Hydrodynamics Modelling for Dock Layout Planning in Fish Landing Port (PPI) Api-Api, East Kalimantan

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***Abstract*— The issue of relocating the national capital city to Penajam Paser Utara is one of the reasons why the Fish Landing Port (PPI) Api-Api needs to be developed. The maritime and fisheries sector in East Kalimantan is also known to have huge potential in supporting the economy. One of the facility that need to developed is the dock. The exisisting dock is a simple wooden dock that is placed perpendicular to the beach and only able to serve small ships. Therefore it is necessary to plan a dock construction at PPI Api-Api so that the dock can serve larger fishing vessels. In this research, hydrodynamics modeling were carried out using Delft3d for three alternative dock layout designs, namely; jetty, wharf, and pier type, henceforth selected which is most suitable to be placed at PPI Api-Api. Based on the simulation results of hydrodynamic modeling, the current velocity around the jetty type is > 0.15 m/s, while in the wharf and pier type it ranges from 0.05-0.15 m/s. Wave modeling shows the maximum wave heights that occur near the dock at the jetty, wharf and pier types are 0.9 m, 0.36 m, and 0.8 m, respectively. From the hydrodynamic modeling results, wharf type is the most feasible dock layout design to be selected.**

Keywords*— *Hydrodynamic Modeling, Wave Height, Current Velocity, Dock Layout Design

I. Introduction

The Indonesian government is currently preparing a marine infrastructure development program. Fish Landing Port (PPI) Api Api in East Kalimantan is one of the marine infrastructures that is need to be developed (Figure 1). The maritime and fisheries sector in East Kalimantan is also known to have huge potential in supporting the economy.

The facilities at PPI Api-api are inadequate in facilitating and supporting fishery product activities and marketing of fish caught by fishermen. Currently the main facilities of PPI Api-Api include 2 jetty units, 1750-meter concrete sheet pile, and 5 hectares of land [1], also there is a simple wooden dock that is placed perpendicular to the beach that only able to serve small ships. In order to increase income from fishery activities, it is necessary to plan a dock construction at PPI Api-Api so that at least the dock able to serve the mooring and anchors of large fishing vessels.

The purpose of this research is to provide dock layout designs that are suitable for placement in PPI Api-api based on hydrodynamic conditions. In this research, three alternative dock layout designs are suggested, namely; jetty, wharf, and pier type. The open source software Delft3d has been used to perform hydrodynamics model. The simulation were carried out for 1 year (2019-2020).

II. Hydrodynamics Modelling

A. General Model Concept of Delft3D

The Delft3D modelling system is designed to simulate wave propagation, currents, sediment transport, morphological developments and water quality aspects in coastal, river and estuarine areas [2].

In this study, Delft3D-FLOW and Delft3D-WAVE was applied in two-dimensional (2DH, depth-averaged). Delft3D-FLOW is is the hydrodynamic module. It calculates nonsteady flow resulting from tidal and meteorological forcing. Delft3D-WAVE is a numerical model to obtain estimates of wave parameters from given stationary wind-, bottom, and current conditions. It is accounts for refractive propagation, wind growth, bottom dissipation, depth induced wave breaking and current dissipation [3].

The governing equations of the Delft3D-FLOW model are momentum equation in *–x* and *–y* component and the continuity equation, respectively [4] :

$$\frac{\partial \zeta}{\partial r} + \frac{u}{\sqrt{G\zeta\zeta}}\frac{\partial u}{\partial \zeta} + \frac{v}{\partial \eta \sqrt{G\eta}}\partial u + \frac{\omega}{d+\zeta}\frac{\partial u}{\partial \sigma} - \frac{V^2\sqrt{G\eta\eta}}{\sqrt{G\zeta\zeta}\sqrt{G\eta\eta}} + \frac{uv\sqrt{G\zeta\zeta}}{\sqrt{G\zeta\zeta}\sqrt{G\eta\eta}} - Fv = \frac{uv\sqrt{G\zeta\zeta}}{\sqrt{G\zeta\zeta}\sqrt{G\eta\eta}} - Fv = \frac{1}{(d+\zeta)^2}v\frac{\partial u}{\partial \sigma} + M\zeta \tag{1}$$

$$\frac{\partial \zeta}{\partial r} + \frac{u}{\sqrt{G\zeta\zeta}}\frac{\partial u}{\partial \zeta} + \frac{v}{\partial \eta \sqrt{G\eta}}\partial u + \frac{\omega}{d+\zeta}\frac{\partial u}{\partial \sigma} - \frac{\omega}{d+\zeta}\frac{\partial u}{\partial \sigma} - \frac{uv\sqrt{G\eta\eta}}{\sqrt{G\zeta\zeta}\sqrt{G\eta\eta}} + \frac{V^2\sqrt{G\zeta\zeta}}{\sqrt{G\zeta\zeta}\sqrt{G\eta\eta}} - Fv = \frac{1}{\rho 0\sqrt{G\zeta\zeta}}P\zeta + F\zeta + \frac{1}{(d+\zeta)^2}v\frac{\partial u}{\partial \sigma} + M\zeta \tag{1}$$

Fig. 1. Reasearch Location in East Kalimantan

$$\frac{\partial \zeta}{\partial r} + \frac{1}{\sqrt{G\zeta\zeta}\,\sqrt{G\eta\eta}}\frac{\partial\left[(d+\zeta)U\sqrt{G\eta\eta}\right]}{\partial \zeta} + \frac{1}{\sqrt{G\zeta\zeta}\,\sqrt{G\eta\eta}}\frac{\partial\left[(d+\zeta)V\sqrt{G\zeta\zeta}\right]}{\partial \eta} = (d+\zeta)Q \quad (3)$$

where: u, v, w: three component of the velocity; x, y, z: space coordinates, Q: Magnitude of dischage, P: Pressure, F: Diffusion term, t: time, ρ: density, ζ: surface elevation, G: gravity.

The governing equation of Delft3D-WAVE model is the wave spectral equilibrium equation [5]:

$$\frac{\partial}{\partial t}N + \frac{\partial}{\partial x}cxN + \frac{\partial}{\partial y}cyN + \frac{\partial}{\partial \sigma}c\sigma N + \frac{\partial}{\partial \theta}c\theta N = \frac{S}{\sigma} \quad (4)$$

The first term on the left side of this equation represents the local rate of density change in time, the second and third terms represent the spread of action in geographic space (with propagation velocity cx and cy in x- and y-space, respectively). The fourth term represents the relative frequency shift due to variations in depth and current (with propagation speed cσ in σ-space). The fifth term represents the depth and current induced refraction (with the space propagation velocity $c\theta$ in θ). This expression of propagation velocity is taken from linear wave theory [6][7][8]. S (= $S(\sigma, \theta)$) on the right side of the equilibrium action equation is the source term in terms of energy density representing the effects of generation, dissipation and non-linear wave-wave interactions.

B. *Layout Design Plan*

The requirement for the length of the dock is calculated only for loading and unloading dock length. The length of the dock for loading and unloading dock length is calculated using empirical equations (5) and (6) below, respectively [9]. The calculation of the length of loading and unloading dock for PPI Api Api shown in Table 1.

$$L_b = \frac{n \times L_u \times Q \times S}{Dc \times U \times T_s} \quad (5)$$

$$L_b = \frac{n \times L_u \times T_s \times S}{Dc \times T_m} \quad (6)$$

where,

- *Lu* = 1.1 LOA
- *n* = Number of ships in operation (units / day)
- *Ts* = Ship service time per hour (hour)
- *Dc* = Average shipping return period (days / trip)
- *T* = Service time per day (hour / day)
- *Tb* = Time of unloading service per day (hour / day)
- *Tm* = Loading service time per day (hour / day)
- *S* = Uncertainty factor
- *Q* = Average catch per voyage (tonnes / day / trip)
- *U* = Average speed of unloading (tonnes / hour)

TABLE I. CALCULATION OF THE LENGTH OF LOADING AND UNLOADING JETTY FOR PPI API-API

Ship [DWT]	Ship Dimension			n	Q	Dc	U	T	Ts	Unloading		Loading	
	Loa [m]	B [m]	Draft [m]	unit	ton	day	ton/hour	hour	hour	S	Lb [m]	S	Lm [m]
5-10	10	1,4	0,8	20	5	2	2	8	0,5	1,5	52	1,2	8,3
10-20	15,2	4,2	1,4	10	10	3	2	8	0,75	1,5	52	1,2	6,3
20-30	17,6	4,3	1,4	5	20	4	2	8	1	1,5	45	1,2	3,6
30-50	19,9	4,4	1,4	3	30	6	3	8	2	1,5	21	1,2	3,3
50-100	25,6	4,9	1,8	2	50	7	3	8	2,5	1,5	25	1,2	3,0
Total Length [m]											195		24

Ship groupings are made for area efficiency. Each vessel is checked in advance where the length of the dock must be longer or equal than LOA of the largest ship in the group. Grouping of ships based on the need for loading/unloading display shown in Table 2. The next step is to make three dock layout designs using the data from those calculations.

The first alternative dock layout design is jetty type (Fig.2.a), the second alternative design layout is wharf type (Fig.2.b), and the third one is pier type (Fig.2.c).

TABLE II. GROUPING VESSELS AGAINST THE NEED FOR LOADING / UNLOADING DISPLAY

Ship	Lb	Lm	Group of Ship	Unloading Pier			Loading Pier		
	[m]	[m]		Length (m)	Check	Final Length [m]	Length (m)	Check	Final Length [m]
5-10 DWT	52	8,3	5-20 DWT	104	>15,2 Ok	104	14,5	< 15,2 needs change	16
10-20 DWT	52	6,3							
20-30 DWT	45	3,6	20-50 DWT	66	>19,9 Ok	66	6,9	< 19,9 needs change	20
30-50 DWT	21	3,3							
50-100 DWT	25	3,0	60-100 DWT	25	< 25,6 needs change	26	3,0	< 25,6 needs change	26
Total (m)	195			195		196			62

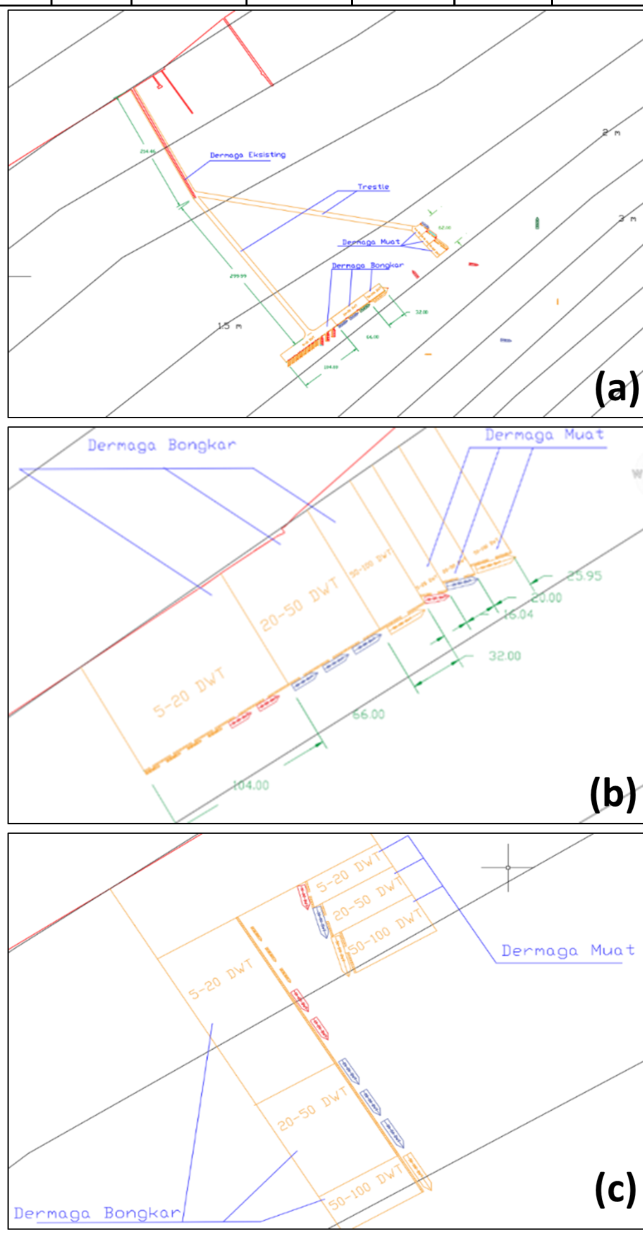

Fig. 2. Three Alternative Dock Layout Design (a) Jetty Type, (b) Wharf Type, and (c) Pier Type

C. Model Set-up

Due to limited time and high cost for data measurement, hydrodynamics condition in the study area for three different scenario will be modeled based on secondary data. The model is run for 1-hour intervals through 1 year simulation (2019-2020).

Flow Grids and Bathymetry. Bathymetry data is obtained from digitizing a nautical map of DISHIDROS. Meanwhile, a curvi-linear grid was constructed (Figure 3) with a relative high resolution of 50 meters at the study area.

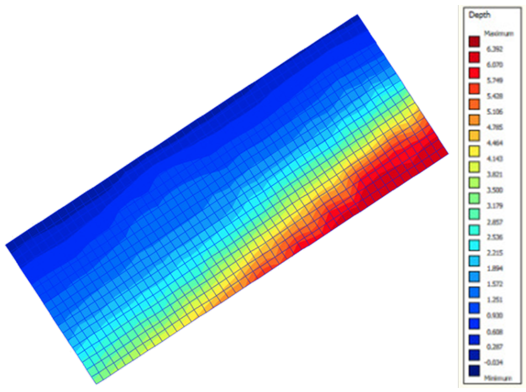

Fig. 3. Bathymetry Model Grid

Boundary Conditions. One of the main components in the measured currents and waterlevels is the tide [6]. Tidal boundary conditions used in Delft3D-FLOW obtained from the Delft Dashboard. Delft Dashboard run automatically to get the value of the tidal components at each boundary. The database used for forecasting using Delft Dashboard is TPXO 7.2.

Wind Forcing. The wind data used in this study is the maximum wind speed and wind direction per 6 hours that occurs over a period of 10 years, from January 1, 2010 to December 31, 2019. Wind data was obtained from the European Center for Medium-Range Weather Forecasts (ECMWF) with data collection located at Sepinggan station, East Kalimantan. Wind data is then used to analyze wind-generated wave generation.

Wave. Hindcasting wave height and wave period were connducted using the SPM method in this study. The assumed directions are the winds coming from the northeast, east, southeast, and south. This assumption is based on the results of determining the fetch, where southwest, west, northwest, and north directions have small fetches. Figure 4 shows the waverose result of hindcasting from 2010 to 2019. It can be seen from waverose that the distribution of the waves that occur is dominated by the south (Figure 4). During the dry season the wave distribution is also dominated from the South and Northeast directions with the dominant wave height ranges from 0.5-2.1 m.

The model also run for extreme waves condition. Extreme waves in a certain time period are obtained by analyzing the high frequency of waves and several types of extreme value distribution functions, namely forecasts for the next 2, 5, 10, 25, and 50 years. The analysis method used is the gumbel distribution, normal, log normal, and log pearson type III. Table 3 shows the wave return periode.

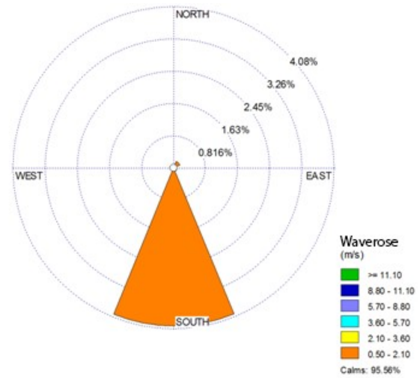

Fig. 4. Waverose 2010 to 2019

From the results of the distribution type test, it was found that the method that is suitable for determining the height and period of the planning wave is the Log Normal method. So, what will be used for modeling is the planned wave from the frequency analysis of the Log Normal method.

TABLE III. RECAPITULATION OF HEIGHT ANALYSIS RESULTS AND DESIGN WAVE RETURN PERIODS

	Period (Yeas)	**Wave Height (m)**
South	2	0,66
	5	0,79
	10	0,87
	25	0,94
	50	1,02
	Period (Year)	**Wave Period (s)**
South	2	3,48
	5	3,71
	10	3,83
	25	3,94
	50	4,07

III. RESULT AND DISCUSSION

A. Validation

Surface water elevation from output model have to validated with observation data. In this study, the surface elevation from model compared with the data from Geospatial Information Agency (BIG) . It can be seen in Figure 6 below that the water elevation of the Geospatial Information Agency (BIG) and the results of Delft3D-Flow modeling has almost the same graphic uniformity. These results indicate that modeling using Delft3D is well validated.

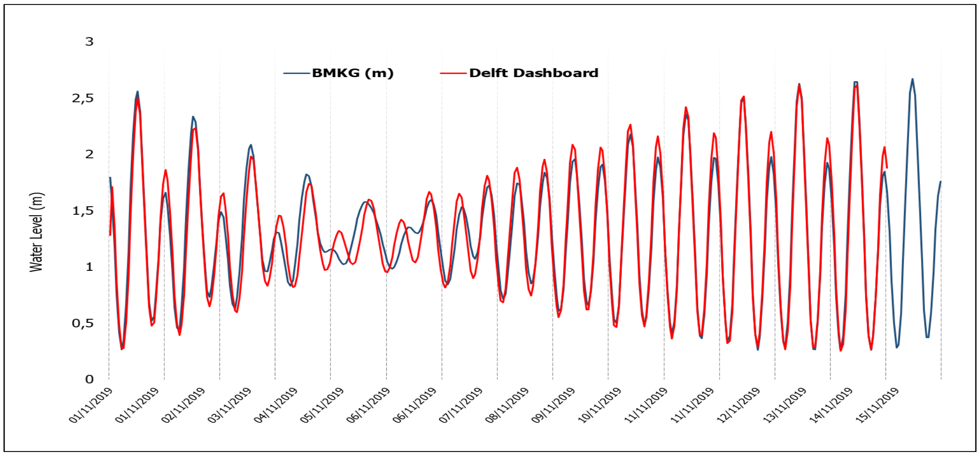

Fig. 5. Water Level Validation between BIG Forecasting Data and Delft3D Modeling

B. Wave Model Simulation Results

Wave transformation modeling is carried out using initial height values and a 50-year return period wave period, Hs = 1.02 m, Tp = 4.07 s, with the wave direction from the south. Figure 6, Figure 7, and Figure 8 are show the significant wave height for dock layout design jetty type, wharf type, and pier type, repectively.

At the jetty type, the significant wave height during high tide reach to 0.8 - 0.9 meters. Still during high tide, at the wharf type, signifikact wave height is 0.3 - 0.36 meters. While at the pier type, significant wave height near the dock is 0.7 - 0.8 meters. The results of the significant wave height near the dock based on the wave model result can be seen in Table 4.

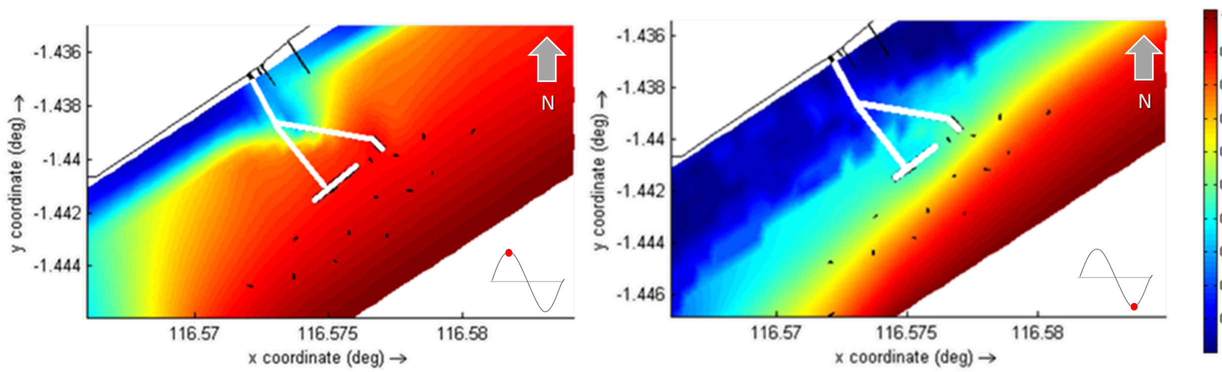

Fig.6. Significant Wave Height of Jetty Type Layout Design during high tide (left) and low tide (right)

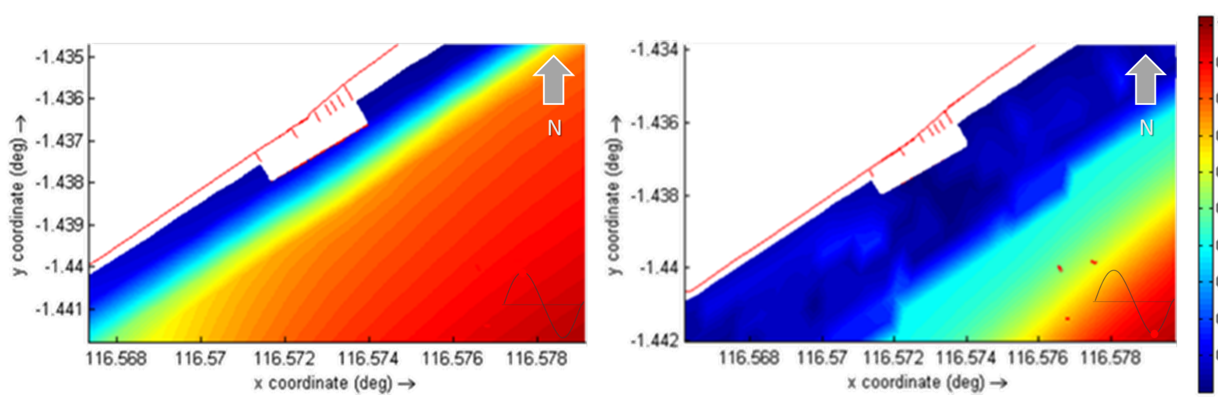

Fig.7. Significant Wave Height of Wharf Type Layout Design during high tide (left) and low tide (right)

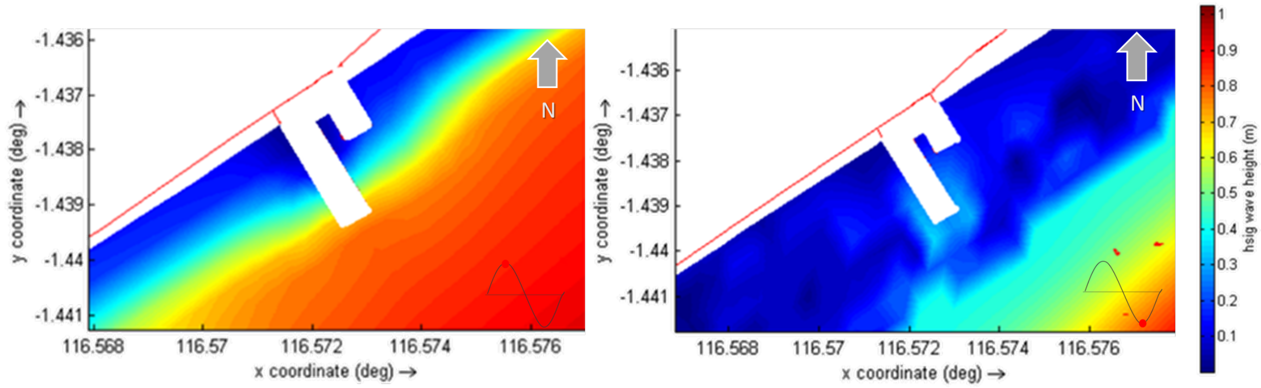

Fig.8. Significant Wave Height of Pier Type Layout Design during high tide (left) and low tide (right)

TABLE IV. RECAPITULATION OF WAVE HEIGHT IN 3 LAYOUT PLANS

Layout	Wave Height [m]	Condition
Jetty	0,90	High tide
	0,52	Low tide
Wharf	0,36	High tide
	0,06	Low tide
Pier	0,80	High tide
	0,31	Low tide

C. Flow Model Results

Current velocity is obtained from Delft-3D FLOW model. The current velocity at the research location is relatively small, ranging from 0.05 - 0.15 m/s. Small current velocity with large wave height can cause sedimentation in the port area. However, large currents can also make it difficult for the ship to lean. The required current velocity value for a port in this study must be <0.05 m/s.

In the jetty type layout design, it can be seen in Figure 9 that the current velocity at the front of the jetty is greater than in other areas, reaching 0.15 m / s. Figures 10 and 11 show the current velocity in the wharf and pier type design layout. The current velocity on the wharf and pier types ranges from 0.02-0.06 m / s.

D. Layout Selection

For selection of which one is the most suitable dock design layout to be placed at PPI Api-Api, waves are considered as the most influential parameter to determine the suitability of a ship carrying out loading and unloading activities. As the parameter that has the greatest impact, the weights given to the scoring calculations for the wave height is 60%. The remaining weight is 40% for the current velocity.

The maximum score is given when the wave height is < 0.2m, while the minimum score is given for docks with wave height > 0.5m. In the aspect of current conditions, The maximum score is given when the current velocity is < 0.05m/s, while the minimum score is given for docks with current velocity > 0.15m. Table 6 shows the results of the assessment for each type of dock design layout.

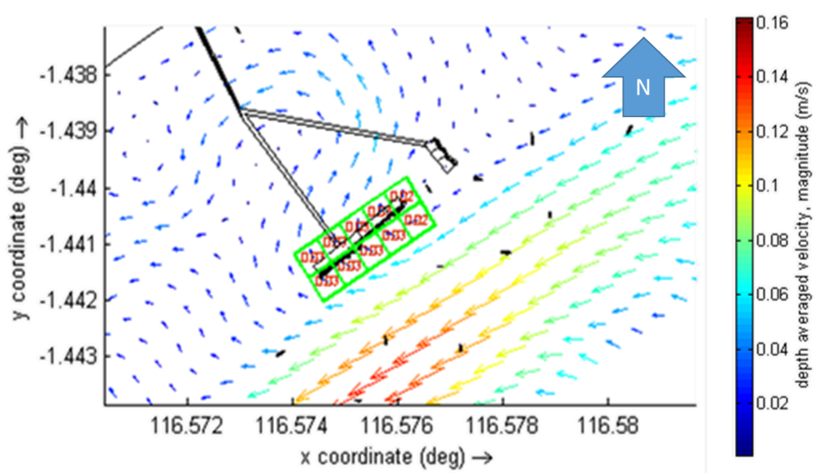

Fig. 9. Current Velocity at The Jetty Type Design Layout

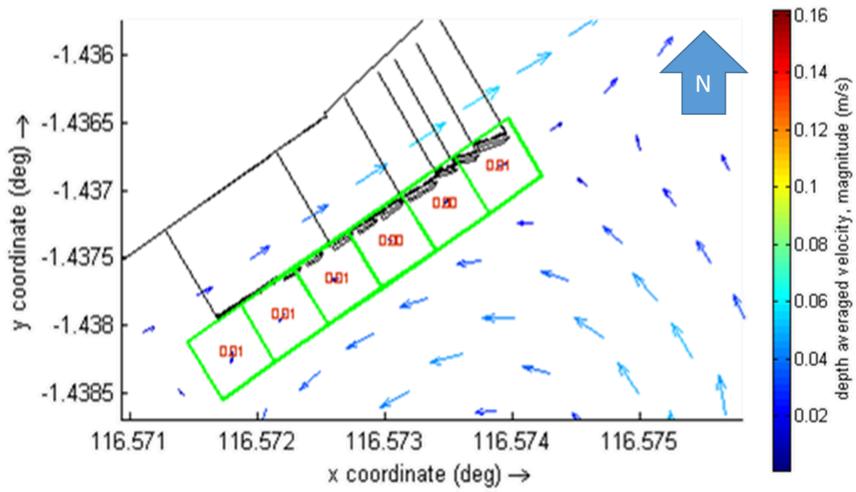

Fig. 10. Current Velocity at The Wharf Type Design Layout

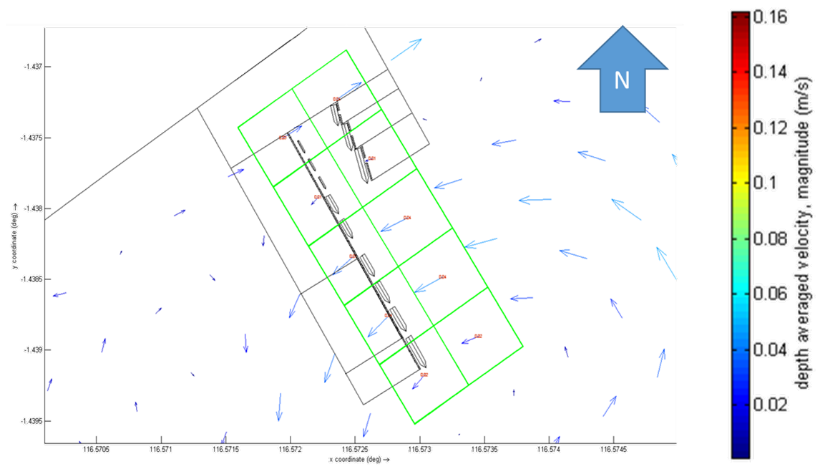

Fig. 11. Current Velocity at The Pier Type Design Layout

Scoring calculation result shows that the feasibility weight from wave and current conditions aspect for the jetty dock layout design is 52%, the wharf layout design is 74%, and 56% for the pier type. For wave and current parameters, each assessment is carried out by taking into account the conditions at high tide, low tide, towards tide and towards low tide.Table 5 shows the recapitulation of three alternative dock layout design assessments.

TABLE V. RECAPITULATION OF ALTERNATIVE DOCK LAYOUT ASSESSMENTS

Criteria	Selection Parameters	Score	Type of *Layout*											
			Jetty				***Wharf***				***Pier***			
Technical (Weight 100%)			P	S	MP	MS	P	S	MP	MS	P	S	MP	MS
a. Wave (60%)	Wave Height < 0,2 m	3	1	1	1	1	2	3	3	3	1	2	1	2
	Wave Height 0,2 - 0,5 m	2												
	Wave Height > 0,5 m	1												
Total aspect of the wave		12	4				11				6			
Wave aspect percentage weight			20%				55%				30%			
b. Current (40%)	Current velocity < 0,05 m/s	3	3	3	2	2	2	3	3	1	2	2	2	3
	Current velocity 0,05-0,15 m/s	2												
	Current velocity > 0,15 m/s	1												
Total aspect of flow		12	10				9				9			
Current aspect percentage weight			33%				30%				30%			
Total Score for hydrodynamic aspects		27	14				20				15			
Total weight for hydrodynamic aspects			52%				74%				56%			
P : High tide														
S : Low tide														
MP : Towards High tide														
MS : Towards Low tide														

IV. CONCLUSION

From this research, conclusions and suggestions that can be drawn are :

- The feasibility weight from wave and current conditions aspect for layout design jetty, wharf, and pier type is 52%, 74%, and 56%, respectively. From these results, it can be stated that the most suitable layout design to be chosen is the type of wharf.
- The high wave height (> 0.5 m) in the jetty and pier type layout design makes these two alternatives have a low score. However, the type of jetty and wharf can be applied by adding a breakwater in front of the dock to reduce wave height.
- Beside wave height and current velocity terms, the design of the dock layout also needs to be seen in terms of erosion and sedimentation. Therefore, for further research it is suggested to do sediment transport modeling to investigating the erosion and sedimentation in dock area.

REFERENCES

[1] Direktorat Jendreal Penguatan Daya Saing Produk Kelautan dan Perikanan. (2018). Potensi Usaha dan Peluang Investasi Kelautan dan Perikanan. Balikpapan: Kementerian Kelautan dan Perikanan.

[2] Roelvink, J.A. and Van Banning, G.K.F.M. (1994). Design and development of Delft3D and application to coastal morphodynamics. Proceedings of Hydroinformatics'94 conference, Delft.

[3] Elias, E. P. L., Walstra, D. J. R., Roelvink, J. A., Stive, M. J. F., & Klein, M. D. (2001). Hydrodynamic validation of Delft3D with field measurements at Egmond. In Coastal Engineering 2000 (pp. 2714-2727)..

[4] Deltares. (2014). Delft3D-Flow User Manual. Netherland: Boussinesqweg 1.

[5] Hasselmann, K., T. P. Barnett, E. Bouws, H. Carlson, D. E. Cartwright, K. Enke, J. Ew-ing, H. Gienapp, D. E. Hasselmann, P. Kruseman, A. Meerburg, P. Müller, D. J. Olbers,K. Richter, W. Sell and H. Walden, (1973). "Measurements of wind wave growth and swelldecay during the Joint North Sea Wave Project (JONSWAP)."Deutsche HydrographischeZeitschrift8 (12).

[6] Whitham, G. (1974).Linear and nonlinear waves. Wiley, New York.

[7] Mei, C.,. (1983).The applied dynamics of ocean surface waves. Wiley, New York.

[8] Dingemans, M. W., (1997).Water Wave Propagation over Uneven Bottoms, Vol. 1 and 2. Advanced Series on Ocean Engineering, Vol. 13. World Scientific, London.

[9] Muliati, Y. (2020). Diktat Kuliah Rekayasa Pelabuhan. Bandung: Institut Teknologi Nasional.