STUDY OF OCEAN CURRENTS AND THEIR EFFECT ON THE DISTRIBUTION OF TOTAL SUSPENDED SEDIMENT IN COASTAL WATERS, SEMARANG

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STUDY OF OCEAN CURRENTS AND THEIR EFFECT ON THE DISTRIBUTION OF TOTAL SUSPENDED SEDIMENT IN COASTAL WATERS, SEMARANG

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ABSTRACT

The problems that exist in Semarang waters are erosion and deposition. This is related to current flow patterns that are closely related to sediment transport patterns. An alternative solution to this problem is to study the sediment transport patterns suspended by the dynamics of the ocean such as ocean waves and ocean currents. The purpose of this study was to determine the pattern of suspended sediment distribution that occurred in the waters of Semarang. In this study, the ocean current and total suspended sediment data were taken when the sea tides and the sea recedes at a depth of 0.2d, 0.6d, 0.8d. Data processing uses a numerical modeling approach. After processing and analyzing the data, an overview of suspended sediment transport patterns that occur in the Semarang Sea is affected by the dynamics of the sea, especially ocean currents.

Key words: Ocean Currents, Ocean Waves, Marine Sediments, Semarang

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1. INTRODUCTION

There are several water canals which lead to Semarang Beach. The shape of the beach in the Semarang waters is an open beach that faces directly with the Java Sea. The Semarang waters are influenced by the existence of marine dynamics such as water quality, sediment, and coastal geometry. In the Semarang waters, there is the river mouth of the Banjir Kanal Timur and the Banjir Kanal Barat. Both rivers cross the western and eastern parts of Semarang, which are densely populated and industrial. Banjir Kanal River has a length of 14.25 km with an average discharge of 295.33 liters/second [7]. Many industrial activities around the watershed, such as textile industry activities, food ingredients industry, plastics industry, carrosserie industry, printing industry, pharmaceutical industry and herbal medicine, paint industry, furniture industry, lubricating oil industry, workshop industry, even there are auction sites fish [7]. So that these waters become a place of disposal or storage of domestic or urban waste and industrial waste generated by activities around the watershed [7].The river mouth is one of the suppliers of suspended sediments that flows from land to sea. According to [11] river mouth is the downstream part of the river that deals with the sea which has a function as the discharge or discharge of river discharge. This condition makes it often encountered many deposits at the mouth of the river so that the appearance of the stream is small, which can interfere with the discharge of river discharge into the sea. The amount of suspended solid material and the influence of oceanographic factors such as currents and tides are potentially in the process of silting at the river mouth.

According to [8] the process of sedimentation in the river mouth is affected by the conditions of waves, currents, and tides. Sediment transport is located at the mouth of the river experiencing a process of load or suspended load. Sediment transport in suspended loads is strongly influenced by the velocity of the current that will transport fine material. Changes in sediment transport with suspended load at river mouths and around the waters. All of them are seen with the level of water turbidity in the Banjir Kanal Barat and Banjir Kanal Timur. The river that has a turbidity level will flow towards the mouth of the river until it reaches the open sea. Seeing these problems, research on the effect of current on suspended sediment loads at river mouths and around Semarang waters by using numerical models using MIKE 21 is needed as information for the community.

2. MATERIALS AND METHODS

This study uses a descriptive method that aims to make an overview of the situation or event that is researched or studied in a limited time and a certain place to get a picture of the situation and conditions locally [4] In this study carried out data collection of currents and suspended solids sediment. Data processing uses a numerical model approach using MIKE 21 software. After going through data processing and analysis, it is expected to provide an overview of suspended sediment transport patterns that occur in the Semarang Sea which is influenced by the dynamics of the waters, especially ocean current.

The sampling method used purposive sampling method because it only takes several key areas that represent the overall state [4] The sampling location in the study area was determined by various considerations. The method of collecting data for the Surface current was conducted by Euler methods using ADCP (Acoustic Doppler Current Profiler), ADCP beams in a technique analogous to that used in stress measurements in radar meteorology [9,12]. The ocean current measured using ADCP to record the current simultaneously and automatically. Hydro oceanographic analysis has also been completed with mathematical modeling analysis methods to determine the characteristics of temporal and temporal physical properties of waters [9].

Sediment sampling in the waters of Semarang, especially at the mouth of the Banjir Kanal Barat and Banjir Kanal Timur, was carried out at 16 sample points scattered in the area near the coast, the river mouth area. Surface sediment sampling is expected to represent sediment conditions in the study area.

2.1. Measurement of Ocean Currents

Current data measurement uses the Eulerian current measurement technique by deploying ADCP (Acoustic Doppler Current Profiler) at the observation location[10]. This instrument emits acoustic waves through the transducer and propagates along the water column [6]. Where data collection is carried out at three depths at each observation location. Current measurement techniques are carried out using a Eulerian approach carried out by observing the current at a certain position in water column so that the data obtained is current data at a certain point in the time function[3]. This method will provide information in the form of direction and current velocity in Semarang at certain depths and positions.

2.2. Collection of Suspended Solids Sediment Samples

Sediments which are carried by the ocean current as a suspension are measured by taking water samples from a measurement column. In this study suspended sediment sampling was carried out using Nansen bottles. The collection of suspended sediments in Semarang waters was carried out at 16 points with a distance of 50 meters perpendicular to the shoreline and near the river mouth of the Banjir Kanal Barat and Banjir Kanal Timur. Suspended sediment removal is primarily intended to determine sediment concentration (or other suspended solid material) which is transported by currents[6].

2.3. Laboratory Analysis of Sediment Suspended Solids

Suspended sediment samples were taken using a Nansen bottle at 16observation. The samples then stored in a sample bottle ± 1 liter. Analysis of suspended sediment samples using the method according to [1] as follows:

- Heat the filter paper (Whatman with a pore size <0.45µm) at a temperature of ± 105°C for 1 hour, cool it in the desiccator then weigh it;
- Shake the sample in the sample bottle until it is homogeneous, take as much as 150 ml of suspended sediment samples, put it into a filter device that has been coated with filter paper, filtered with a suction pump until the water sample runs out and precipitate is formed on filter paper;
- Dry the filter paper in an oven with a temperature of ± 105°C, put it to the desiccator
- Calculate the level of suspended sediment using the formula:

$$C = \frac{a-b}{V} \quad (1)$$

where :

C = concentration of suspended sediment (g/L)

b = the weight of dry filter paper contains sediment (gr)

a = the weight of dry filter paper (gr)

V = volume of water (ml)

2.4. Hydrodynamic Modeling and Suspended Sediment Distribution

Hydrodynamic modeling in this study uses DHI MIKE 21 software module Flexible Mesh Hydrodynamic Flow Model. DHI MIKE is a mathematical solution program which can be used for hydraulic simulations and environmental phenomena in lakes, estuaries, bays, coastal and oceanic regions. In the model simulation used input in bathymetry and tidal data. Bathymetry data uses digitization results from the Indonesian Navy's Bathymetry Dishidros Map. While for input the boundary conditions use tidal forecasting. Hydrodynamic simulations using the Hydrodynamic module simulate variations in water level and current.

In the numerical solution, MIKE 21 uses a two-dimensional unsteady flow which uses the equation of mass and momentum. Here is the equation of the mass conservation equation.

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = \frac{\partial d}{\partial t} \qquad [2]$$

The momentum equation in the x-direction:

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial x} + \frac{gp\sqrt{p^2+q^2}}{C^2.h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx}) + \frac{\partial}{\partial y}(h\tau_{xy})\right] - \Omega_q - fVV_x + \frac{h}{\rho_w}\frac{\partial}{\partial x}(p_a) = 0 (3) \qquad [2]$$

The momentum equation in the y-direction:

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial y}\left(\frac{q^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial y} + \frac{gq\sqrt{p^2+q^2}}{C^2.h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy}) + \frac{\partial}{\partial x}(h\tau_{xy})\right] - \Omega_p - fVV_y + \frac{h}{\rho_w}\frac{\partial}{\partial xy}(p_a) = 0 (4) \qquad [2]$$

where:

$h(x,y,t)$	depth (= ζ,-d,m)
$d(x,y,t)$	Variation in depth to time (m)
$\zeta(x,y,t)$	Surface elevation (m)
$p,q(x,y,t)$	flux densities in x- and y- directions (m^3/s/m) = (uh,vh); (u,v) = depth averaged velocities in x- and y- directions
$C(x,y)$	Chezy resistance ($m^{1/2}$/s)
g	Gravity acceleration (m/s^2)
$f(V)$	Wind friction factor
$V, V_x, V_y(x,y,t)$	Wind speed in the direction of x and y (m/s)
$\Omega(x,y)$	*Coriolis* parameter, latitude dependent (s^{-1})
$p_a(x,y,t)$	*atmospheric pressure* (kg/m/s^2)
ρ_w	Water density (kg/m^3)
x, y	*space coordinates* (m)
t	Time (s)
$\tau_{xx}, \tau_{xy}, \tau_{yy}$	*components of effective shear stress*

Simulation of suspended sediment distribution in Semarang waters with river suspended sediment concentration input was carried out using a numerical modeling approach using the DHI MIKE 21 software transport material Advection-Diffusion material. From the results of numerical modeling using this module, it will be known the pattern of distribution of suspended sediment concentrations affected by the current. The equations used in numerical modeling of the distribution of suspended sediment distribution are as follows:

$$\frac{\partial C}{\partial t}+\frac{\partial uC}{\partial x}+\frac{\partial vC}{\partial y}+\frac{\partial wC}{\partial z}=\left[\frac{\partial}{\partial x}\left(D_h\frac{\partial}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_h\frac{\partial}{\partial y}\right)\right]C-k_pC+C_sS \quad (5)$$

where:

u, v = current velocity in direction-x (east-west) and direction-y (north-south)

C = suspended sediment concentration

D_h = horizontal diffusion coefficient

k_p = linear decay rate

C_s = suspended sediment concentrations at the source [2]

The model simulated sediment distribution in accordance with the scenario that is designed the same as the current model simulation scenarios as described in advance, due to hydrodynamic models and models of sediment run concurrently or so-called model coupled from the two models.2D model equations are solved by numerical methods upstream and sediment exchange coefficient between the sea and air using empirically derived formulation [5].

3. RESULT AND DISCUSSION

3.1. Analysis of Sediment Suspended Solids

The following suspended sediment data in each sampling location are shown in the following table:

Table 1 Suspended sediment concentrations at each station in Semarang Waters in September 2018

Station	Concentration (mg/l)	Station	Concentration (mg/l)	Station	Concentration (mg/l)
ADCP	36	6	13.6	12	9.4
1	14.4	7	19.6	13	15.4
2	18.6	8	25	14	41
3	19.4	9	25	15	20.2
4	16.8	10	7.4	16	27.8
5	23	11	16.6		

The results of measurements of suspended sediments in the field showed that the highest concentration was found at station 14 at 41 mg/l while the lowest concentration was found at station 10 at 7.4 mg/l. The station in the west of the research location has a relatively higher concentration than the station in the east.

The closer to the shoreline, the sediment grain size will be even greater. The distribution of bottom sediment in the Morodemak Village was mainly influenced by the ocean dynamics and sediment input from rivers can be ignored because in areas along the coastline there is no difference in the type of sediment between near and far from the river mouth[13].

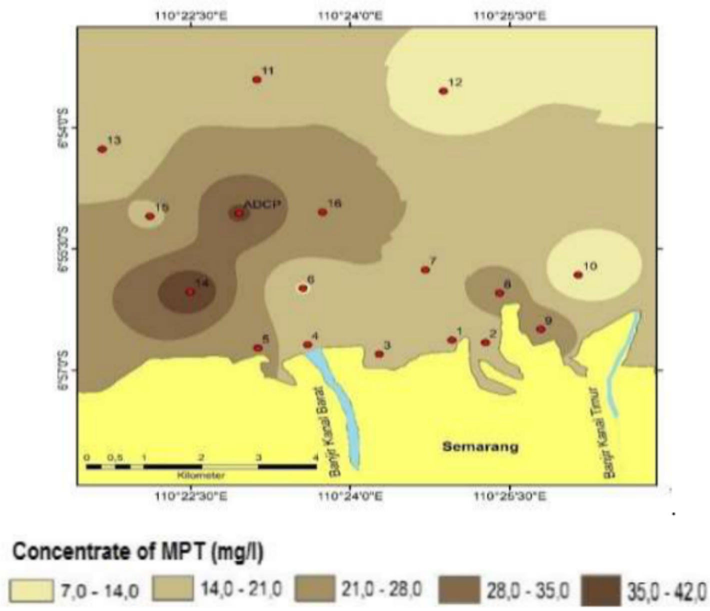

Figure 1 The pattern of suspended sediment distribution in September 2018 in the waters of Semarang

3.2. Ocean Current Data Analysis

Ocean currents in Semarang waters have speeds that vary with depth. Measurements were made on 5 ADCP cells, resulting in the highest maximum current velocity value in cell 4 which was 0.12 m / s. The lowest current velocity is known in cells 1, 2, 3 and 4 with a speed of 0 m / s. The highest average current velocity in cells 3, 4, and 5 with a value of 0.04 m / s while the lowest average current velocity in cell 1 is 0.03 m / s.

Table 2. The velocity of ocean currents at each depth in the waters of Semarang September 2018

	Cell 1 (m/s)	Cell 2 (m/s)	Cell 3 (m/s)	Cell 4 (m/s)	Cell 5 (m/s)
Average	0.03	0.039	0.04	0.04	0.04
Max	0.08	0.099	0.1	0.12	0.107
Min	0	0	0	0	0.001

The results of field data processing produce a form of scatter plot processing and plot sticks from the form of the analysis illustrating the dominant current direction from various depths. In general, the measurements in the 5 depths of the dominant direction of the current in the waters of Semarang are northeast-southwest.

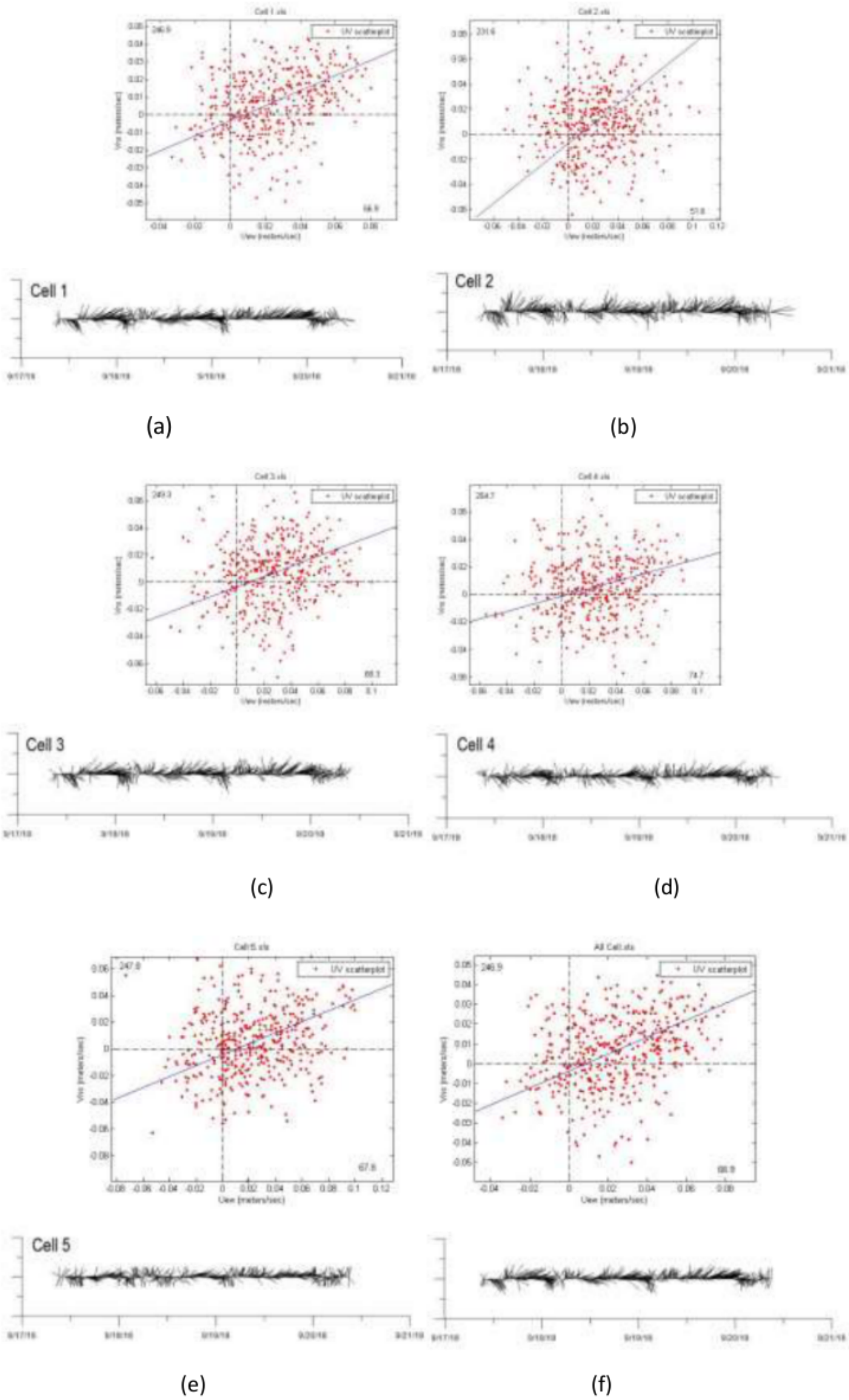

Figure 2. Vector and scatter plot at a) Cell 1; b) Cell 2; c) Cell 3; d) Cell 4; e) Cell 5 and f) average depth

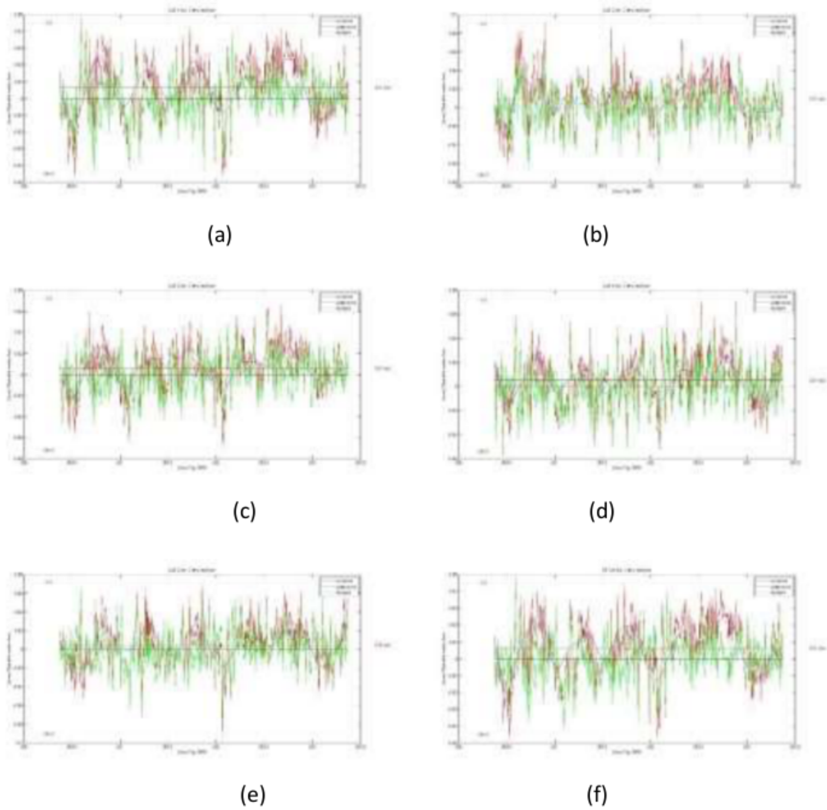

Figure 3 Tidal current and non-tidal current at depth: a) Cell 1; b) Cell 2; c) Cell 3; d) Cell 4; e) Cell 5 and f) average depth

The results of field data processing produce a form of processing scatter plots and stick plots from the form of analysis that describes the dominant current direction from various depths. In general, the measurements in the 5 depths of the dominant direction of the current in the waters of Semarang are northeast-southwest. This can generally be seen in Figure 2. Although the current appears to move northeast-southwest, it appears that the tidal currents are not too dominant. In Figure 3, shows the residual current in Semarang waters is also large relative. This shows that the currents in the Semarang waters are still influenced by non-tidal factors, such as wind.

3.3. Modeling of ocean currents and suspended sediments

The results of ocean current modeling and suspended sediment distribution are shown in Figure 4 and Figure 5 below.

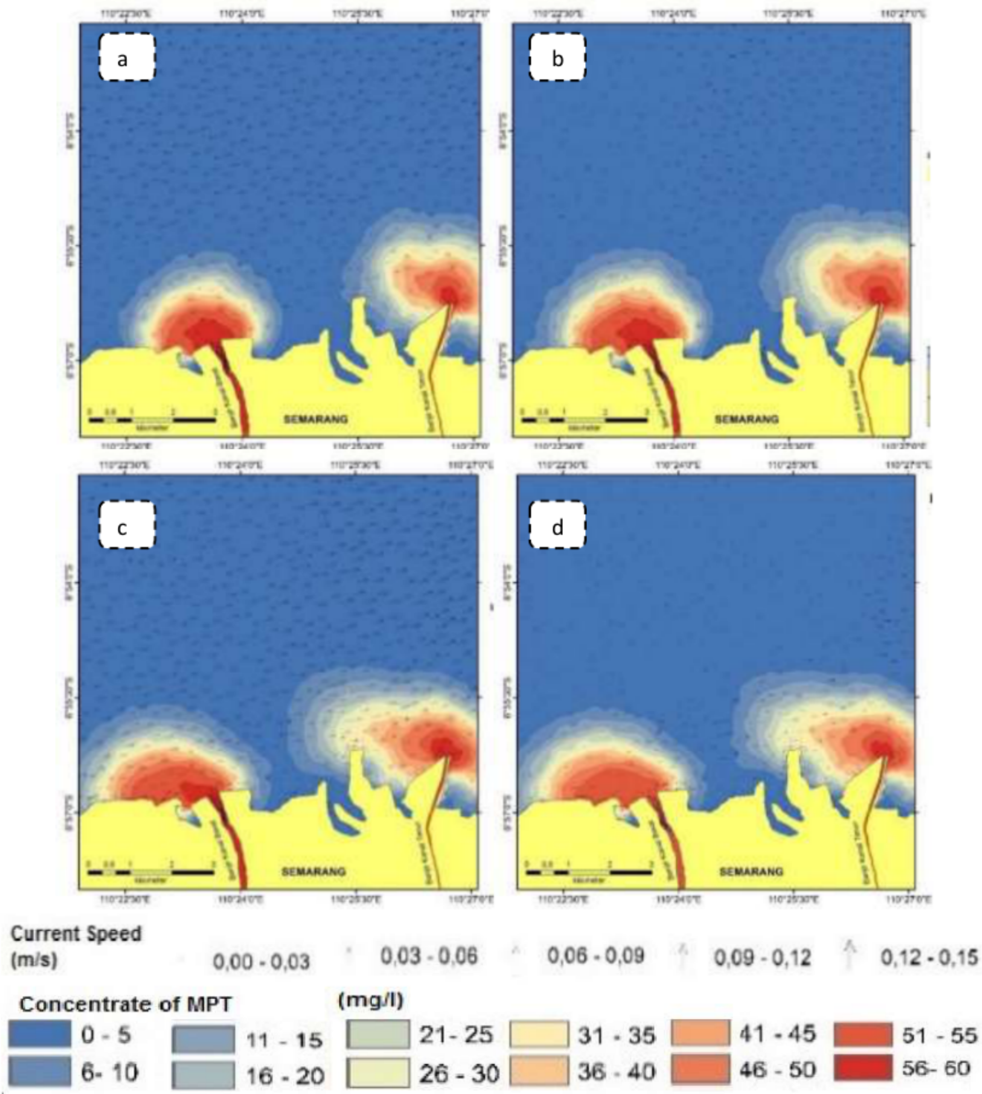

Figure 4. The pattern of the current movement and the distribution of suspended sediments (a) ebb towards flood (*neap tide*), (b) highest flood (*neap tide),* (c) in flood towards ebb(*neap tide*), (d) in lowest ebb (*neap tide*)

At neap tide, ocean currents when ebb towards flood condition has velocity ranging from 0.01 to 0.12 m / s with the direction of the current moving towards the west. When conditions are highest flooded the velocity of ocean currents ranges from 0.01 to 0.08 m / s with the direction of current moving westward. The pattern of ocean currents at the lowest ebb has speeds ranging from 0.01 to 0.07 m / s with the direction of the current moving to the east. When flood towards ebb conditions the current velocity ranges from 0.01 to 0.12 m / s with the direction of the current moving to the east.

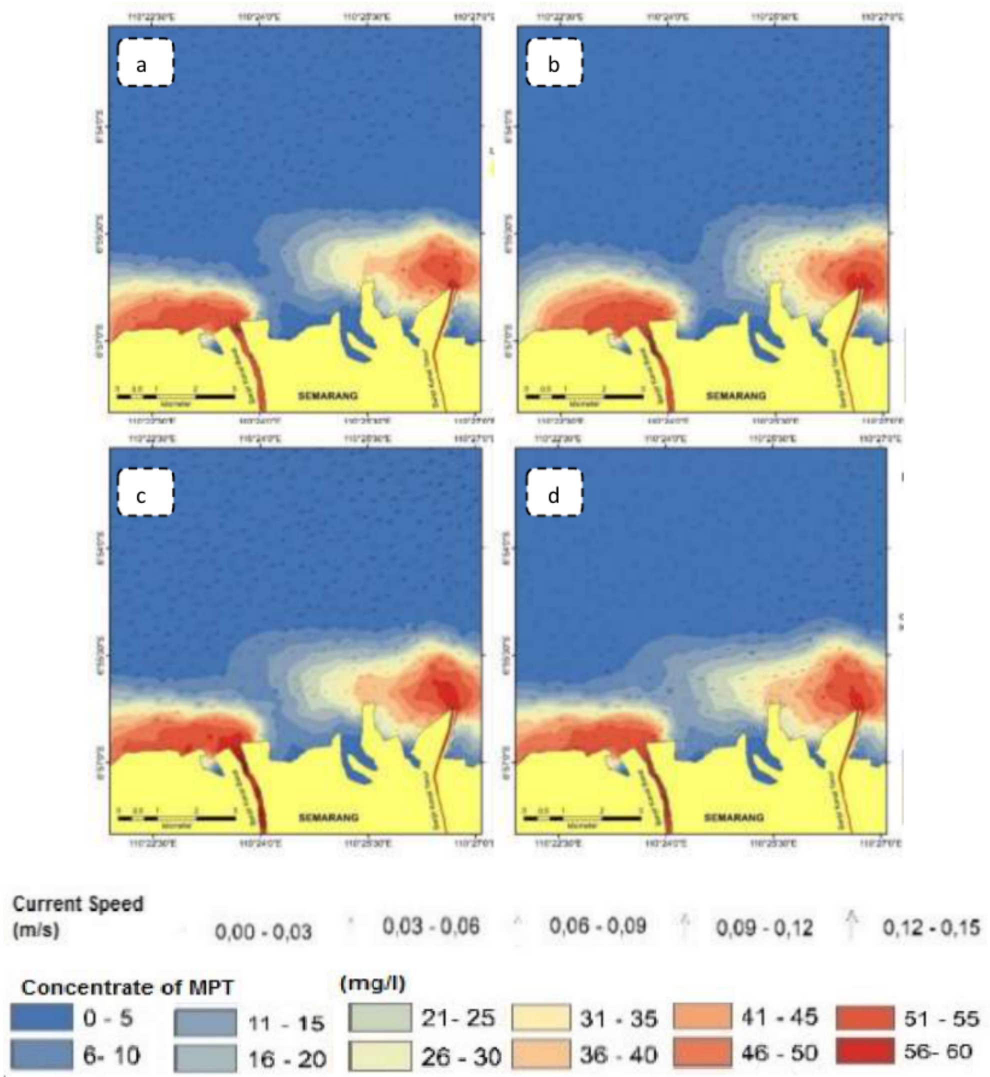

Figure 5. The pattern of the current movement and the distribution of suspended sediments (a) in ebb towards flood (*spring tide*), (b) in the highest flood (*spring tide*), (c) in flood towards ebb (*spring tide*), (d) in lowest ebb (*spring tide*)

In the spring tide condition, the current when the ebb towards flood has a velocity ranging from 0.01 to 0.14 m/s with the direction of the current moving to the west. When the highest flood condition the current velocity ranges from 0.01 to 0.07 m/s with the direction of the current moving westward. Current patterns at lowest ebb have velocities ranging from 0.01 to 0.08 m/s with the direction of current moving eastward. When the tide conditions to recede the velocity current ranges from 0.01 to 0.15 m/s with the direction of the current moving eastward. In neap tide conditions can be seen in Figure 4 to Figure 7 current velocity is relatively smaller than at the time of spring tide, which is shown in Figure 8 to Figure 11. The strength of the smaller velocity current at neap tide than when the spring tide is due to spring conditions tide, the position of the Earth-Moon-Sun is in a straight line so that the gravitational force of the Earth-Moon-Sun becomes stronger. This is what causes the tidal elevation gradient to become larger so that the tidal current velocity becomes larger than when it is tidal.

The model simulation results of suspended sediment distribution placed the initial concentration of suspended sediments at the Banjir Kanal Barat estuary at 61 mg / l and Banjir Kanal Timur at 56 mg/l. When the tide conditions at low tide move westward. However, when conditions begin to recede the movement of suspended sediment turns towards the east. Throughout the simulation, suspended sediments moved more dominantly along the coastline in Semarang. Until the end of the simulation, the concentration of suspended sediments in most of the waters near the Semarang coast ranged between 21 - 60 mg/l. In general, based on numerical modeling simulations the distribution of suspended sediment using MIKE21 modeling shows that the dispersion of suspended sediments is affected by the current. Suspended sediments are spread due to the advection process, although there is a diffusion process which is the spread of suspended sediment concentration due to the concentration gradient of the suspended sediments. Deployment of suspended sediments follows the tidal current pattern, which is affected by tidal conditions. In neap tide conditions, when the current speed is not too strong, it can be seen that suspended sediments do not spread too much to the waters of Semarang.

Suspended sediments are more concentrated around the mouth of the Banjir Kanal Barat and Banjir Kanal Timur River. This can be seen in Figure 4 to Figure 7. While in the Spring Tide condition, which is when the current velocity is relatively high, can be seen in Figure 8 to Figure 11, it can be seen that the concentration of suspended sediments spreads more to the waters of Semarang, this is because the current with a relatively greater speed will transport the suspended sediment more strongly. So this causes the concentration of suspended sediment to spread more to the waters.

4. CONCLUSION

In Semarang waters, the current velocity at Neap Tide conditions is relatively smaller than at the time of spring tide. At low tide conditions, the current at low tide to the tide has a speed ranging from 0.01 to 0.12 m/s with the direction of the current moving westward. During high tide conditions, the current velocity ranges from 0.01 to 0.12 m/s with the direction of the current moving towards the east. At the spring tide condition, the current at low tide to the tide has a speed ranging from 0.01 to 0.14 m/s with the direction of the current moving to the west. The current pattern at high tide to low tide has a speed ranging from 0.01 to 0.15 m/s with the direction of the current moving to the east.

Based on numerical modeling simulation the distribution of suspended sediment concentrations using MIKE21 modeling shows that the dispersion of suspended sediments is affected by the current. Suspended sediment distribution follows the tidal current pattern, which is influenced by tidal conditions. In neap tide conditions, when the current speed is not too strong, it can be seen that suspended sediments do not spread too much to the waters of Semarang. Suspended sediments are more concentrated around the mouth of the West Flood Canal River and East Banjir Kanal River. In the Spring Tide condition, that is, when the current velocity is relatively high, it can be seen that the concentration of suspended sediments spreads more to the waters of Semarang.

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