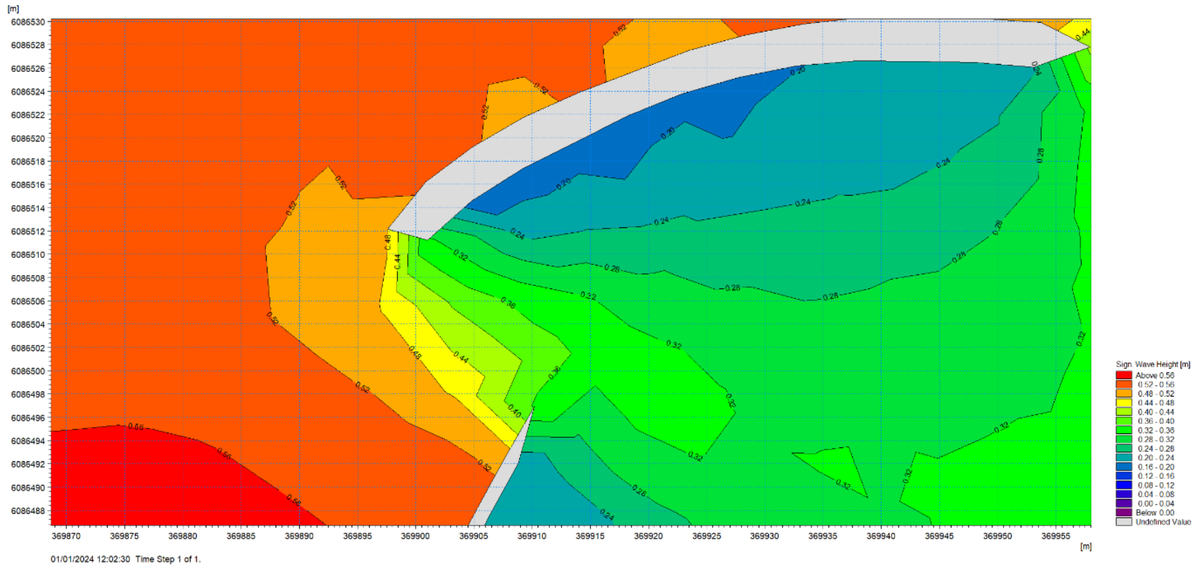

Figure 6.3 Significant wave heights passing through “gap” during 1 in 50 year storm from 270°

Concern was raised at the Consultations about how the proposed marina would be affected by a loss of length of the East Pier which is currently showing signs of decay and dilapidation. Fairhurst thus requested RPS to model a scenario where there was a loss of 50 metres in the northern extent of the East Pier and to test protective works which could be installed to compensate for the potential loss of length of the East Pier.

RPS ran simulations of the 1 in 1, 10, 50 and 200 year return period events at MHWS for the proposed marina expansion scheme with the northern end of the east pier moved south by 50 metres. The simulations showed that the wave climate at the proposed floating breakwater would be increased by 20% to 25% as a result of the reduction in length of the East Pier. This increase in the wave climate would significantly reduce the ability of the floating breakwater to attenuate the waves to a point where the use of such a structure would no longer be effective.

RPS has designed a fixed mole breakwater located on the edge of the shallows to the north of the extended marina berths as shown in the model bathymetry in Figure 6.4.

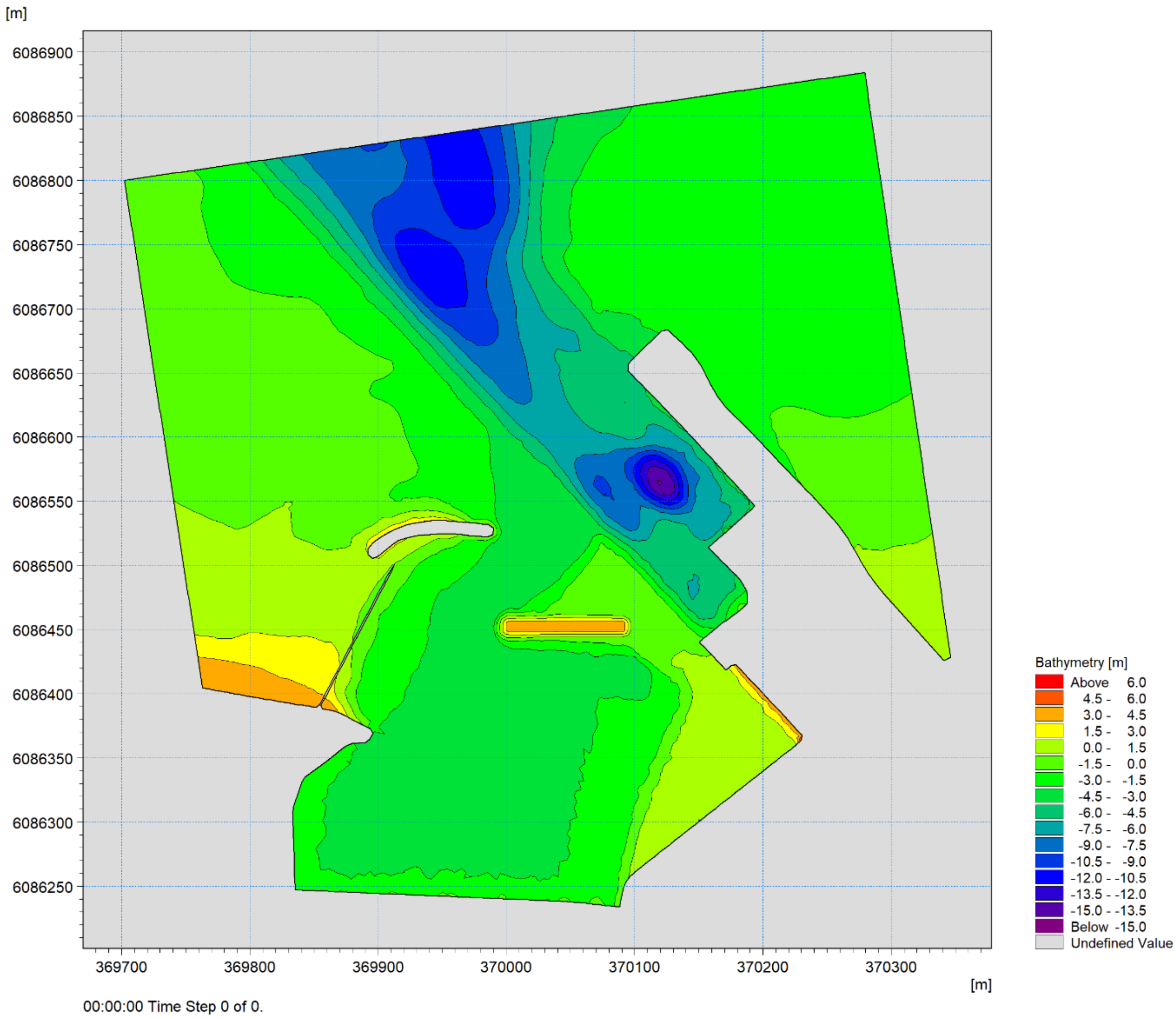

Figure 6.4 Model bathymetry of Marina Expansion project with reduced length of East Pier and rock mole breakwater located on shallow area to north of marina basin

The revised model was used for simulations of 1 in 1, 10, 50 and 200 return period storms from directions 285°N to 45°N at MHWS. It was found that storms from 360°N were the most critical direction for waves in the proposed marina basin with the reduced length East Pier. The results of the simulations for storms from this northerly direction are shown in Figures 6.5 to 6.8.

It will be seen from the diagrams in Figures 6.5 to 6.8 that the fixed rock mole breakwater would be effective in sheltering the proposed marina basin with the 50 metre reduction in the length of the East Pier.

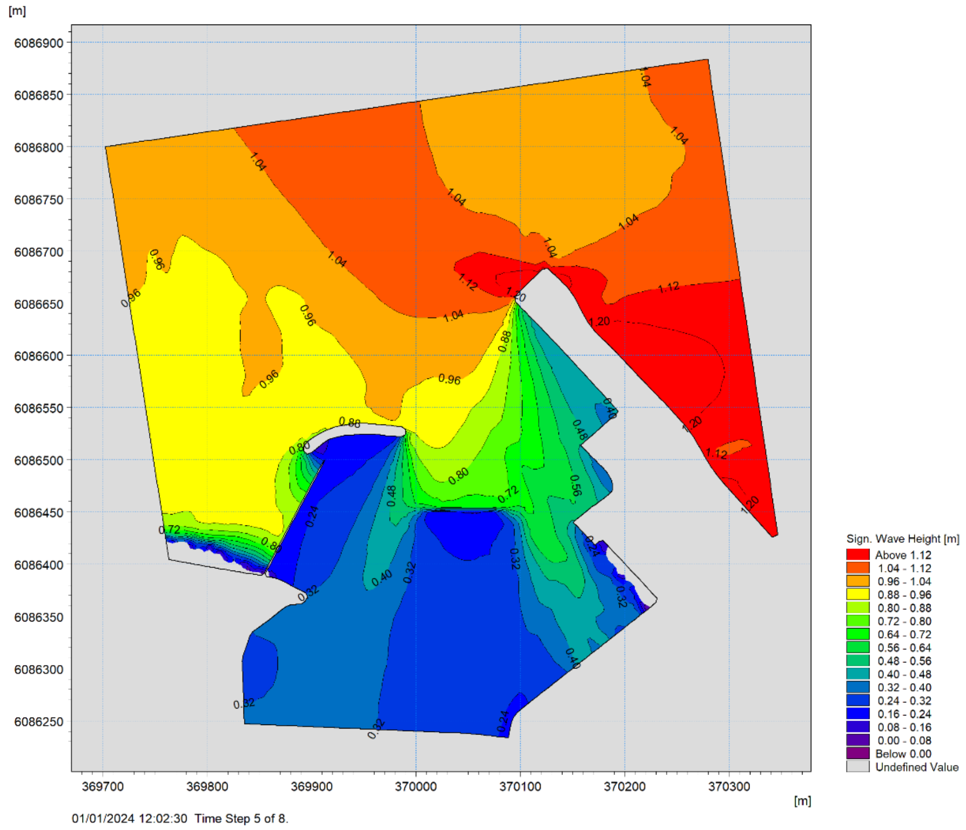

Figure 6.5 Significant wave heights 1 in1 year storm from 360° with fixed mole breakwater

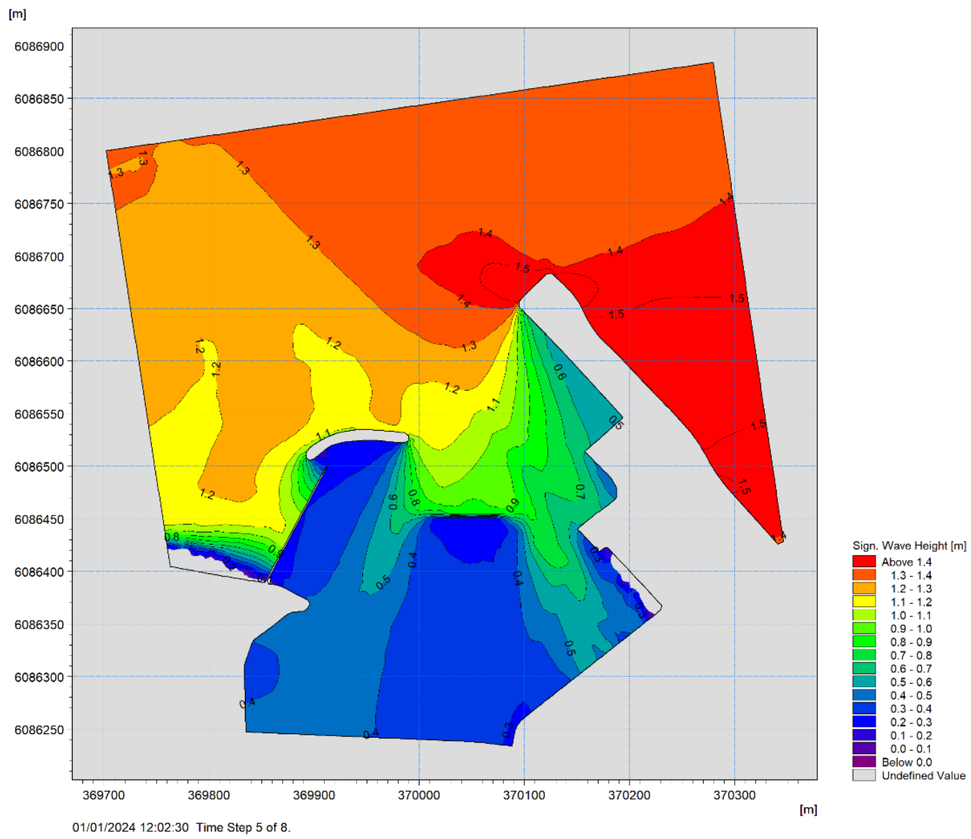

Figure 6.6 Significant wave heights 1 in10 year storm from 360° with fixed mole breakwater

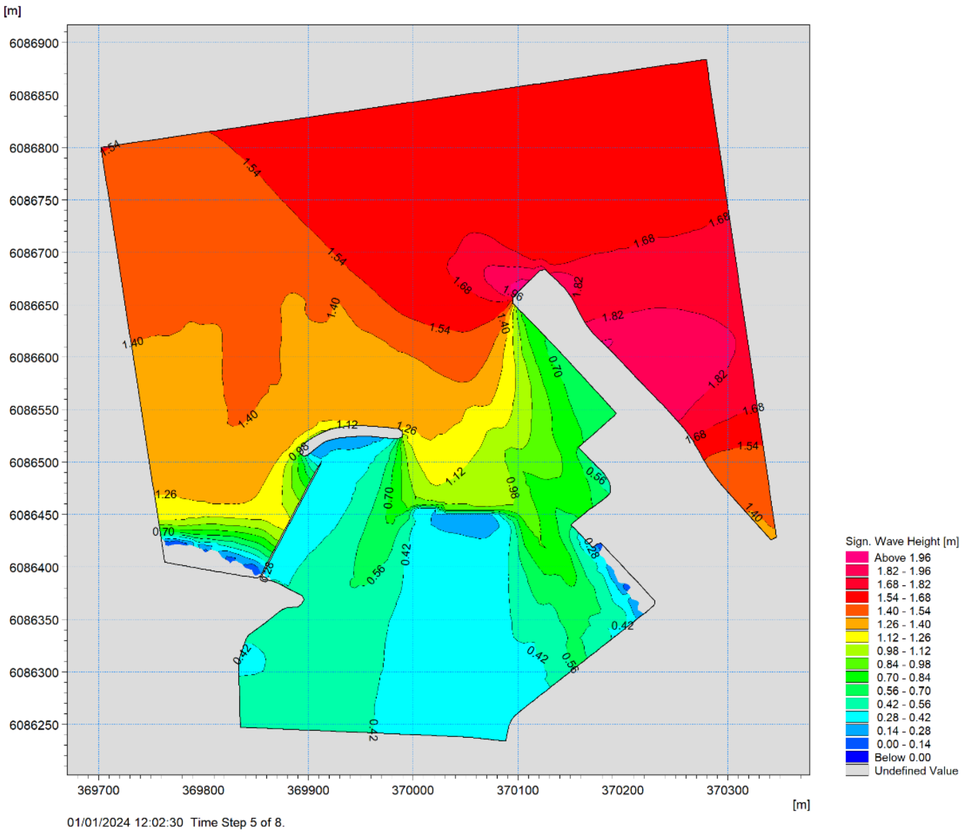

Figure 6.7 Significant wave heights 1 in 50 year storm from 360° with fixed mole breakwater

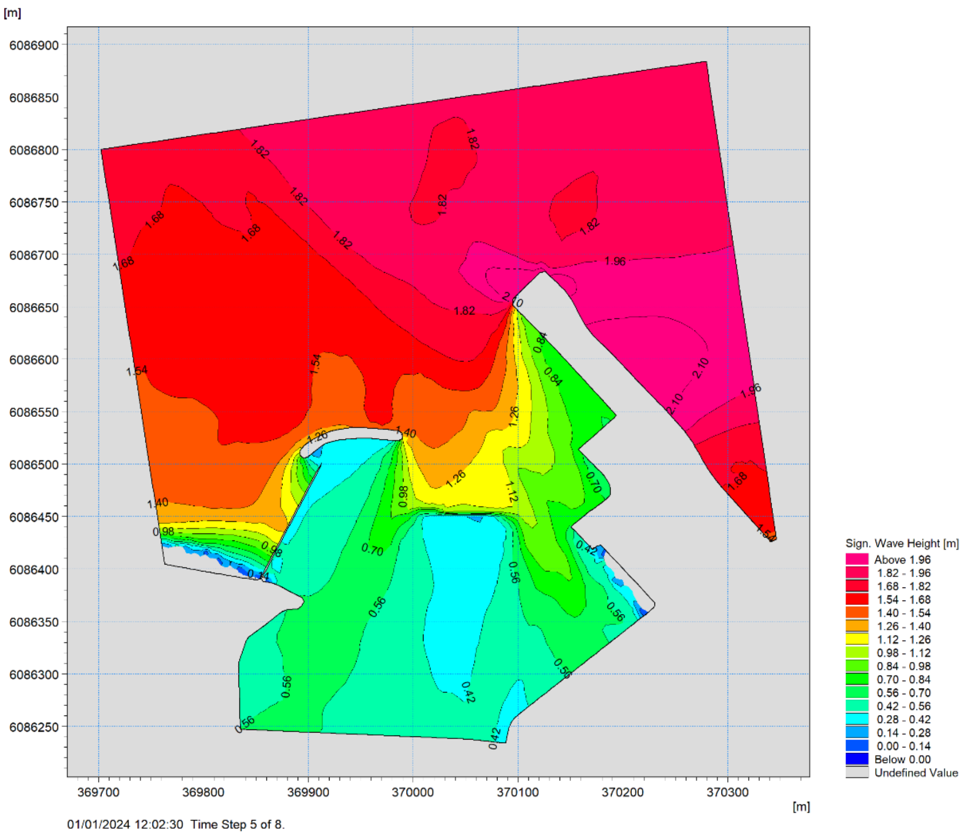

Figure 6.8 Significant wave heights 1 in 200 year storm from 360° with fixed mole breakwater

7. Conclusions

The storms which occurred on the 7th December 2024 have been investigated and were found to be equivalent to a 1 in 10 year return period event from the most critical sector for wave penetration into Stranraer Harbour. The event has been simulated in RPS's computational model of Stranraer Harbour and the results compared with video footage taken at the time of the storm. There was good agreement between the modelled wave climate and that observed from the video clips.

1 in 1, 10, 50 and 200 year return period storms entering the existing Stranraer harbour from directions between 285° and 45° have been simulated in the computational model. The results of these simulations show that, with the exception of the area of the existing pontoon berths, the wave climate in the existing Stranraer Harbour would be too energetic to allow a marina development without additional breakwater protection.

The storm wave modelling undertaken for the amended revised layout for the proposed marina expansion project has shown that the combination of the eastward extension of the existing rubble mound breakwater with the 120m long, 5m wide, floating breakwater positioned as shown on the latest Fairhurst drawings, will provide acceptable wave heights at all the proposed pontoon berths.

Issues raised at the Public Consultation concerning wave penetration during westerly storms and the possible reduction in the length of the existing East Pier have been simulated in the models. The wave penetration through the gap between the SW end of the existing mole breakwater and the northern end of the West Pier during westerly storms has been simulated in the models. The wave penetration was found to be relatively insignificant in terms of the overall wave climate in the harbour and only affected the northern end of the existing berths. As the waves are within normally acceptable limits for marina development, no additional mitigation measures are considered necessary.

The loss of 50 metres off the northern end of the East Pier has been shown to increase the wave energy which can approach the proposed floating breakwater by about 20% to 25%. This increase in wave climate results in a reduction in the attenuation capacity of the proposed floating to the extent that it would no longer be able to adequately shelter the pontoon berths. However, the construction of a rubble mound rock breakwater on the shallow area to the north of the marina basin has been shown to be effective in sheltering the marina berths in the event that the length of the East Pier was to be reduced by 50 metres.

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