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DISTRIBUTION PATTERN OF TOTAL SUSPENDED SOLIDS (TSS) IN KAMPAR RIVER ESTUARY, PELALAWAN REGENCY, RIAU PROVINCE

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ABSTRACT

The Kampar River Estuary is the main river in Riau province, which empties into the Malacca Strait and has a unique potential for research. The characteristics of the Kampar River Estuary are concurrent and have high tidal elevations, resulting in the occurrence of a Tidal Bore, which is referred to as Bono. The impact of sedimentation is generally quite detrimental, namely the siltation in several places, such as the waters of the Kampar River Estuary, which are dense areas of human activity. This study aimed to determine the relationship between hydrodynamic patterns, suspended solids' distribution pattern, and the concentration value of suspended solids distribution in the Kampar River estuary. This research method is surveyed and discussed descriptively. Current patterns affect the distribution of sediments in the Kampar River estuary. The TSS distribution pattern tends to follow the same direction as the movement of tidal currents where, during high tide, it tends to lead to the southwest of the Kampar River estuary, while during low tide tends to lead to the northeast and northwest, it this is because, in the Kampar River estuary, there is an island that makes the mouth of the Kampar River estuary V-shaped. Between hydrodynamic patterns and TSS distribution patterns, there is a moderate negative relationship (r = 0.50), which means that there is a significant influence between hydro patterns and TSS distribution patterns in the waters of the Kampar River estuary, between hydrodynamic patterns and TSS distribution patterns in the waters of the Kampar River estuary. The lowest value of TSS concentration in the waters of the Kampar River Estuary at high tide to low tide is Station 7, with a range of 102 mg/L, and the highest value at Stations 3, 4, and 9. At station 3, there are values ranging from 1756 mg/L; at Station 4, there are values ranging from 2823 mg/L; and at Station 9, there are values ranging from 1269 mg/L; the high concentration of TSS results in low brightness in the study area.

Keywords: Kampar River Estuary, Total suspended solid, Sedimentation

1. INTRODUCTION

Sedimentation is the process of transporting eroded material from land through river flow or from the air, then deposited in a basin due to erosion; the impact of sedimentation is generally quite detrimental, namely the siltation in several places, the waters of the Kampar River Estuary is a dense area of human activity. In addition, in this area, there is also a Bono phenomenon that occurs at high tide, where there is a meeting of tidal currents from the sea and a meeting of currents at low tide from the river, which results in a collision of energy that produces large waves where these waves stir up materials around the coast which will eventually cause siltation in several places and turbidity along the Kampar River estuary, This can lead to coastal changes and also affect the distribution of total suspended solid (TSS) around the water[1]. TSS consists of mud, fine,

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sand, and microorganisms mostly caused by soil erosion or soil erosion carried into water bodies.

The environment around the coast of the Kampar River Estuary is expected to be vulnerable to changes in the surrounding environment. Due to the Kampar River Estuary, the coastal area faces the Malacca Strait, which is expected to receive frequent pressure from this strait, ultimately increasing TSS. The increase in TSS affects changes in the coastal environment, such as the formation of mud material due to the abrasion process not settling much along the coast or turbidity along the Kampar River estuary or river flow. This study aims to determine the relationship between hydrodynamic patterns, suspended solids' distribution pattern, and the concentration value of suspended solids distribution in the Kampar River estuary.

2. RESEARCH METHOD

Time and Place

The research was conducted in July-November 2022 in the estuarine waters of the Kampar River, Pelalawan Regency, Riau Province. The research used materials used for field observations and analyzed primary tidal data (15 days for 1 hour), TSS data, and PKA Parameter data. Secondary data consists of BMKG wind data, NOATide and Pushidrosal tidal data, DEMNAS bathymetry data, and Google Earth coastline data.

Methods

This research was conducted using a survey method involving direct observations through measurements and sampling in the field. The data collected were primary results from field water quality measurements and water samples analyzed in the laboratory, and secondary data were then analyzed descriptively. The data analyzed used the simple linear regression method to determine the relationship between current patterns and TSS distribution patterns.

Procedures

Data Collection

Data collection is carried out in primary and secondary ways. Primary data was obtained through fieldwork using tools. Primary data is needed to verify the comparison of similarity between field data and model data. Primary data required include tidal, current velocity, and TSS data. Secondary data collection is done by downloading data from several sites that provide data as needed, including wind, tide, and bathymetry.

Data Processing

Tidal

Tidal measurement begins with the determination of the measurement area. The location is determined at a particular location considering that it can represent the characteristics of the local water area and pay attention to the ease of data collection. The tidal observation points were determined by using the area sampling method. The area sampling method is used to determine whether the sample is extensive and whether the object or data source to be studied is extensive. Tidal measurements were made using the conventional method (tide bar) for 15 days at 1-hour intervals. The water level was recorded every hour manually.

TSS Sampling

TSS sampling was conducted from high tide to low tide. Water sampling was carried out once per sampling point, namely on the surface and at a depth of 3 m at 10 sampling points using a Vandorn bottle. The volume of sample water taken, as much as 250 mL, is put into the sample bottle, and then the sample bottle is put into the coolbox. Then, the sample is analyzed in the laboratory using the Standard Analysis Method 2540 D.

Flow Speed

Measure surface current velocity using a current drug tied to a rope of known length. A stopwatch was used to calculate the time.

Current speed is measured by comparing the distance traveled by the current draug meter in time (seconds) using the following formula:

$$v = s/t$$

Description:

v = Current speed (m/s)
s = Range (m)
t = Second (s).

Tidal Data

The first step is to download tidal data in the Kampar River estuary waters to obtain the tidal constant values. 9 main components of tidal harmonic constants are used: M2, S2, K2, N2, K1, O1, P1, M4, and MS4. NAOTide tidal data is the main parameter used as the main input of the current model

Wind Data

Wind data can be collected through the BMKG (Meteorology, Climatology, and Geophysics Agency) website and based on a predetermined research location. The parameters contained in this wind data are wind direction at maximum speed (ddd_x) and wind speed at maximum (ff_x). The data obtained will then be processed with MIKE 21 software using the Mike Zero - Time Series (dfs.0) - Wind function.

Bathymetry Data

Bathymetry data was obtained through the DEMNAS website, one of the Geospatial Information Agency's forms, to serve the availability of elevation data in Indonesia. DEMNAS itself stands for National DEM. DEM (Digital Elevation Model) a digital elevation model, visualizes topography or land surface elevation built based on deterministic interpolation results. DEMNAS consists of integrating several elevation data processed by the GMT-surface 1 method. Bathymetry data is required to create model boundaries with the method GMT-surface[1].

Shoreline Data

Shoreline data was obtained through the digitization of Google Earth maps and then inputted into Global Mapper to change the appropriate format into MIKE 21. This and bathymetry data are needed to create a mesh boundary and a model boundary (boundary condition).

Flow Pattern Modeling

Current velocity modeling with a mathematical model by inputting secondary data in bathymetry, shoreline, tide, and wind data. The hydrodynamic module in MIKE 21 HD is a general numerical model system for modeling water level and flow simulations in estuaries, bays, and beaches. The model can simulate two-dimensional undrained flow in a single-layer (vertically homogeneous) fluid and three-dimensional flow. The MIKE 21 hydrodynamics module (MIKE 21 HD) is the basic MIKE 21 flow model program module. The mass and momentum conversion equations written as DHI Software, 2007:

- Equation of Continuity

$$\frac{\partial h}{\partial t} + \frac{\partial h\bar{u}}{\partial x} + \frac{\partial h\tilde{v}}{\partial y} = hS$$

- Momentum equation

The momentum equation for two-dimensional flow in the x and y directions can be written as the following equation.

$$\frac{\partial u}{\partial t} + v\frac{\partial u}{\partial y} + \frac{\partial u}{\partial t} + g\left(\frac{\partial h}{\partial x} + \frac{\partial \alpha_0}{\partial x}\right) - \frac{\varepsilon_{xx}}{\rho}\frac{\partial^u tt}{\partial x^2} - \frac{\varepsilon_{xy}}{\rho}\frac{\partial^2 u}{\partial y^2} + \frac{gu}{C^2 h}\sqrt{u^2 + v^2} = 0$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial y} + v\frac{\partial u}{\partial t} + g\left(\frac{\partial h}{\partial x} + \frac{\partial \alpha_0}{\partial x}\right) - \frac{\varepsilon_{xx}}{\rho}\frac{\partial^u v}{\partial x^2} - \frac{\varepsilon_{xy}}{\rho}\frac{\partial^2 u}{\partial y^2} + \frac{gv}{C^2 h}\sqrt{u^2 + v^2} = 0$$

Description:

u = horizontal velocity of x-direction flow
v = horizontal velocity in the y-direction
t = time function
g = acceleration of gravity
h = water depth,
a0 = elevation of the bottom of the cross-section
ρ = density
εxx = x-direction normal turbulence exchange coefficient,
εxy = x-direction tangential turbulence exchange coefficient,

εyx = y-direction tangential turbulence exchange coefficient,
εyy = y-direction normal turbulence exchange coefficient
C = Chezy roughness coefficient (or coef. Manning, n = 1/C h1/6)

Modeling of TSS Scatter Patterns

The model's formula is a two-dimensional system with an average depth where the vertical concentration is assumed to be uniform. The Mud Transport (MT) module is an application for sediment transport with clayey silt base material. The Mud Transport (MT) module specializes in cohesive materials. The Mud Transport (MT) model based on the suspended sediment convection-diffusion equation:

$$\frac{\partial C}{\partial t}\bar{U}\frac{\partial C}{\partial x}+V\frac{\partial C}{\partial y}+\frac{\partial}{\partial x}\left(Dx\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(Dy\frac{\partial C}{\partial y}\right)+\alpha 1C+\alpha 2$$

Description:
C = concentration,
U = average velocity of x-direction flow,
V = average velocity of y-direction flow,
Dx = effective diffusion coefficient in x direction,
Dy = y direction effective diffusion coefficient,
α1,α2 = source coefficient

Relationship between Hydrodynamic Patterns and TSS Distribution Patterns

Data processing carried out on the relationship between hydrodynamic patterns and TSS distribution patterns will be analyzed using linear regression:

$$Y' = a + bX$$

Description:
Y' = Dependent variable (predicted value)
X = Independent variable A
a = Constant (the value of Y' if X = 0)
b = Regression coefficient (increase or decrease value)

Data on the relationship between hydrodynamic patterns and TSS distribution patterns are processed through the Microsoft Excel application program with the scatter chart type to get a simple linear regression analysis graph between the relationship between hydrodynamic patterns and TSS distribution patterns.

Data Analysis

Hydrodynamic modeling is processed using the hydrodynamic module in MIKE 21, wherein several data are required, including tidal data, shoreline data, wind data, bathymetry data, and TSS data. These data will then become input for modeling currents and TSS distribution patterns. Analysis and interpretation of model data consists of making mesh boundaries, time series, and point series. As explained earlier, a mesh boundary is made based on the study area, including shoreline and water bathymetry data. Furthermore, the time series results from tidal elevation predictions are stored in Dfs0 format to model ocean currents. In contrast, the point series results from processed models that display tidal data, current speed, and current direction shown through the arrow symbol.

The hydrodynamic model is a horizontal two-dimensional finite element method with depth averaging. The flow patterns, water level elevations, and horizontal velocity components were predicted with a numerical model. Then, the output that has been run is re-layout on Mike Zero in the result viewer module. The simulation results were rechecked for 15 days; in this study, the layout of current patterns and TSS distribution patterns was divided into several days on simulation day 5, day 10, and day 15. Then, proceed with the analysis of observations of simulation results and perform data processing of current patterns on TSS sebran patterns using the simple linear regression method to determine the relationship between the x variable and the y variable. Validation of tidal data by comparing field tidal data with NAOTide and Pushidrosal TNI-AL predicted tidal data where the time taken is for 15 days, namely on July 13, 2022, at 18.00 WIB until July 28, 2022, at 17.00

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WIB. The data was visualized in the form of a line graph

3. RESULT AND DISCUSSION

Description of the Research Location

Kampar River Estuary is a river located in Riau Province, Pelalawan Regency. The mouth of the Kampar River is in Teluk Meranti District, Pelalawan Regency. This river is a meeting of two rivers of almost the same size, called Kampar Kanan and Kampar Kiri.

The length of the Kampar River is ±413.5 km with an average depth of ±7.7 m. which passes through several villages, namely Pulau Muda Village, Mutiara Peat Village, Segamai Village, and Labuhan Bilik Village located at coordinates 0^{o}15'11.6760 "LU and 102^{o}47'59.7600" East- 0^{o}15'17.4978 "LU and 102^o 58'41.6400" East where the area of Teluk Meranti District is 423. 984, 41 ha. Mendol Island borders the Kampar River estuary to the north, Muda Island to the south, Merati Bay to the west, and Labuhan Bilik Village to the East.

The Kampar River estuary is typical of passive and lumpy lithology, so these waters can be categorized as unstable to increase turbidity and sedimentation. Also, at the mouth of the Kampar River, there is Bono, a natural phenomenon caused by tidal waves that meet the current of the Kampar River. The condition of the 'V' (funnel) shaped estuary allows the meeting of the two kinds of currents to generate the formation of Bono. Bono waves are included in the tidal bore category, which spreads upstream to Tanjung Pungai (about 60 km from the estuary). According to the people on the banks of the Kampar River in the estuary, the height of Bono in this river can reach 4-6 m. This bono event is a powerful tidal wave that suddenly raises the river water level

Tidal

Measurement of tidal data in the field is needed to validate NAOTide tidal data, that the data is used as one of the inputs of hydrodynamic pattern processing data, but also a validation of pushidrosal tides in validating the data so that it can be seen clearly how the difference in the data. The field tidal value data and Pushidrosal tidal value data are obtained through the graph in Figure 1.

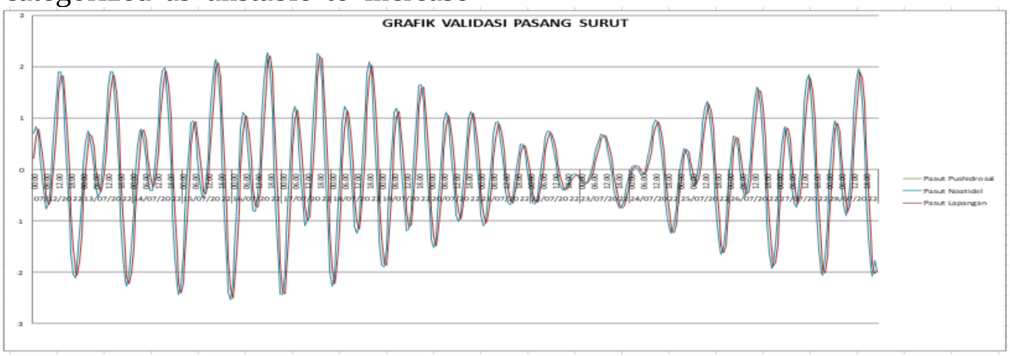


Figure 1. Verification Chart of NAOTide Tidal Value, TNI-AL Pushidrosal Tidal Value 2022, and Field Tidal Value

Based on the graph, it is known that there is a similar pattern between NaoTide tides, Pushidrosal tides, and field tides. In the graph, it is found that the type of tides of NAOTide, Pushidrosal, and Field is double daily tides (semi-diurnal tide) because, in one day, there are two tides and two tides with almost the same average intensity of 12 hours. The waters of the Kampar River have a semi-diurnal tidal type when viewed based on the tidal components generated in the waters of the Kampar River Estuary. In addition, the type of tides in the waters of the Kampar River Estuary is semi-diurnal, with two high tides and two low tides in one day.

Concentration and Distribution of Total Suspended Solid (TSS)

The content of TSS particles in the waters of the Kampar River Estuary ranges from 85 to 2823. The average TSS content at high tide to low tide is 536 mg/L. The overall content of each station from high to low tide can be seen in Table 1.

Table 1. Concentration and Distribution of Total Suspended Solid (TSS)

Total suspended solid (TSS) (mg/L)		
Station	Surface	3 m
1	165	417
2	134	582
3	272	1756
4	301	2823
5	236	376
6	85	105
7	125	102
8	226	639
9	334	1269
10	356	415
Average	231.3	848.40

The TSS content in the waters of the Kampar River Estuary ranges from 85 - 2823 mg/L. At low tide, the suspended solids content is higher at high tide towards low tide on the surface at 356 mg/L at station 10, and the lowest is around 85 mg/L. In comparison, at a depth of 3 m, the suspended solids content is higher at high tide towards low tide at 2823 mg/L located at station 4.

According to Sarjono[2], the location of the estuary, which is influenced by currents and high tides, causes the stirring process of bottom sediments, which also plays a role in increasing the turbidity value of the waters. Turbidity can inhibit the illumination of light into the water, affecting the spread of temperature in these waters.

The process of stirring up the bottom sediments of these waters occurs in shallow waters, in this case, the mouth of the river, so the value of suspended sediment concentration is high. The concentration of suspended sediments at high tide towards low tide is higher due to the more significant dilution of sediments. The water volume at high tide enters the waters more significantly than at low.

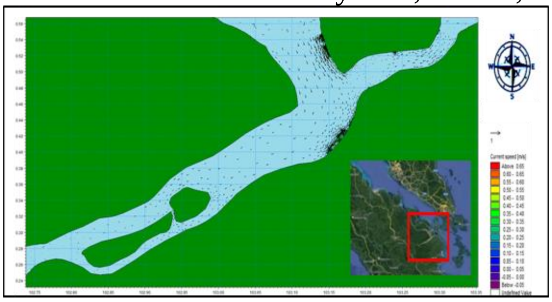
Hydrodynamic Patterns at the Kampar River Estuary at High Tide

Based on the processing results of the MIKE 21 current model simulation, the model simulation was carried out for 15 days during high tide conditions. The results of the current model simulation on July 16, 2022, day 5, presented in Figure 3 (a), show the simulated current velocity in the waters around the Kampar River estuary ranging from 0.25 - 0.45 m/s. The day 10 model simulation results on July 21, 2022, presented in Figure 3 (b), show the current velocity of the waters around the mouth of the Kampar River ranging from 0.30 - 0.35 m/s.

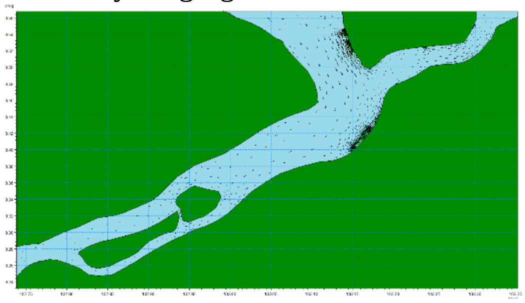
Then, the 15th day of model simulation results on July 26, 2022, presented in Figure 3(c), shows the simulation of current velocity in the waters around the Kampar River estuary ranging from 0.20 - 0.35 m/s, the current moves at high tide. The current comes from the northwest of the Kampar River estuary and the northeast of the Kampar River estuary and heads to the southwest of the Kampar River estuary. That is because the Kampar River estuary is shaped like the letter "V," where the mass of water enters through the mouth of a vast bay and is retained until the tide fills the estuary area.

Hydrodynamic Patterns in the Estuary of the Kampar River at Low Tide

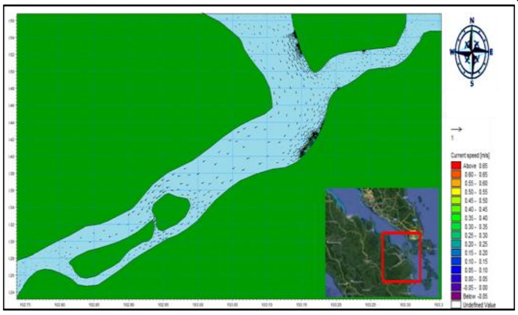
Based on the results of MIKE 21's current model simulation processing, simulations were carried out for 15 days during low tide conditions. The results of the current model simulation on July 16, 2022, day 5, presented in Figure 4 (a), show the simulated current velocity in the waters around the Kampar River estuary ranging from 0.25 - 0.35 m/s. The day 10 model simulation results on July 21, 2022, presented in Figure 4 (b), show the current velocity in the waters around the mouth of the Kampar River ranging from 0.30 - 0.35 m/s. Then, the 15th day of model simulation results on July 26, 2022, presented in Figure 4 (c), shows the simulation of current velocity in the waters around the Kampar River estuary ranging from 0.20 - 0.35 m/s



(a) day 5

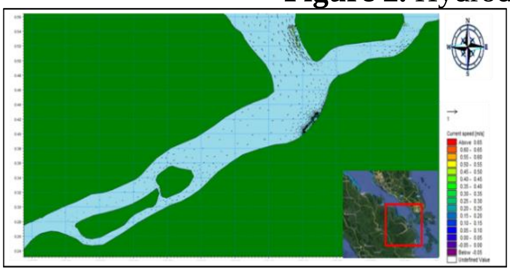


(b) day 10

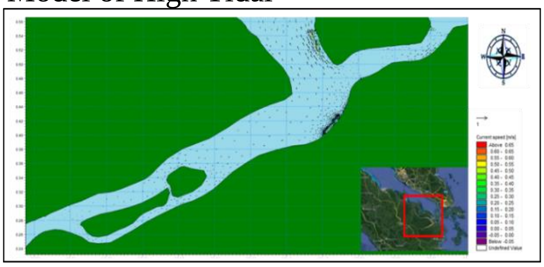


(c) day 15

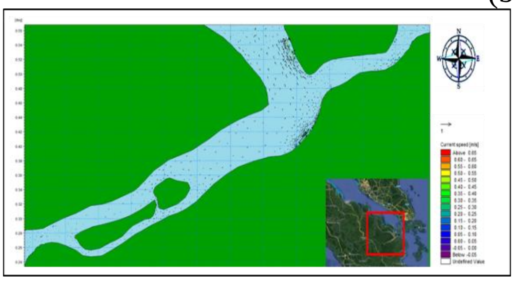
Figure 2. Hydrodynamic Model of High Tidal



(a) Day 5



(b) Day 10



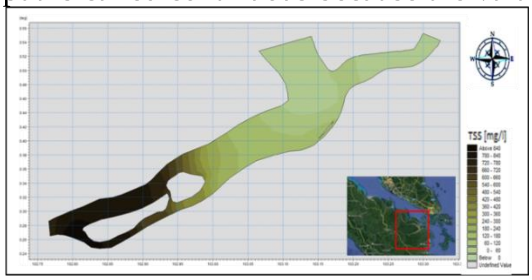
(c) Day 15

Figure 3. Hydrodynamic Model of Tidal Flows

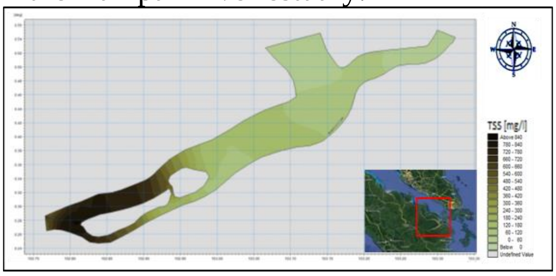
The pattern of current movement around the waters of the Kampar River estuary at low tide can be seen that the current moves from the upstream of the river through the flow of the right and left of Pulau Muda due to the narrowing of the river channel due to the presence of Pulau Muda in the middle of the river channel. Then, it leads towards the mouth of the estuary towards the sea with the same direction of movement, namely moving towards the northwest of the Kampar River estuary and the northeast direction of the northeast Kampar River estuary, which follows the river's flow.

TSS Distribution Pattern at High Tide

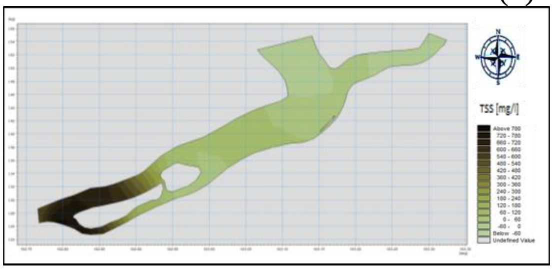
Based on the TSS distribution model simulation processing results in MIKE 21, the model simulation was carried out for 15 days by following constant and continuous values. The river input is called constant because it uses a fixed value, and the river input is called continuous because the value is given continuously without stopping during the model running period (15 days). The model simulation results on day 5 are presented in Figure 4(a). When tidal conditions occurred on July 16, 2022, the TSS concentration in the model area was 180 - 600 mg/L with the dominant direction towards the southwest of the Kampar River estuary. On July 21, 2022, the day 10 model simulation results are presented in Figure 4(b), showing a large TSS concentration ranging from 160 - 600 mg/L with the dominant direction towards the southwest of the Kampar River estuary.



(a)Day 5



(b) Day 10



(c) TSS Distribution Model at High Tide Day 15

Figure 4. TSS Distribution Model at High Tide

The 15th day of model simulation results on July 26, 2022, are presented in Figure 4(c), showing TSS concentrations ranging from 120 - 660 mg/l towards the southwest of the Kampar River. The pattern of TSS distribution tends to follow the pattern of tidal currents that occur because the current is one of the factors stirring sediment in the waters. At the mouth of the Kampar River, the wave speed can be lower than that of the river current coming from upstream. Therefore, the generated tidal currents are large compared to the tidal currents[3]**Error! Reference source not found.**.

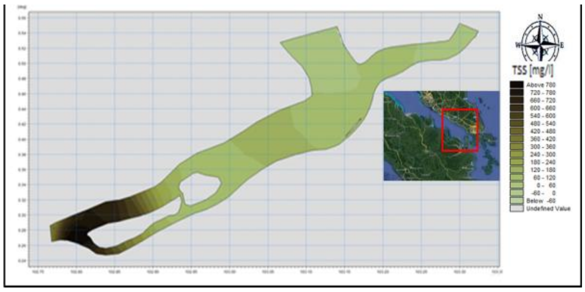
TSS Distribution Pattern at Low Tide

Based on the processing results of the TSS distribution pattern model simulation, MIKE 21 Model simulations were carried out for 15 days. Model simulation results on day 5 are presented in Figure 5(a). On July 16, 2022, low tide conditions showed a TSS concentration of 120- 720 mg/L, with the dominant direction towards the northeast of the Kampar River estuary. According to Rifardi[4], the speed and direction of the current determine the content of suspended sediment distribution in the waters. Currents influence the process of stirring bottom sediments.

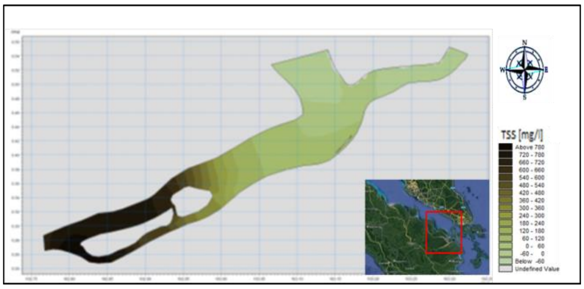
Then, on July 21, 2022, the day 10 model simulation results are presented in Figure 5(b). It shows a large TSS concentration of 240-780 mg/L, with the dominant direction towards the northeast and northwest of the Kampar River estuary.

On day 15, the results of the model simulation on July 26, 2022, are presented in Figure 5(c), showing the TSS concentration ranging from 180 - 660 mg/L, with the dominant direction at the mouth of the Kampar River estuary towards the northwest and northeast. When there is a high or low tide, the suspended sediment content will be affected by its value.

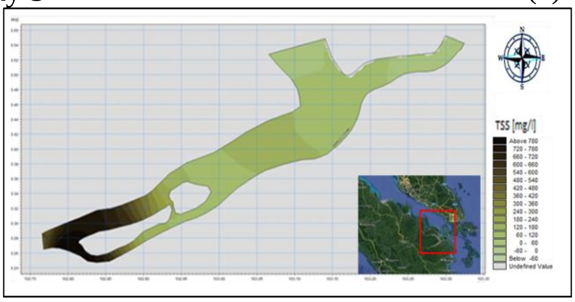
The current that moves towards the land will carry material from the land, then when the waters begin to recede, the current moves away from the land and transports sediment from the land to the sea so that the value of suspended sediment concentrations in the estuary is high The current transports sediment from the bottom to the surface vertically and horizontally, during low tide conditions the concentration of suspended sediment in the estuary spreads towards the sea which is influenced by the ebb current. The distribution of suspended sediments follows the movement of the current. Poerbandono & Djunasjah[5] stated that small sediments tend to be transported as a suspension. In this case, the speed and direction follow the speed and direction of the current.



(a) Day 5



(b) Day 10



(c) Day 15

Figure 5. TSS Scattering Model at Low Tide

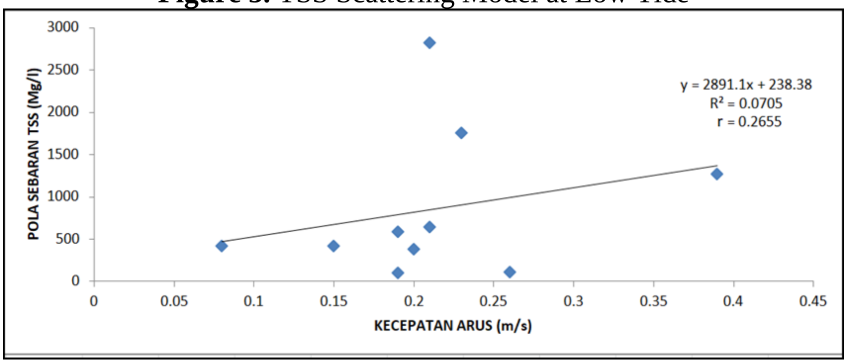


Figure 6. Regression Test Results of Hydrodynamic Patterns on TSS Distribution Patterns

Analysis of Hydro-Pattern Relationship with TSS Distribution in Kampar River Estuary

The high distribution of TSS harms ecosystems in coastal rivers and the sea. One of them is high turbidity in the waters. TSS concentrations that continue to increase will interfere with the penetration of incoming light and cause water productivity. After obtaining the results of the hydrodynamic pattern with the TSS distribution pattern, data processing is carried out using linear regression, and the analysis results can be seen in Figure 6.

From the data processing results of hydrodynamic patterns with TSS distribution patterns, the correlation value (r) between hydro patterns and TSS distribution is 0.2655. According to Safitri[6], this value is included in the low category. Fsig. 0.4584>0.05 significantly influences current velocity and TSS distribution patterns.

Correlation value R^2 or Coefficient of Determination = 0.070. This value can be interpreted as the relationship between the study's two variables (current velocity and TSS distribution) in the low category. The KD value obtained can be interpreted as current velocity contributing to TSS distribution. The regression equation model obtained from the current velocity on TSS distribution at high tide to low tide is Y = 2.89.1x + 238.38.

In the results of the linear regression carried out, it was found that R^2 or determination in the analysis of the relationship between hydrodynamic patterns and TSS distribution patterns had a value of 0.2655 or 26%, which means that the TSS distribution pattern is influenced by hydro patterns by 26%, the rest is influenced by other factors. The cause of turbidity in the waters at the mouth of the Kampar River is caused by nature, such as the bono phenomenon, currents or tides that are too strong, and climatic factors or extreme weather changes can cause a high increase in turbidity in the waters.

Turbidity in the Kampar River estuary can also be caused by human activities such as Bono sand mining in the river; lack of awareness of the surrounding community will result in impacts on the aquatic environment in the Kampar River such as turbidity, changes in hydro-oceanographic patterns, habitat changes. Local residents in the Kampar River estuary are fishermen and provide water transportation services from upstream to the mouth of the Kampar River.

Activities in the Kampar River estuary greatly affect the balance of ecosystems around the waters, as various activities can cause water pollution. All materials from these activities enter the water and settle to the bottom of the water. The impact is caused by the additional supply of materials that are quite detrimental to coastal areas, resulting in increased sedimentation in the Kampar River Estuary.

Based on the above statement, the author is interested in studying the distribution of suspended solids in the Kampar River Estuary. The relationship between hydrodynamic patterns and TSS distribution patterns in the Kampar River estuary is significant. Hydrodynamic patterns are the movement of currents that will affect the processes in coastal and marine waters the distribution of sediments, pollutants, and biotic communities in a body of water.

4. CONCLUSION

Current patterns influence the distribution of sediments in the Kampar River estuary. Total Suspended Solid (TSS) concentration value tends to be higher at high tide towards low tide. TSS distribution patterns tend to follow the same direction as the movement of tidal currents, where at high tide, it tends to lead to the southwest of the Kampar River estuary, while at low tide, it tends to lead to the northeast and northwest. This is because Mendol Island is in front of the Kampar River estuary, which makes the mouth of the Kampar River estuary V-shaped. The value of TSS concentration in the waters of the Kampar River Estuary at high tide to low tide: the lowest value is Station 7 with a range of 102 mg/L, and the highest value is at Stations 3, 4, and 9. At Station 3, there is a value of around 1756 mg/L; at Station 4, there is a value of around 2823 mg/L; and at Station 9, there is a value of around 1269 mg/L. The high concentration of TSS resulted in low brightness in the study area. The average TSS content at high and low tide ranged from 848.4 mg/L.

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