MODELLING STUDY OF THE NEARSHORE WAVE CLIMATE IN QUY NHON

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Abstract: *This paper presents the model results of a wave modelling study using SWAN spectral wave model. The main objectives of the study are to determine nearshore wave climate along the coast of Quy Nhon city. The nearshore wave climate can be then used to provide inputs for the design of the access channel and to assess the siltation rate in the nearshore coastline. A wave model for Quy Nhon has been setup to transform offshore waves to inshore locations. This has been undertaken to derive the normal wave conditions in the existing situation. The SWAN spectral modelling software has been used to transform offshore wave information obtained from NOAA to inshore locations. For the normal conditions, the combined sea and swell wave climate has been considered. The model was validated against measured wave data for a period of most severe monsoon waves, i.e. December 2013. An advanced technique has been used to make it possible to transfer 34 year waves conditions from offshore to nearshore.*

Keywords: *Nearshore wave climate, Quy Nhon wave, Modelling study, SWAN model, transformation matrix.*

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1. Introduction

Nhon Hoi Economic Zone is located in Binh Dinh Province in Central Vietnam [1]. It is located on a peninsula (named Phuong Mai) to the North of the provincial capital Quy Nhon. Access to the new Industrial Zone is by road from the North or across the Thi Nai Bridge, crossing over the lagoon from the West. Fig. 1 presents the master plan of Nhon Hoi Economic Zone. The industrial zone has a small waterfront along the lagoon on the south west side. A rocky hillside of approximately 50 meters above sea level is present on the east side of the economic zone.

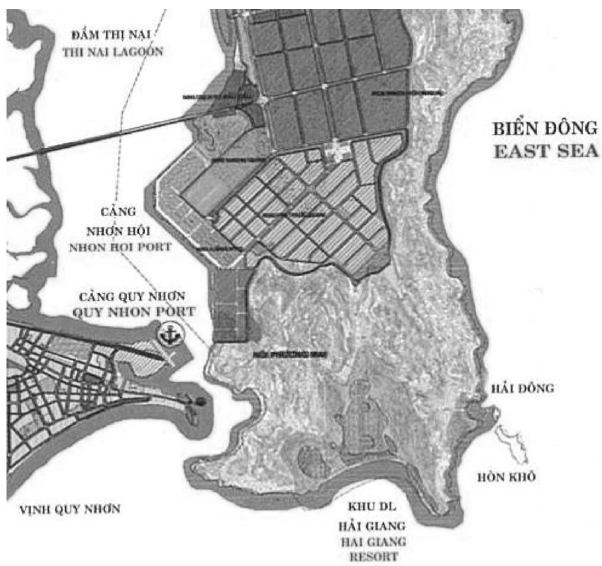

Figure 1. *Indicative Quy Nhon coastline and Nhon Hoi Economic Zone*

An oil $27bn refinery complex is planned to be built in this Economic Zone. The main investor is Thailand's PTT [2]. Import and export are important activities for Nhon Hoi Economic Zone and thus require marine facilities access. The following port facilities are envisaged.

- SPM (Single Point Mooring) for importing crude oil;

- Export jetties for refinery and petrochemical liquid products;

- Export quay/jetties for exporting the containerized/ solid products;

- Import jetties/quays for coal and limestone for the power plant.

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Such port facilities require a detailed study on the hydrodynamic conditions at the site. Key important issues that could have large impact on the feasibility of the plan are as below.

- Nearshore wave climate along the coast of Quy Nhon, especially at locations where ports and breakwaters are proposed. This is crucial for downtime assessment and for the optimization of the breakwater layouts. The nearshore wave conditions also determine morphological behavior nearshore and directly have impact on the siltation rate.

- Extreme nearshore wave conditions. These conditions will be used for the design of port facilities such as breakwater and jetties.

- The flow conditions at the study area. It is important to investigate the effect of the port facilities on the current patterns in the normal as well as in flood conditions. The impact of the port facilities and the land reclamation on the drainage capacity of the lagoon outlet.

- Morphological impact of the port facilities. This is to assess volumes of maintenance dredging.

This paper presents the results of a wave modelling study. The objective of the study is to determine operational wave conditions for input into the sedimentation study and for layout design of the breakwater and downtime analysis. It is noted that the required wave data is a long-term (>30 years) time series of wave parameters at various project locations. Such data has not been available from any previous study.

A nearshore wave climate is often derived by translation of few ten-year offshore time series waves to nearshore. If one simulation takes 2 minutes, a conventional transformation would require 4 months for 1 PC to translate the 30 year offshore wave conditions to the nearshore, making it not feasible in practice. In this study, an advanced technique is used to quickly obtain nearshore wave conditions (the total simulation time is 875 runs × 2 minutes/run = 30 hours). This is discussed in Section 2. The method is validated by compare the model results with measurements..

2. Methodology

The following approach was followed throughout the study:

- Offshore wind and wave data covering a time span of 34 years (1979-2012) were obtained from NOAA database and statistically analysed to derive the offshore normal wind and wave conditions.

- Determination of matrix of boundary conditions in which matrix nodes are chosen to cover wave conditions at the offshore boundary. The total wave is transferred from the offshore to the nearshore locations.

- Simulations of wave for each condition as described in the selected matrix of offshore conditions. The results are used to determine the matrix of wave conditions for any given point nearshore.

- Derivation of the nearshore wave conditions by translating the time series of wave conditions from the offshore location to the nearshore location. The resulting time series is then analysed to obtain the required tables and statistics.

3. Offshore wind and wave condition

3.1 Hindcast data location

Offshore hindcast data obtained from NOAA has been used for this study. NOAA operates a 3rd generation wave prediction model (WAVEWATCH-III) that has been used to produce a continuous hindcast of 3-hourly winds and waves on a 0.50×0.50 grid. The data used for the study is a combination of the 30 year (1979-2009) reanalysis and the latest hindcast data (2010-2012). Details of these data are given in the NOAA website of operational wave models (NOAA, Operational Wave Models, http://polar.ncep.noaa.gov/waves/).

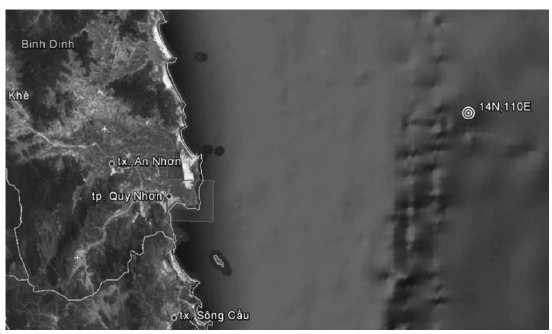

***Figure 2.** Location of offshore wind and wave hindcast data*

The data (99,264 records, 3 hourly from the period Jan 1979-December 2012) has been extracted from the NOAA database for a grid point located at 14°N, 110°E (see Fig. 2). Water depth at the area is roughly 1000 m which can be considered "deep water". Data at this point was considered to be the most representative to derive the offshore wind and wave conditions. The data contains the wind speed (hourly averaged wind velocity at 10 m above the surface), wind direction, significant wave height, wave peak period and mean wave direction.

3.2 Wind climate

Apart from the frequent typhoons within the region, the offshore wind climate is relatively mild. Normal wind speeds are most of the time from 4 m/s to 8 m/s. Winds are principally driven by the monsoon. In October to February, we see that the predominant wind direction is north-east, which is associated with the North-East monsoon. During June to August, the predominant wind direction is south-west, which is associated with the South-West monsoon. As expected, the wind speed are generally more intense during the North-East monsoon. The seasonal variation of wind speed and direction is analyzed using NOAA data and is presented in Fig. 3.

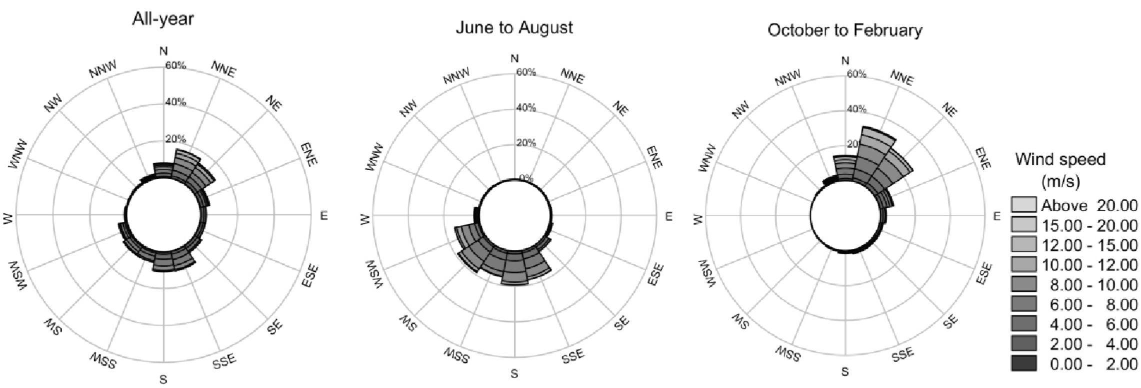

Figure 3. *Seasonal variation of wind velocity and direction*

3.3 Wave climate

The offshore wave climate is relatively mild. Normal waves are usually between 0.5 m to 2 m. The wave climate is strongly related to the local wind conditions. The seasonal variation of wave height and direction is presented in Fig. 4. From October to February, the predominant wave direction is north-east, which is associated with the North-East monsoon. From June to August, the predominant wave direction is south-west, which is associated with the South-East monsoon. As expected, the wave heights are generally more intense during the North-East monsoon.

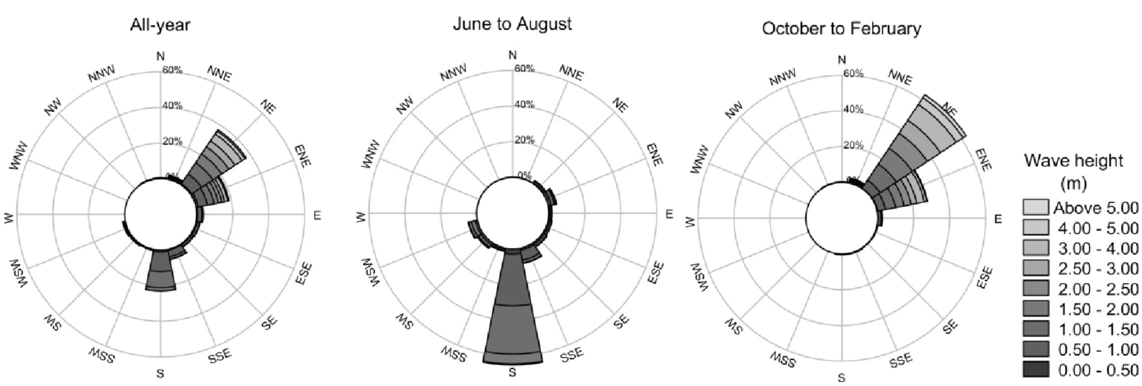

Figure 4. *Seasonal variation of wave height*

4. SWAN model setup

4.1 Computational grids

To derive the wave conditions at the project site a flexible mesh SWAN model [3] was used. At each grid point, SWAN represents the complete 2D action density spectrum discretely as a function of frequency and direction. The following information has to be specified: the spatial grid resolution and the area covered by the grids.

The computational meshes have a resolution that ranges between node distances of 1.4 km in the offshore areas to a node distance of 20 m to 40 m in the coastal area. The mesh consists of 29,137 elements and 15,630 nodes. Fig. 5 shows an overview of the model domain, model grid and bathymetry. Note that the Eastern offshore boundary is extended to the location of offshore NOAA wave and wind 14^{O}N, 110^{O}E.

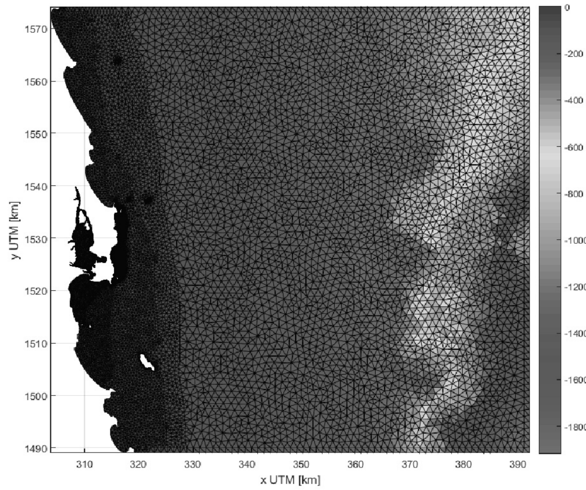

Figure 5. *An overview of SWAN model grid and the bathymetry*

4.2 Boundary conditions

The normal wave conditions are derived by translation of the offshore time series from the NOAA database to nearshore. The NOAA data is based on a well calibrated hindcast model and contains offshore wind and wave parameters. However, the NOAA data is not available at the location of the shore, in shallow water where the water level is important and wave breaking and bottom friction determine the local waves. The translation of the time series, 3 hourly records from January 1979 until December 2012, was made based on transformation matrices as described in Section 2.

Wave and wind parameters which influence the modeling results should be taken into account when considering the combinations of wave parameters. Based on the sensitivity analysis, winds in the approximate same directions as the waves should be considered.

The boundary conditions used for the nearshore wave modelling are based on the NOAA hindcast data extracted at point 140N, 1100E. The boundary conditions that define the matrix are described in terms of wind speed (Uw), wave height (Hs), wave direction (MWD), wave steepness (S0) as presented in Table 1 below. For the computational matrix 5 wind speeds are selected, ranging from 0 m/s to 20 m/s.

The total number of simulations needed to assess the nearshore wave climate is 875 runs. For the proposed layout: 1 water level × 7 wave heights × 5 wave directions × 5 steepness's × 5 wind speeds = 875 runs.

Table 1. *Range of boundary conditions for simulations of normal waves*

Parameters	The range of values						
Water level (m)	0						
Hs (m)	0.1	1.0	2.0	3.0	4.0	6.0	8.0
Uw (m/s)	0.0	5.0	10.0	15.0	20.0		
S_0 (-)	0.001	0.006	0.012	0.025	0.055		
MWD (0N)	22.5	45	90	135	180		

4.3 Model validation

Wave data measured in December 2013 at a nearshore location (13°48'24.12"N, 109°17'33.55"E) was used for model validation. Fig. 6 presents a comparison between measured and calculated wave parameters. The comparison clearly shows that the model is able to predict nearshore wave conditions with acceptable accuracy. This also confirms that the transformation matrix method is suitable for transforming offshore waves to nearshore.

5. Model results

This section presents the results of the wave modelling for normal conditions in the Quy Nhon area. The wave results including significant wave height (Hs), peak wave period (Tp) and mean wave direction (MWD) are extracted at a number of points along the coast, especially along the navigation channels and at possible SPM location as shown in Fig. 7. This paper focuses on the wave results at location A, B and D.

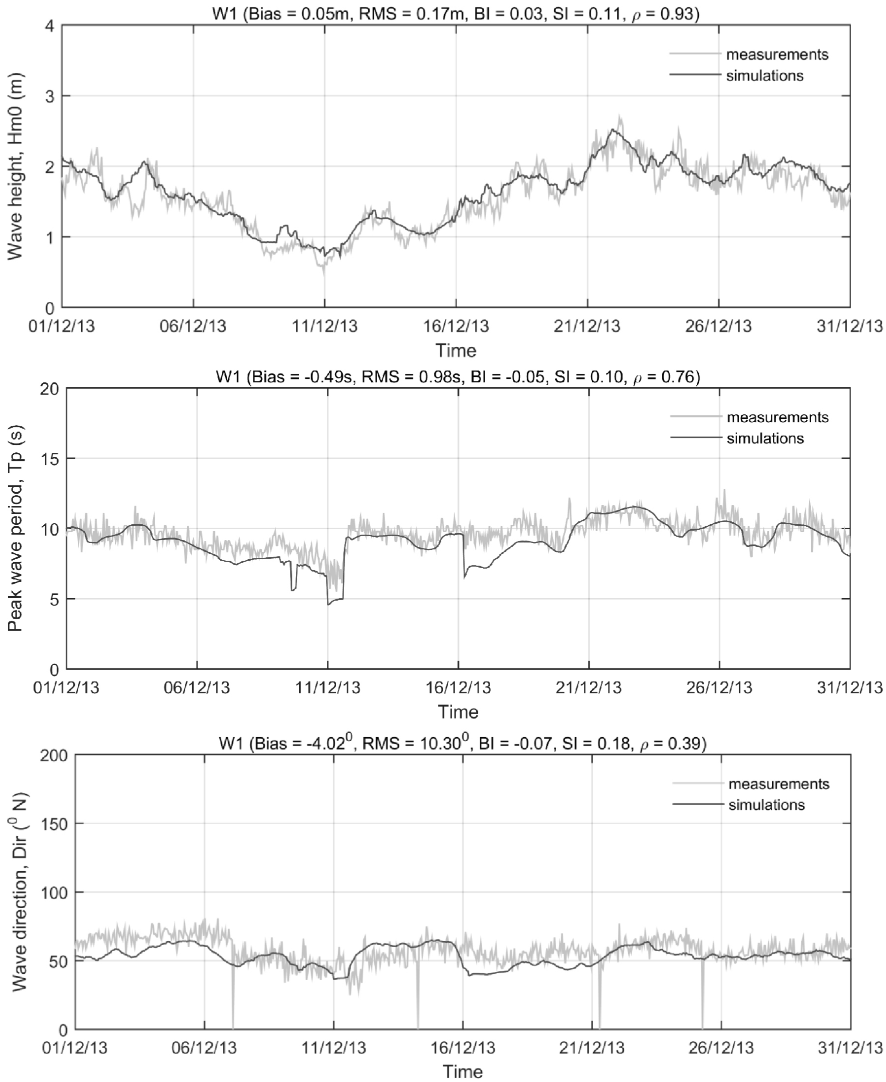

Figure 6. *Comparison of measured and calculated wave parameters*

The larger waves that occur during normal wave conditions are predominantly Nort-East monsoon waves. For this reason, location A is more exposed to waves. The wave roses at A are plotted in Fig. 8 for all year data (1979-2012). The probability of occurrence of wave height and wave direction in the given classes is presented in Table 2. Wave conditions at location A can be considered as representative nearshore waves at a fully open coastline.

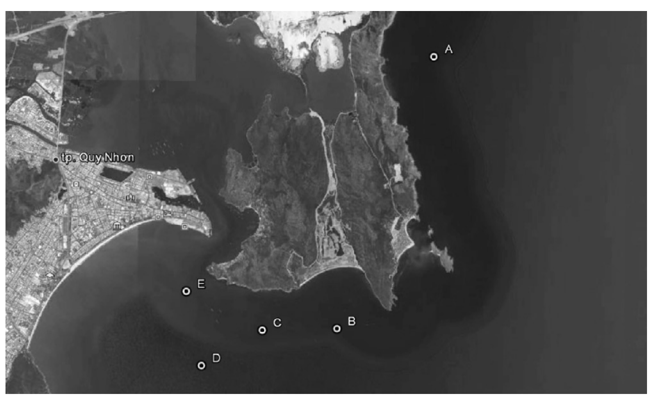

Figure 7. *Indication of output locations*

The bathymetry does have an influence on the wave height and wave directions. Most of the offshore waves from the NE are dragged around the ENE sector. Offshore waves from the S are dragged around to the SSE sector. The waves are relatively large at the northern coastline (location A) during NE monsoon (October to February). During this season, 78% of the time the wave height is larger than 0.5m and 35% of the time the wave height is larger than 1.0m. The peak wave period is between 6s and 12s.

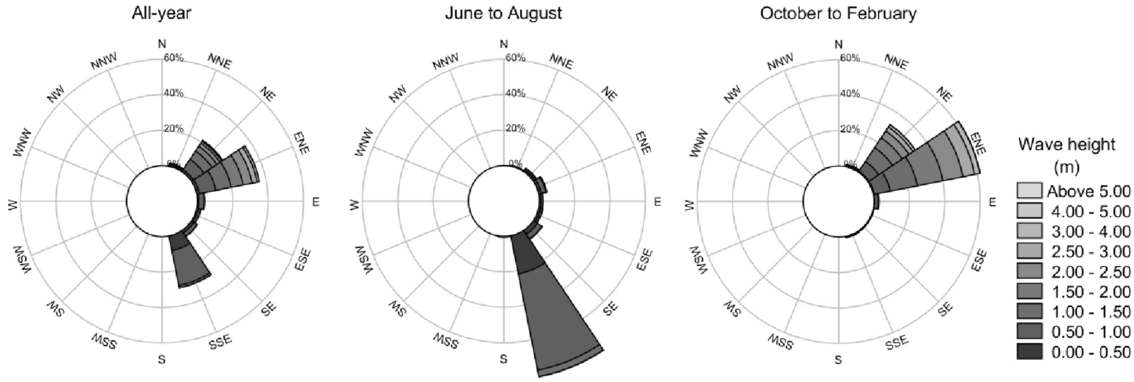

Figure 8. *Seasonal variation of wave roses at location A*

Table 2. *Joint frequency table (%) showing Hs against Dir at location A*

Directional interval	Wave height interval (m)								
	0.0-0.5	**0.5-1.0**	**1.0-1.5**	**1.5-2.0**	**2.0-2.5**	**2.5-3.0**	**3.0-4.0**	**4.0-5.0**	**Above 5.0**
N	-	-	-	-	-	-	-	-	-
NNE	0.30	0.83	0.47	0.15	0.10	0.03	*	-	-
NE	1.35	7.01	5.63	3.25	2.14	1.19	0.69	0.03	*
ENE	1.61	9.37	8.81	6.99	5.15	2.85	1.30	0.06	*
ENE	0.82	2.91	0.32	0.04	0.02	*	*	-	-
ESE	1.07	1.26	0.09	0.01	*	*	-	-	-
SE	1.58	2.29	0.13	0.01	*	-	-	-	-
SSE	8.52	20.07	1.27	0.06	0.01	-	-	-	-
S	0.15	*	-	-	-	-	-	-	-
SSW	-	-	-	-	-	-	-	-	-
SW	-	-	-	-	-	-	-	-	-
WSW	-	-	-	-	-	-	-	-	-
WSW	-	-	-	-	-	-	-	-	-
WNW	-	-	-	-	-	-	-	-	-
NW	-	-	-	-	-	-	-	-	-
NNW	-	-	-	-	-	-	-	-	-
All direction	15.41	43.75	16.72	10.51	7.44	4.08	1.99	0.09	0.00

During SW monsoon (June to August), offshore waves are mainly from the S and SSW. Nearshore wave conditions are considered very calm. During this summer time, 57% of the time the wave height at the port area is less than 0.5m. 98% of the time the wave is less than 1.0m. The peak period is between 4s and 9s.

Fig. 9 shows the wave roses at several locations along the coast of Quy Nhon. From the figure, it can be concluded that Quy Nhon Bay is well protected from the NE monsoon waves by the Nhon Hai headland.

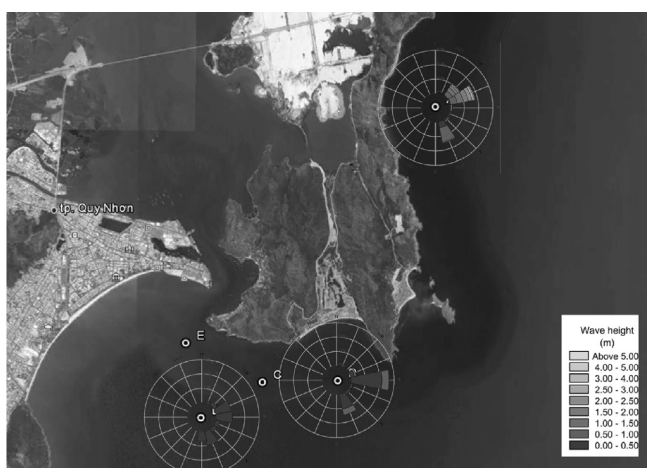

Figure 9. *Wave rose at selected output locations*

6. Conclusion

A wave model for Nhon Hoi has been set up to transform offshore waves to inshore locations. This has been undertaken to derive the wave climate at key area along the Quy Nhon coastline. The SWAN model software has been used to transform offshore wave information obtained from NOAA to inshore locations. The model has been validated against measured wave data. The validation results confirm that the model is able to reproduce nearshore wave conditions with acceptable accuracy and that the technique to quickly transfer offshore time series wave to nearshore is valid.

With regards to the nearshore wave climate, following can be summarised and concluded.

- The nearshore waves are relatively large at the northern coastline during NE monsoon (October to February). During this season, 78% of the time the wave height is larger than 0.5m and 35% of the time the wave height is larger than 1.0m. The peak wave period is between 6s and 12s.

- During SW monsoon (June to August), offshore waves are mainly from the S and SSW. Nearshore wave conditions are considered very calm. During this summer time, 57% of the time the wave height at the port area is less than 0.5m. 98% of the time the wave is less than 1.0m. The peak period is between 4s and 9s.

- For a whole year, 78% of the time the nearshore wave height is larger than 0.5m and 35% of the time the wave height is larger than 1.0m.

- Wave conditions in Quy Nhon Bay (location B, E, D, E) are rather calm due to a good protection from the Nhon Hai headland./.

Reference

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