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Wave Simulation to Compare Existing and Extended Jetty in River Estuary, Pekalongan, Central Java, Indonesia

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***Abstract*—Pekalongan River has two functions, i.e., as fishing boat transportation and the main drainage of Pekalongan City. The Pekalongan river estuary has a Jetty located on two sides of the river mouth. The jetty is used to protect from waves and sediment. The Pekalongan river has upstream flow from Kupang and Banger river. Because of the flood incident around 2003, Since 2014, the two rivers became two estuaries. The condition caused a negative impact on sediment in the river mouth. Therefore, this research aims to find solutions by simulating waves, currents, and sediments. In this paper, the focus is on the wave simulation. This research method begins with the collection of primary data in the form of bathymetry measurements at the river mouth. While the secondary data is wind data for 13 years and tidal. Calculation of wind hindcasting figures out a wave at a significantly high value of 1.38 m and a significant period of 4.80 seconds. For wave simulations, it used SMS software in the CGWAVE module. The simulation compares the two jetties condition, in existing and development conditions. Based on the simulation, the wave is still high for existing conditions and becoming low by an extended jetty of 200 m lengths. The simulation results can be used to analyze the movement of sediment transport that is affected by the movement of waves around the river mouth.**

Keywords—Water, Estuary, Wave, simulation

I. INTRODUCTION

The estuary of the Pekalongan River is the principal estuary in Pekalongan city. This river estuary is used as fishing ship traffic (shipping channel). For this reason, a jetty (breakwater) has been built on both sides of the river mouth which is useful for protecting the sediment of longshore transport and the Pekalongan River [1]. The current issue that occurs in the estuary is the sedimentation from the upper watershed and longshore transport. The sedimentation disturbs the fishing ships that utilize river mouths as fishing port-channel and parking area [2]. Sediments originating from the Pekalongan watershed will be carried along with the river flow and can cause a rise of the riverbed of the Pekalongan River.

The existing condition of the research location is in Fig. 1. According to the Figure, Pekalongan river is on the West side (left), while the Banger river is on the east side (right). Previously both rivers had only one river mouth, but since 2004, the Banger river had its own estuary. Because the discharge from upstream is divided into two, then the energy to flush the sediment in the estuary decreases.

Fig. 1. Pekalongan estuary (left side) as Research area

II. METHODS

The first research activity was to collect the data needed to support the analysis and simulation. One of the data was Visual Earth Map with a scale of 1: 25.000. The analysis required a digital map. This map was used to get an illustration of the situation in the research area and its administrative boundaries [3].

In addition, primary data were also gained by conducting a Hydro-oceanographic survey. The stages of the Hydro-Oceanographic Survey included several parts of the work, namely observations of tides and bathymetry. The tidal observation survey was carried out for 15 days with a one hourly interval. Through the Least Square analysis, we could determine the dominant tidal components needed (at least 9 components), complete with phase information and amplitude [4].

Secondary data needed were wind data. Verification and processing of wind data included recording and making wind-rose representing wind conditions every month. The measurement position of wind data (altitude □ 10 m from the surface of water) was in the form of a sea point in the study area [5]. The wind data used were the result of the interpolation of wind data from several closer meteorological stations. The location of the study became the center of the wind rose, the wind fetch point and the center of the wave rose.

Based on the wind data that had been obtained, then analysis of hind-casting and wave transformation was carried out. Input data for wave hind-casting are wind direction and speed data (daily average for wave rose and daily maximum for maximum wave hind-casting and effective fetch length for eight wind directions [6].

After all of the data have been collected, we simulated a wave model in the study area. The simulation obtained wave refraction/diffraction modeling, including water bathymetry contour presentation, significant height and wave period, and grid system in the model area.

III. Description of Location

The estuary of the Pekalongan River is located on the north coast of Central Java. Administratively, Pekalongan fishing port is located in Pekalongan City, Central Java Province. This estuary is located adjacent to Pekalongan fishing port so that it has a direct impact on the activities. According to history, the Pekalongan fishing port is one of the largest traditional ports in Southeast Asia.

The Pekalongan River Estuary is equipped with a Jetty used to protect coastal areas against the influence of waves and sediment. As in Fig. 1, the two existing Jetties are equal in length. Currently, the sedimentary motion is dominant from east to west. It can be observed that sediment accumulation is on the east side of the jetty and erosion area is on the west one. According to Fig. 1, there are also jetties in Banger estuary and the groin which are parallel to the coast and perpendicular to the coast. The objective of jetty extension about 200 m length is to have more protection against sedimentation and to reduce the impact of waves. As a result, fishing ships can pass more easily in the river mouth. Pekalongan fishing port is used for loading and unloading fishing boats and as a mooring area.

IV. Results and Discussion

According to the research objectives, the outcomes are tidal analysis, windrose making, hindcasting to get wave rose and wave simulation. The wave simulation was conducted to existing jetty conditions and extended jetty plans. The extended jetty was arranged to reduce sedimentation and also protect the port pool from waves. The following will be submitted in sequence the results of the analysis and simulation.

A. Tidal Analysis

Tidal data and its verification at the Pekalongan Archipelago Fisheries Port (PPN) were carried out for 15 days, from July 23 to August 6, 2018 with an hourly reading. Tidal data was graphed according to Fig. 2.

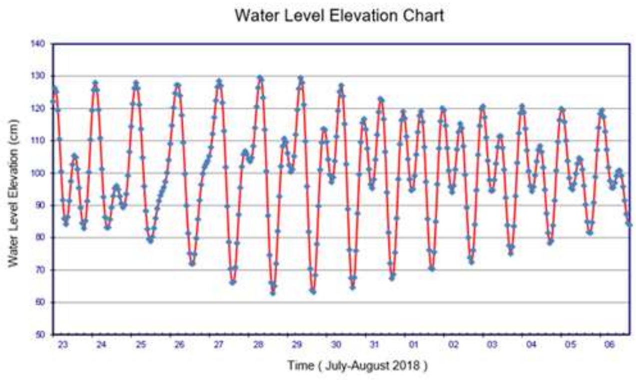

Fig. 2. Water Tide Elevation Chart

The maximum result value of tidal measurements was equal to 1.30 meters and the minimum value obtained was 0.67 meters. After tidal results were obtained for fifteen days, the data were analyzed by using the Least Square method [7]. The results of the Least Square method in Pekalongan fishing port were presented as follows.

TABLE I. TIDAL COMPONENTS OF THE LEAST SQUARE METHOD

Component	Amplitude	Phase Difference
M2	13.82	69.55
S2	12.85	31.97
N2	5.03	-30.66
K2	12.82	163.34
K1	6.79	211.83
O1	5.97	172.23
P1	9.17	-54.61
M4	0.01	-61.47
MS4	0.01	-81.95
S0	59.99	

Where as:
A : Amplitudo (cm)
g : Phase difference (0)
S0 : Water surface rate toward measuring sign zero point (cm)
M2 : Moon main component (semi diurnal) (cm)
S2 : Sun main component (semi diurnal) (cm)
N2 : Moon elliptical component (cm)
K1 : Moon Component (cm)
K2 : Moon component (cm)
O1 : Moon main compont (semi diurnal) (cm)
P1 : Sun main component (semi diurnal) (cm)
M4 : Moon main component (semi diurnal) (cm)
MS4 : Sun-Moon main component (cm)

To get the tidal type in certain location was by using Formzhal (F) as shown below:

$$F=(K1+O1)/(M2+S2) = 0.47 \text{ (Mixed Semidiurnal)}$$

With the value of F = 0.47, the estuary area of the Pekalongan River has a mixed semidiurnal, meaning that there are two high tides in one day, that is one small high and one higher tide level.

After obtaining tidal harmonic component values with the Least Square method, then a global tidal analysis was carried out. Considering that the sea level is always changing at any time, a specified elevation was needed based on tidal data. To figure out tidal component that has been produced, it can be determined by several important water level elevations. The results of important elevation analysis were presented in Table I. Some of these important elevations that will be used as references related to the surface elevation of the bathymetric contour are LWS. To find out the comparison between survey results data and estimated results data, then the water elevation reference was used as in the following Table II:

TABLE II. IMPORTANT ELEVATION OF THE CASE IN PEKALONGAN FISHING PORT

Type of Elevation	Least Square Method	
	Elevation (m)	**Elevation (0-LWS)**
Highest High Water Level (HWL)	1.60	1.01
Mean High Water Spring (MHWS)	1.60	1.01
Mean High Water Level (MHWL)	1.60	1.01
Mean Sea Level (MSL)	1.60	1.01
Mean Low Water Level (MLWL)	1.60	1.01
Mean Low Water Spring (MLWS)	1.60	1.01
Lowest Low Water Level (LLWL)	1.60	1.01

From the results of the tide analysis using the Least Square method, the highest tidal mounts are taken or called tidal riding as follows. High tide (HWS - LWS) is 0.81 meter. And the Z0 (MSL - LWS) is 0.40 meter.

B. *Windrose Analysis*

Data and analysis of wind were used to predict the waves. Wind data were obtained from the nearest and complete Meteorology and Climatology Station. In this case, the data were from the Maritime Meteorological Station of Semarang. The wind data used were wind data measured by the intensity of measurements per hour for 13 years (2004-2017). The results of processing hourly wind data from the Semarang Meteorology and Maritime Station can be seen in the following Table III. Wind data were divided into 8 wind directions. [8]. Then data were presented on wind velocity (knots) and duration blowing (hours).

TABLE III. TOTAL WIND EVENTS AT WORK LOCATIONS 2004 – 2017

Direction	Number of Hours						Percentage					
a	< 5	5-10	10-15	15-20	> 20	Total	< 5	5-10	10-15	15-20	> 20	Total
North	4986	8184	1815	168	23	15176	4.06	6.67	1.48	0.14	0.02	12.37
North East	1780	2268	275	16	11	4360	1.45	1.85	0.22	0.01	0.01	3.54
East	10722	6104	868	40	9	17743	8.74	4.97	0.71	0.03	0.01	14.46
South East	8410	3771	660	36	6	12883	6.85	3.07	0.54	0.03	0.00	10.50
South	5192	778	70	8	5	6053	4.23	0.63	0.06	0.01	0.00	4.93
South West	2814	657	49	10	2	3532	2.29	0.54	0.04	0.01	0.00	2.88
West	4082	2987	646	109	9	7833	3.33	2.43	0.53	0.09	0.01	6.38
North West	4086	6349	1831	388	50	12704	3.33	5.17	1.49	0.32	0.04	10.35
Windy					=	80274					=	65.41
Calm					=	42435					=	34.58
Not Recorded					=	19					=	0.02
Total					=	122728					=	100.00

a Wind speed in knots

From the Table above, a wind-rose rose graph can be made as shown in the Fig. 3 below.

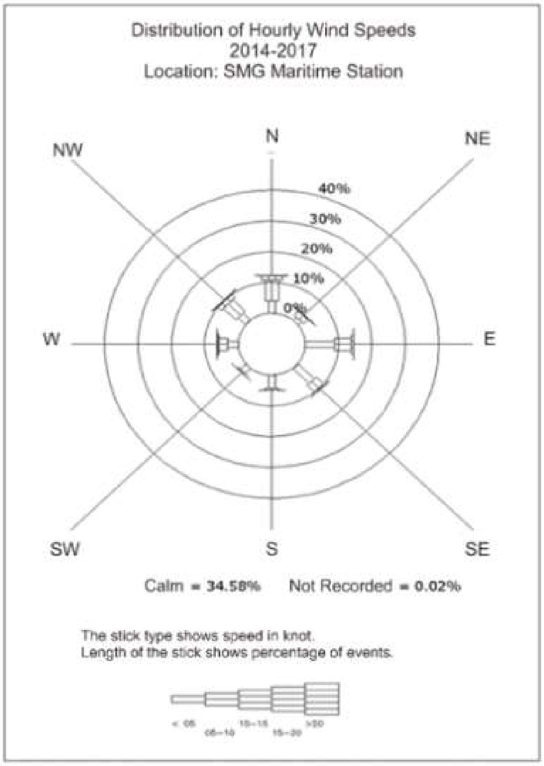

Fig. 3. Wind-rose in the Semarang Area and Surroundings 2004 – 2017

C. *Waverose Analysis*

To determine the wave height and period from the results of hind-casting, the fetch was needed to the distance of wind blowing. The wind speed blew above the surface of the water that would cause stress on the surface of the sea. The water surface would be disrupted, and small wave would arise. The high and low wave ripples that occur depended on the blowing wind speed and the distance of the fetch. Fig. 4 presents fetch for the wave-affected wind direction. Fetch on the work location was made every 50 in each direction of the wind. In this case, the fetch was made in the West (W), North West (NW), North (N) and North East (NE) and East (E).

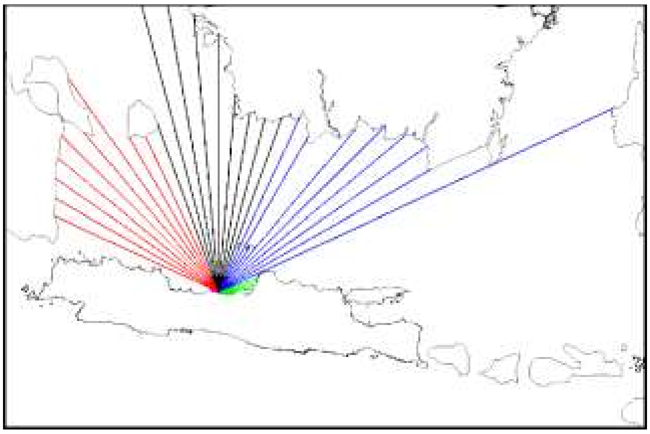

Fig. 4. Fetch in the Pekalongan River Estuary

Wave hindcasting was done by calculating wind speed, wind direction and fetch length. The hindcasting could find the wave direction and height in depth sea of Pekalongan River Estuary. Table IV presents wave height and percentage of wave events.

TABLE IV. PERCENTAGE OF WAVE YEAR EVENTS 2004-2017

Direction	Wave Height (m)						
	< 0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	> 2.5	Total
North	5.896	4.519	1.473	0.374	0.089	0.018	12.37
North East	2.835	0.623	0.064	0.019	0.000	0.005	3.55
East	9.377	3.916	1.053	0.104	0.000	0.012	14.46
South East	0.000	0.000	0.000	0.000	0.000	0.000	0.00
South	0.000	0.000	0.000	0.000	0.000	0.000	0.00
South West	0.000	0.000	0.000	0.000	0.000	0.000	0.00
West	5.348	1.032	0.000	0.000	0.001	0.002	6.38
North West	5.118	2.878	1.256	0.588	0.246	0.268	10.35
Bumpy						=	47.11
Calm						=	52.89
Not Recorded						=	0.00
Total						=	100.00

Then each wave event was included in the graph to determine a significant wave. The significant wave will be used in wave simulation. While the significant wave was defined as the average wave height of 33% the highest value of the wave hindcasting results [9]. The wave analysis found a significant annual wave height (Hs): 1.38 m with a period (Ts): 4.80 seconds. The chart to determine significant waves can be seen in Fig. 5 below.

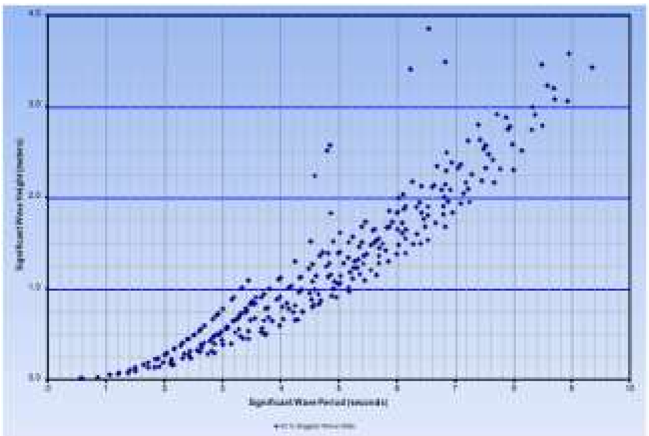

Fig. 5. Significant Wave Chart

Furthermore, each wave direction was analyzed and summarized in wave rose. The direction of the wave analyzed was the direction of the wave that was possible to reach the estuary of the Pekalongan river. The directions of the wave were from the west, northwest, north, northeast and east. The results of wave rose can be seen in Fig. 6 below.

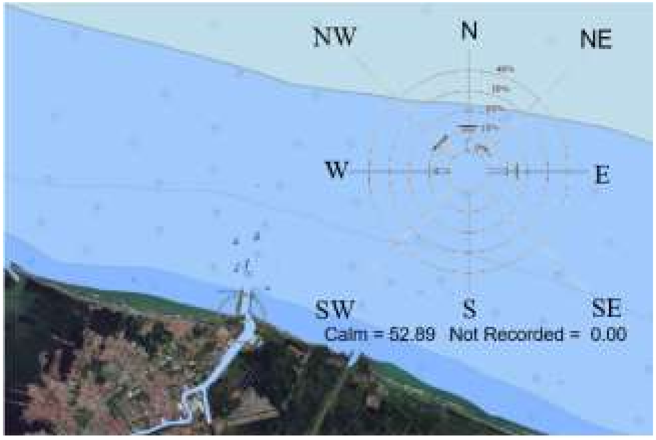

Fig. 6. Pekalongan Fishing Port Waverose

D. Wave Simulation

Modeling Wave Transformation was conducted with the CGWAVE (A Coastal Surface Water Wave Model of the mild Slope Equation) Module. Simulations were carried out using the CGWAVE module of the SMS (Surface Water Modelling System) 10.1 software. CGWAVE simulated the combined effect of wave refraction-deffraction included in the basic mild-slope equation. The wave model used a bathimetric map of the sounding results combined with the bathimetric map of the PUSHIDROS TNI-AL (Center of Hydro-Oceanografi of Indonesia Army).

Wave simulation was carried out when tidal sea conditions with the wave direction come predominantly from the North [10]. The wave height was 1.38 m, and the period was 4.80 seconds. Wave simulation was carried out on the existing conditions, where the position of the right and left jetty has the same length. The simulation results can be seen in Fig. 7. It can be seen in the picture that the wave size at the mouth of the river is green, meaning that the wave is more than 1 meter.

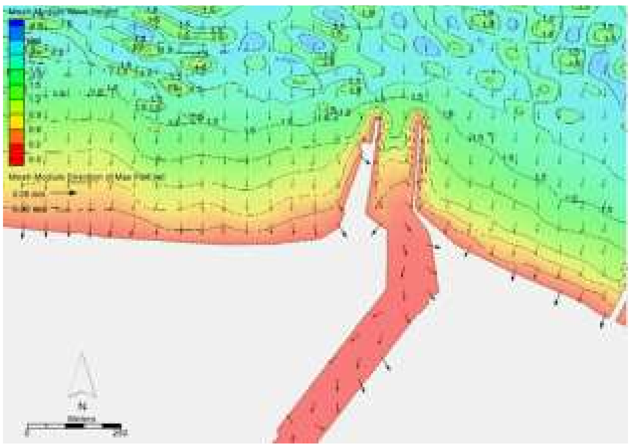

Fig. 7. Wave Simulation of Existing Jetty

The planned extension jetty is in the right (east) of Pekalongan estuary. The jetty is extended to around 200 m. Based on the wave simulation at the yellow estuary, it means below 0.9 m.

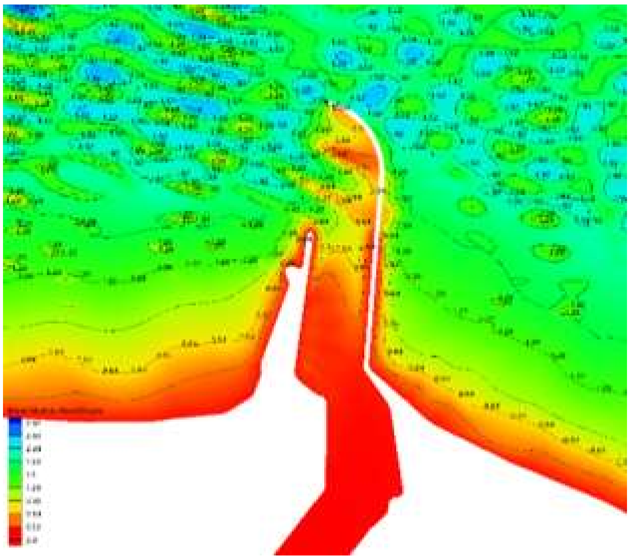

Fig. 8. Wave Simulation of 200 m Extended Jetty on East Side

V. CONCLUSION

Based on the research, several conclusion can be taken, include:

- Tides that occur in the studied locations showed that the type of tides which occur is mixed semidiurnal, where in a day occurs two pairs tide.
- Wind-rose produced from wind data showed that the dominant wind direction value comes from the north direction.
- The hint-casting analysis found a significant wave height reaching to 1.38 meters with periode 4.8 seconds.
- The wave simulation of existing conditions showed that the wave height still ranges from more than 1 meter so that it can disrupt the cruise lines.
- Based on the wave simulation of east jetty, the wave height ranges is less than 1 meter, so that the extended jetty can reduce the strength of the waves entering the river mouth.

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