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STUDY OF WAVE DOMINANT DIRECTIONS ON SEDIMENT TRANSPORT IN THE ESTUARY OF KAPUAS RIVER, PONTIANAK, WEST KALIMANTAN

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Abstract

The Kapuas River is a very important water transportation route in West Kalimantan, crossing 5 districts and 1 city. The problem that occurs in the shipping lane on the Kapuas River is the accumulation of severe sediment at the mouth of the estuary. This becomes an obstacle for ships with large loads to sail, for this reason, this research was carried out. The purpose of this study was to determine the dominant direction of waves and sediment transport. This study was calculated using the CERC (Coastal Engineering Research Centre) method and using secondary data. It was found that the dominant wave direction came from the North (N) direction with an incidence percentage of 22.496%. Percentage of occurrence from the Northwest (NW) direction is 12.145%, from the West (W) direction is 6.253%, and from the Southwest direction (SW) is 11.724%. While the amount of sediment transport from the Northwest is -393062.1306 m^3/year with the characteristics of the sediment being clay, from the West it is -250.1672 m^3/year with the sediment characteristics being silty clay and from the Southwest, it is 579090.2782 m^3/year with sediment characteristics of silty clay. The results of the sediment calculation have negative results which indicate that there is no sediment transport from the Northwest and West, but the sediment is deposited. For this reason, it is necessary to carry out appropriate handling of these problems to reduce sediment build-up in the study area.

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1. Introduction

West Kalimantan with geographical conditions has hundreds of large and small rivers, some of which are navigable. One of the largest and longest rivers in Indonesia is the Kapuas River which empties into Pontianak City. Its length reaches 1,086 Km and a navigable length of 942 Km. The Kapuas River is very important to carry out water transportation in West Kalimantan by crossing 5 districts and 1 city, including Kapuas Hulu Regency, Sintang Regency, Sanggau Regency, Landak Regency, Kubu Raya Regency and Pontianak City (Dinas Perhubungan Provinsi Kalimantan Barat, 2018).

Sedimentation occurs as a result of the entry of sediment loads into a particular aquatic environment through water media and is deposited in that environment (Mawardi, 2016). The problems caused by sedimentation are the expansion of the land area, silting of the port and silting of the mouth of the estuary. This siltation at the mouth of the estuary will certainly disrupt shipping lanes, consequently, it will spread to the regional economy.

In the case of writing this research, the researcher focuses on the factor of the direction of the wave to sedimentation. The waves move from the deep sea to the coast which causes sediment turbulence at the bottom of the water and there is a transfer of sediment from one location to another which is called sediment transport. Nevertheless, the energy generated by the waves will transport sedimentary material, it will cause the displacement of sedimentary material to the deposited area. The direction of the incoming wave depends on the speed of the wind blowing towards the beach and will form an angle. Sediment transported across the mouth of the estuary will accumulate as the current velocity weakens. According to Lestari et al., (2017) that the current strength at the mouth of the Kapuas estuary becomes weak which is proportional to the size of the bottom sediment in the area, the weak current velocity very rarely transports large sediment particles.

The shipping lane on the Kapuas River has a fairly severe buildup of sediment at the mouth of the estuary. This becomes an obstacle for ships that have large loads to sail. Moreover, at low tide, ships with large loads cannot pass through the estuary and will stop in front of the mouth of the estuary until high tide. Therefore, dredging has been carried out to reduce sediment that has accumulated in the estuary, but sedimentation is still occurring in the area. Accumulation of sediment can occur from several factors, but in this study, utilize the dominant wave direction as the researcher's parameter for analysis.

2. Materials and Methods

This research uses quantitative research and uses secondary data. The purpose of this study was to determine the dominant direction of the waves and the magnitude of sediment transport at the mouth of the Kapuas River Estuary.

2.1 Flow Chart

The flow chart of this research is presented to simplify the implementation process. Thestages of the research can be seen in Fig. 1 below

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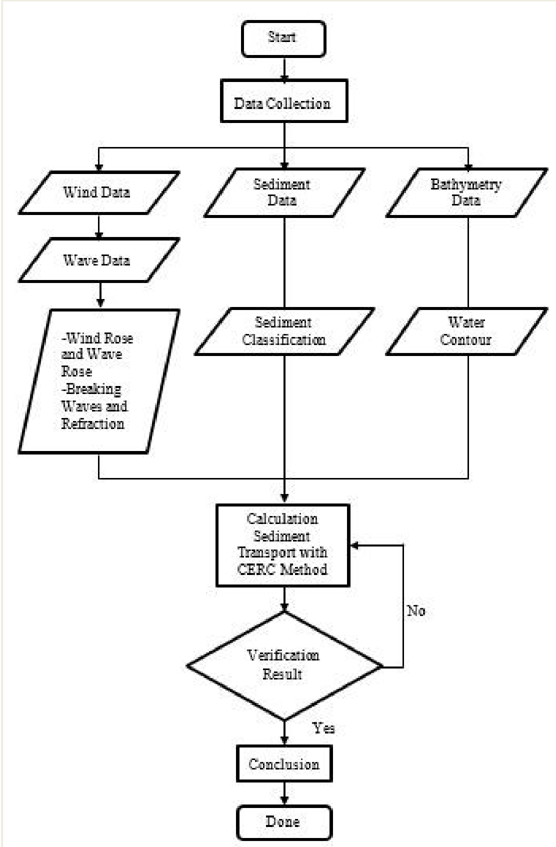

Fig.1 Flow Chart

2.2 Location of Research

The research site is located in the Kapuas River Estuary (Fig. 2), West Kalimantan Province, Indonesia or usually called Muara Jungkat. This study focuses on the mouth of the estuary with coordinates 0°03'50.00 "N, 109°10'00.00" B. The Jungkat estuary is directly adjacent to the South China Sea or the Karimata Strait with an estuary mouth width of ± 2.5 Km. The morphological condition of the estuary is flanked by a muddy beach and dense forest with a slope of the bottom of the estuary based on the slope degree of 0.0014° (Budiman et al., 2020).

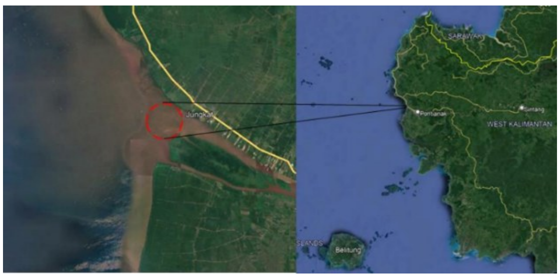

Fig.2 Point Location of Research (Google Earth)

2.3 Wind Data

Utilize of wind data is very important in this study and is the first data to be analyzed. Wind data was used for 10 years, from 2011 to 2020 every 3 hours. The need for wind data processing includes wind speed and wind direction. The data was obtained from the Meteorology, Climatology and Geophysics Agency (BMKG) closest to the research location and processed using Excel. Therefore, the purpose of this data processing is to get the percentage of wind direction (which is presented in the Wind Rose graph) and processed it as wave data. The stages to achieve these goals are:

1. Data from BMKG is converted to Excel and the data is processed annually to make it easier to work with;
2. The direction of the wind is converted from degrees (º) to the cardinal directions (such as North (N), Northeast (NE), East (E), Southeast (SE), South (S), Southwest (SW), West (W), and Northwest (NW)) and processed using AutoCAD into a Wind Rose graphic;
3. The wind speed is converted to U10 in Eq. (1).
   $$\mathrm{U}(10) = \mathrm{U}(\mathrm{y}) \left(\frac{10}{\mathrm{y}}\right)^{\frac{1}{7}} \quad (1)$$
   (if the wind speed is not taken from a height of 10 m above sea level);
4. Determination of the UW value from the RL relationship graph (if the wind speed is taken above ground level, not above sea level);
5. Determine the value of the wind stress factor (UA) in Eq. (2).
   $$\mathrm{U_A} = 0{,}71\ \mathrm{U}^{1{,}23} \quad (2)$$

2.4 Wave Data

Wave data is processed using Excel which is obtained after wind data processing is carried out. This wave data processing aims to get the value of significant wave height (Hs), wave period (T) and the percentage of the direction of the wave. The direction of the incoming wave is obtained from the Meteorology, Climatology and Geophysics Agency (BMKG) to obtain the percentage of the direction of the dominant wave which is presented in the form of a Wave Rose graph. Therefore, here are the steps for doing wave forecasting:

1. Calculate the effective fetch value (Feff) in Eq. (3)
   $$\mathrm{F}_{eff} = \frac{\sum \mathrm{X_i} \cos\alpha}{\sum \cos\alpha} \quad (3)$$
2. Determine the significant wave height and period from the graph of the relationship between the wind stress factor (UA) and the effective fetch length.
3. Calculates the height and period of significant waves in each direction (NW, W, and SW)

2.5 Sediment Data

Sediment data uses secondary data from data processing of scientific articles written by the author himself. The size of the diameter of the sediment grains used is the median value (middle value) or also called the D50 size of the sediment grains in each direction (NW, W, and SW). Then calculated sediment transport using the CERC (Coastal Engineering Research Center) method. The steps for calculating sediment transport are as follows:

1. Determine the estimated refraction coefficient or Krbr estimate along with the angle of incidence of waves at a local depth of each direction by entering the parameters of wave height and period, wave direction angle, local depth, and the slope of the beach slope in the wave calculator application (Wave Parameter);
2. Calculates L_0, C_0, dan H_0'.
3. Calculate the breaking wave height (Hb) and breaking wave depth (db) from the graph;
4. To get the value of the refractive coefficient, if the result is very different from the estimated value of Krbr, then do it from point (1). And if the results are close to the estimated value of Krbr then the calculation can be continued;
5. Determine the CERC coefficient;
6. Calculate the total sediment transport from each direction of the wave with Eq. (4).
   $$\mathrm{S} = \mathrm{A} . \frac{1}{32}\, \rho . \mathrm{g} . \mathrm{H_0^2} . \mathrm{C_0} . \mathrm{K_{RBR}^2} . \sin\alpha\,\mathrm{br} . \cos\alpha\,\mathrm{br} \quad (4)$$

2.6 Bathymetry Data

Bathymetry data were obtained from government agencies, namely the Department of Marine Affairs and Fisheries (DKP) of West Kalimantan Province. The data is presented in the form of a bathymetric map, this map is used to determine the depth at a predetermined research location or local depth. In addition, the bathymetry map can also determine the percentage of the slope of the coast in each of the three directions of view (NW, W, and SW) which is used as an iteration to obtain the refractive coefficient and the angle of incidence of the waves.

3. Result and Discussion

From the analysis of the processed data, the following results are obtained:

3.1 Wind Rose and Wave Rose

From the analysis of wind data, the percentage results of wind speed from each cardinal direction are presented in Fig. 3 and the wave height is presented in Fig. 4.

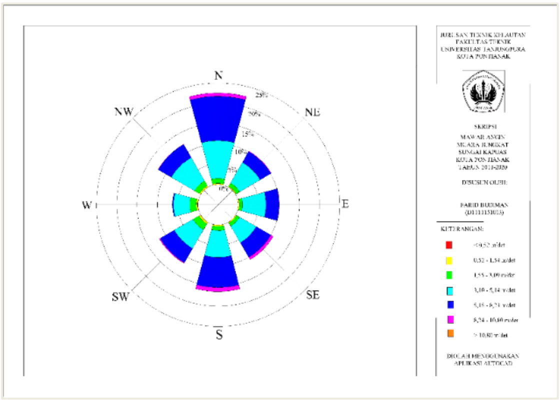

Fig.3 Wind Rose

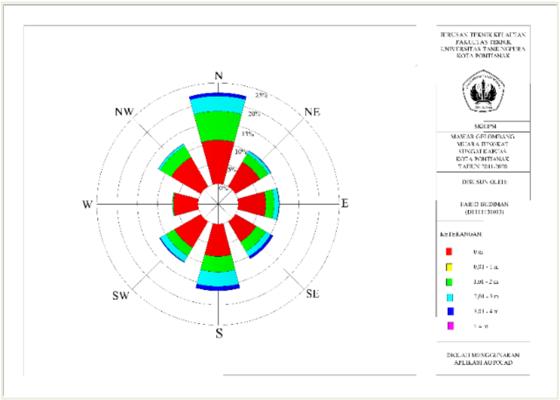

Fig.4 Wave Rose

3.2 Analysis of Sediment Characteristics

Sediment samples were tested in the laboratory to obtain the percentage of sediment content. To get the percentage of sand, clay, and silt can be done by sieve analysis test as shown in fig. 5.

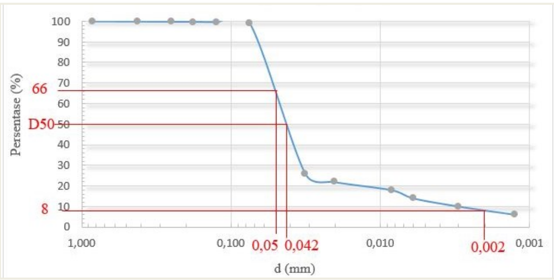

Fig.5 Sieve Analysis

The results of laboratory tests for each sample are presented in table 1 below.

Table 1. Classification Sediment

Wind Direction	Percentage Content (%)			USDA sediment classification	D50 (mm)
	Sand	Silt	Clay		
NW	20	57	23	Silty Clay	0,028
W	46	46	8	Clay	0,048
SW	34	58	8	Silty Clay	0,042

After getting the percentage of each sediment content, then classify the type of sediment using the USDA chart as shown in Fig. 6.

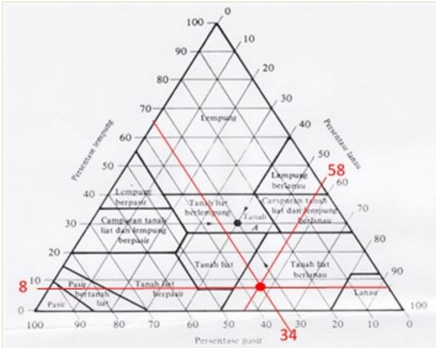

Fig.6 USDA Classification

3.3 Sediment Transport (Bed Load) With CERC Method

Furthermore, after all the data has been collected, the next step is to calculate the sediment transport parameters in table 2.

Table 2. CERC Method Calculation Parameters

Wave Direction	Wave Height (H s) (m)	Period (T) (s)	Percentage of Occurrence (%)	Kr' (Local Depth 5 m)	α' (Local Depth 5 m)	D50 (mm)	Slope
NW (315)	1,7902	7,6990	12,1450	0,8760	-22,878	0,0280	0,0200
W (270)	1,8571	8,1759	6,2530	0,0471	-31,407	0,0470	0,0200
SW (225)	2,1479	8,5856	11,2740	0,8692	20,655	0,0420	0,0200

The following are the steps for calculating the amount of sediment transport from each direction of the study in table 3

Table 3. CERC Method Calculation Steps

Wave Direction	L_0	C_0	Kr' Estimate	H_0'	H_0'/L_0	H_0'/gT^2	H_b/H_0'
NW (315)	92,5918	12,0265	0,8760	1,5681	0,0169	0,0027	1,2700
W (270)	104,4195	12,7716	0,0471	0,0875	0,0008	0,0001	2,3250
SW (225)	115,1457	13,4115	0,8692	1,8669	0,0162	0,0026	1,2900

H_b	H_b/gT^2	d_b/H_b	d_b	d_b/L_0	tan h $(2\pi * d_b/L)$	d/L_0	tan h $(2\pi*d/L)$
1,9915	0,0034	1,1340	2,2584	0,0244	0,3815	0,0540	0,5494
0,2034	0,0003	0,9600	0,1952	0,0019	0,1090	0,0479	0,5210
2,4083	0,0033	1,1380	2,7407	0,0238	0,3771	0,0434	0,4984

C_b/C_0	sin α	C_b/C_0* sin α	asin $(C_b/C_0$* sin α)	$K_{r,br}$	S= Sediment Rate (m^3/year)
0,6944	-0,3888	-0,2700	-15,6619	0,8568	-393062,1306
0,2092	-0,5211	-0,1090	-6,2591	0,0436	-250,1672
0,7566	0,3527	0,2669	15,4796	0,8565	579090,2782

Where in:
L_0 = Wavelength in the deep sea (m)
C_0 = Speed of waves in the deep sea (m/s)
Kr' = Estimated refraction coefficient
H_0' = Equivalent wave height (m)
g = Acceleration due to gravity (m/s^2)
T = Period wave (s)
H_b = Wave height in the deep sea (m)
d_b = Breaking wave depth (m)
d = Wave depth (m)
C_b = Speed of breaking waves (m/s)
C_5 = Speed of breaking waves at a 5 m (m/s)
K_{rbr} = Result of refraction coefficient

Seen from the percentage, the highest significant wave height is from the North (N) direction, which is 22.496% and the lowest is from the West (W) direction, which is 6.253%. Even in the Northeast, East and Southeast directions, the percentage is quite large, reaching a total of 30.969%. Whereas based on the map of the research location points, in the Northeast, East and Southeast directions, it will not form waves from the deep sea. This happens because the wave data is processed based on the direction of the wind speed that blows. The direction of the wind that blows is very random and can come from any direction. While in this study using the dominant direction of the wave. So based on the location of the dominant direction of waves from the deep sea, they are taken from the Northwest (NW), West (W), and Southwest (SW), although there is a higher percentage of the three directions. At the mouth of the estuary, sediment transport usually occurs due to land activities from the upstream of the river to the estuary, so it is also necessary to analyze the amount of sediment transport coming from the upstream of the river due to tides, current velocity and land activity in the riverbank area.

Looking at the results of sediment transport using the CERC method in 3 directions of review, there are negative results. The negative result indicates that there is no sediment transport, but the sediment is deposited at the mouth of the estuary as a result of waves heading toward the estuary from the Northwest and West. For this reason, it is necessary to carry out appropriate handling of these problems to reduce the accumulation of sediment in the research area. So it can be concluded that in the direction of NW and W, the shear stress that occurs does not exceed the critical erosion stress. When total from the three directions of sediment figures obtained, the total sediment transport yield is 185777.9804 m^3/year with an average sediment grain of 0.0390 mm and the classification of sediment types is silty clay.

4. Conclusion

The dominant direction of the wave comes from the North (N) with a percentage of 22.496%. Moreover, the highest wave heights (other than 0 meters) from the 3 viewing directions are 1 to 2 meters with a percentage of 23.86% and the percentage of occurrences from each directions are: Northwest (NW), with a percentage of 12.145%; West (W), with a percentage of 6.253%; and Southwest (SW), with a percentage of 11.724%. Furthermore, the total sediment transport total is 185777.9804 m^3/year and in each wave directions, specifically: Northwest (NW), is -393062.1306 m^3/year with the characteristics of the sediment being clay; West (W), is -250.1672 m^3/year with sediment characteristics of silty clay; Southwest (SW), amounting to 579090.2782 m^3/year with sediment characteristics of silty clay.

5. Acknowledgement

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6. Author's Note

The author ensures that there is no plagiarism in the writing and this research.

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