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SEA SAND MINING ZONATION THROUGH THE INTEGRATION OF OCEAN DYNAMIC AND GIS IN RIAU ISLAND WATERS

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Abstract

Sea-sand mining has both advantages and disadvantages particularly in its destructive capabilities. The damages caused by sea-sand mining are mostly due to the unorganized mining zones. In order to minimize the negative effects of mining activities, the well-organized mining zones that have evaluated all related aspects are required. There are several aspects which are closely related to the sea-sand mining zones, one of those is hydro-oceanography aspect in its relation with the sea environments. A comprehensive analysis can be made by integrating hydro-oceanography and GIS as a system of both data-organizer and software. This method is supported by using the remote sensing technology as a verification data comparison to the results of hydro-oceanography analyses.

The application of image analysis as a verification tool is a good method to proof the results given by the numerical simulation model. In this study, we use the Landsat images as the data verification. The results of the integrated system between the hydro-oceanography and the GIS analysis have indicated that the mining can be continuously conducted in several locations without imposing any hazardous impacts to the adjacent environment. By considering the results above, the integrated system between the numerical model and the GIS is highly effective as a foundation to determine the mining zone where the negative effects of the oceanographic-dynamical-changes on the environment due to the mining activities can be easily recognized and predicted.

Keyword: Geographic Information System, Hydro-oceanography, Image Analysis

I. Introduction

Sea-sand is one of the main commodities for the incomes of Indonesian development. The sea-sand mining was actively made in the adjacent of Riau island territories due to the extensive demands from Singapore related to its reclamation project. Inevitably, the demands bolstered the legal and illegal activities of sea-sand mining up to point where they were out of control and eventually causing many problems.

One of the problems as the consequence of the extensive sea sand mining viewed from the oceanography perspectives is the alteration of the hydro-oceanography patterns (Rifera, 1997). According to the previous study, it implies that the sea-sand mining could harm the coastal ecosystem because of the degradation of the sea water quality following the increasing of turbidity (Hasugian, 2003).

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management equipped with a comprehensive analysis could be obtained by the application of Geographic information system (GIS) as a system of organizing data and software with the ultimate purpose to determine and locate the best mining zones.

II. Methodology

The methodology applied in this study is the combination between Oceanography and *Geographic information science* as depicted in Figure 1.

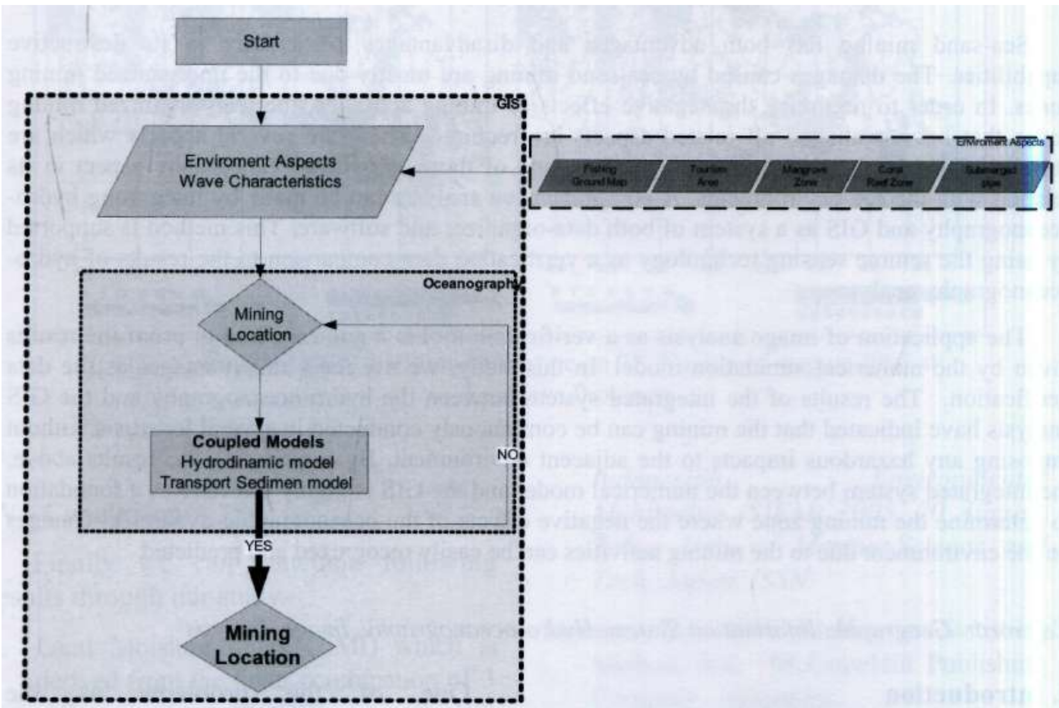

Fig. 1. General Workflow

a. Hydro-oceanography

The sea-sand mining exploited in the surrounding of Riau waters (Figure 2.) exerts a huge impact on the oceanographie process in the adjacent of that location. In order to minimize the environmental catastrophes due to the sand mining, the study of ocean dynamics where the activities take place is inevitable. The study includes with the analysis of current-sediment transport and also the investigation of wave characteristics. The purpose of this study is to evaluate the impact of sea-sand mining to the spreading of turbidity (suspended sediment), associated with the flow regime in the study area. The result of this study is a map of suspended sediment dispersal. One way of knowing the flow pattern will be made by numerical model.

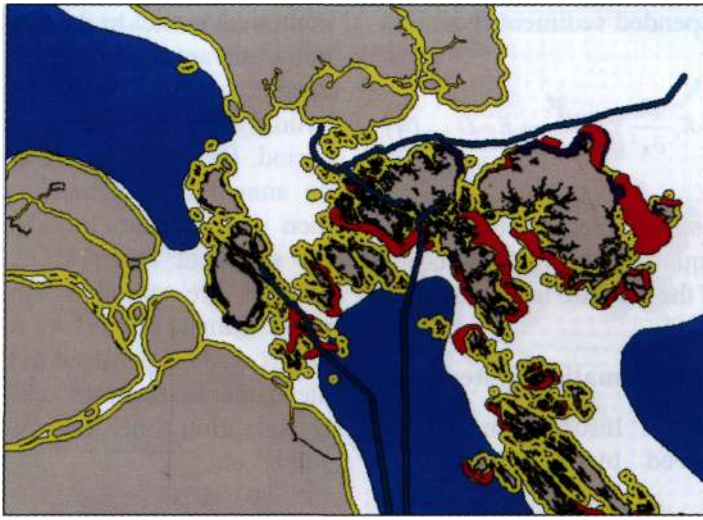

Fig. 2. Area of Research

The interaction between the pattern of flow circulation and the sediment transport occurring naturally or due to the sea-sand mining could be estimated and determined by the mathematical model. The governing equations used in the depth averaged model consist of the continuity equation (equation 1) and the 2D horizontal momentum equation (equation 2 and 3). The solution for these equations is in the explicit finite difference.

- Continuity equation:

$$\frac{\partial \xi}{\partial t} + \frac{\partial uH}{\partial x} + \frac{\partial vH}{\partial y} = 0 \qquad (1)$$

- Momentum equation in x and y direction:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} - fv = -g\frac{\partial \xi}{\partial x} + \frac{\tau_{sx} - \tau_{bx}}{\rho H} + A_h\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) \qquad (2)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + fu = -g\frac{\partial \xi}{\partial x} + \frac{\tau_{sy} - \tau_{by}}{\rho H} + A_h\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) \qquad (3)$$

where

x,y : coordinate represents north-south *(y)* direction and east-west *(x)* direction

u,v : current velocity in x dan y direction respectively (m/s)

t : time (s)

ξ : sea surface elevation with respect to certain reference (m)

g : gravitational acceleration (m/det^2)

H : total depth = $d + g$ (m)

D : constant sea depth (m)

τ : bottom friction coefficient

A : horizontal diffusion coefficient (m^2/det)

τ_{sx}, τ_{sy} : surface stress in x dan v (N/m^2)

τ_{bx} τ_{by} : bottom stress in x *dmy* (N/m^2)

The next procedure after simulating the flow pattern based on the hydrodynamics model is to compute the movement of suspended sediment in light of sea-sand mining applying sediment transport model which is leading to the information of the eroded and the deposit area, and also the information of the dispersal of suspended sediment (equation 4).

$$\frac{\partial c}{\partial t}+u\frac{\partial c}{\partial x}+v\frac{\partial c}{\partial y}=K_x\frac{\partial^2 c}{\partial x^2}+K_y\frac{\partial^2 c}{\partial y^2}+E-D \quad (4)$$

We use the stream method for solution applying this equation and the results are then verified by the satellite images.

b. Geographic Information System

The Geographic Information System (GIS) is achieved by integrating the numerical model to the system. One of the main advantages of the system is the database of flow pattern, resulted from the hydrodynamics model up to one year period. By assuming, no extreme changes on annual flow patterns, the database is then used in spatial analysis as the input for sediment transport model. The flow patterns are stored as spatial data witk raster format. The enitity relationship used in this study is depicted in Figure 3., where the database includes with flow patterns, conservation zones, bathymetric, etc.

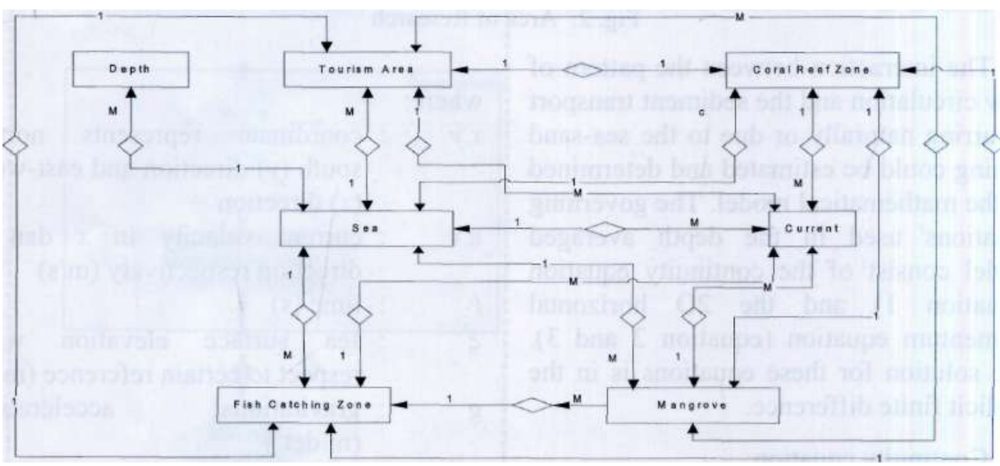

Fig. 3. Entity-relathionship diagram

III. Results and Analysis

By using the hydrodynamic numerical model analysis, we find that the interchanging direction of current due to the influence of tidal current and the wind driven current are not taking important role for determining the magnitude and the pattern of current in the Riau island waters.

From the pattern of sea current, we can recognize the pattern during spring and neap tides which are similar except for its magnitude, and when the North-West monsoon prevails, the magnitude of eastward current increases. The simulation results during the South-East monsoon reveals the aligned current direction with the direction of the wind resulting in the stronger northward current (Fig. 3 and 4).

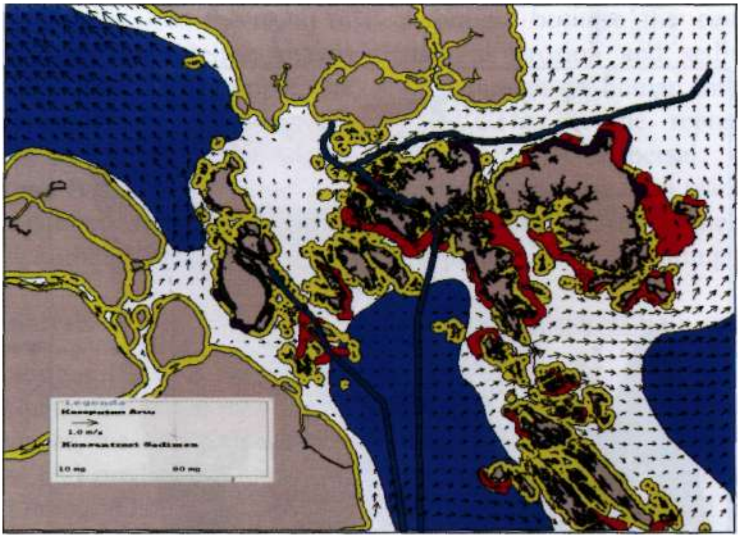

Fig. 3. Current pattern on high to low water during spring tide (West Monsun)

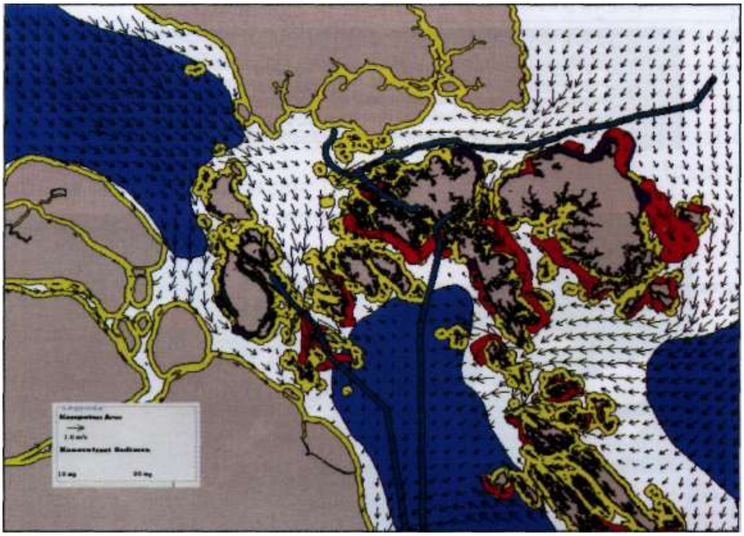

Fig. 4. Current pattern on low to high water during spring tide (West Monsun)

a. Model Verification by Using Satellite Images

<u>Verification of turbidity level in the Riau Island Waters</u>

The verification of suspended sediment concentration is done qualitatively by comparing the dispersal pattern given by the numerical model simulation and satellite data. The satellite data are images from LANDSAT satellite which can covers the area 0° 30' - 2°N; 103° 30' - 105° E in 2 April 2002. The simulation result on April (Figure 5) during the lowest spring tide is used for verification purpose.

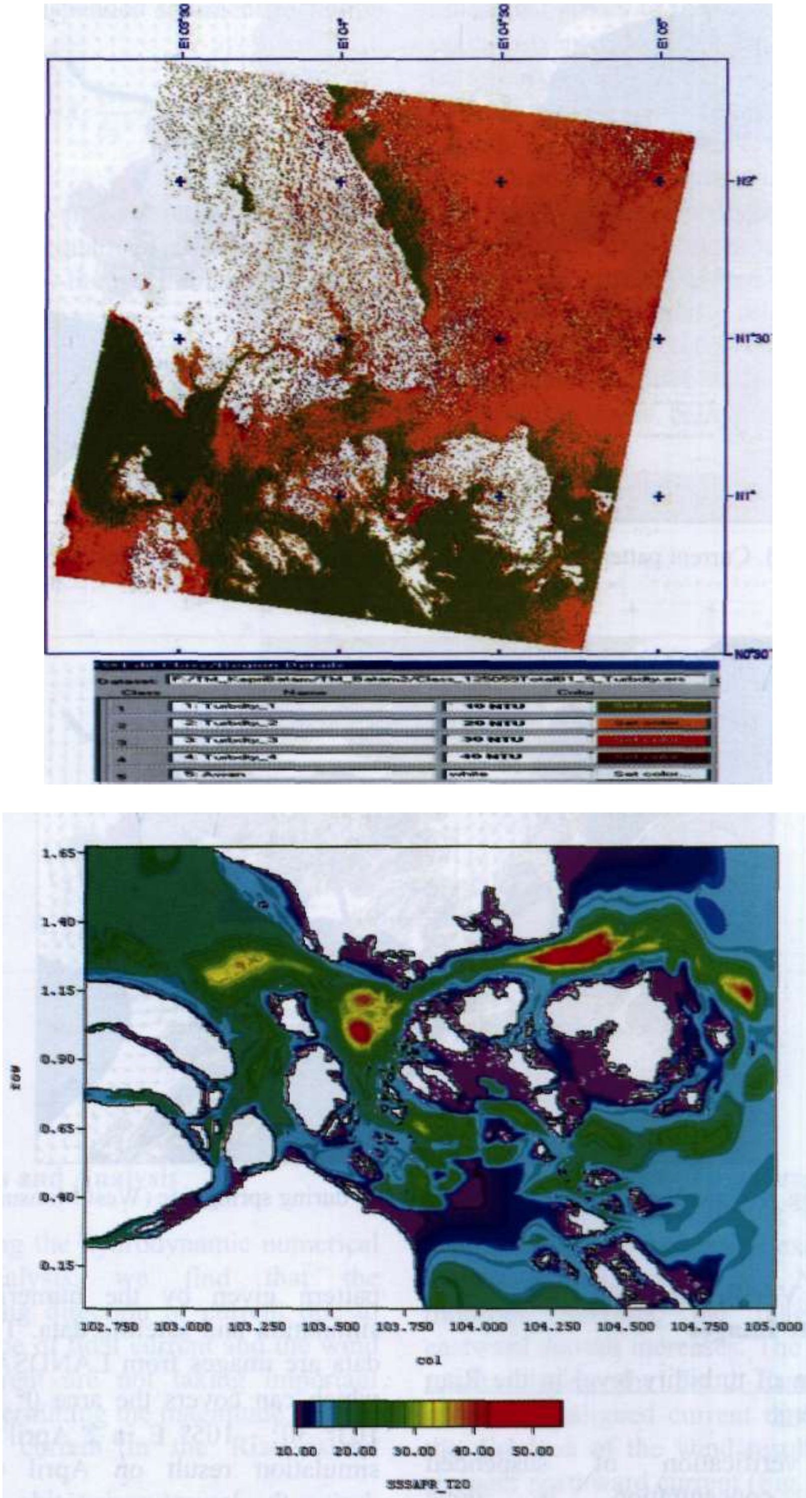

Fig. 5. Comparison Between landsat image and The Result of Sediment transport Model Date 2-April-2002 (PPK-ITB, 2003)

The comparison between the result of numerical model and the satellite images shows good similiarity. For example, the LANDSAT satellite data indicating the turbidity in the southern part of Bintan island, Batam and Bulan is lower than that in the northern part which agrees well with the result of the numerical model.

b. Spatial Analysis

By integrating GIS with the hydro-oceanography numerical model verified by the satellite images, we obtain the system is able to view and predict the impact of the sea-sand mining. Three scenarios are applied to evaluate the performance of the GIS integrated with the numerical model as follows.

1. Natural state
2. One mining zone
3. Several mining zones

<u>Sediment dispersal with Natural state</u>

This scenario is done to investigate the state of nature without the mining activities, because the coastal processes such as erosion and sedimentation still exist though no human intervention takes place. This is the representative case because the dispersal of suspended sediment concentration (sand) in the water column is influenced by the magnitude and the pattern of the prevailing flows.

<u>Sediment dispersal with one mining zone (Figure 6)</u>

The selection of this zone is because the zone is located in the safe zone for mining referring to the result of the overlaying environmental data with the flow speed which is relatively small for each condition. The pattern of sediment dispersal with some mining zone shows that the effect of the sea-sand mining does not impose hazardous impact environmentally to the waters surrounding the mining zone. This is affirmed by the low sediment concentration and weak spreading without breaching the non mining zones.

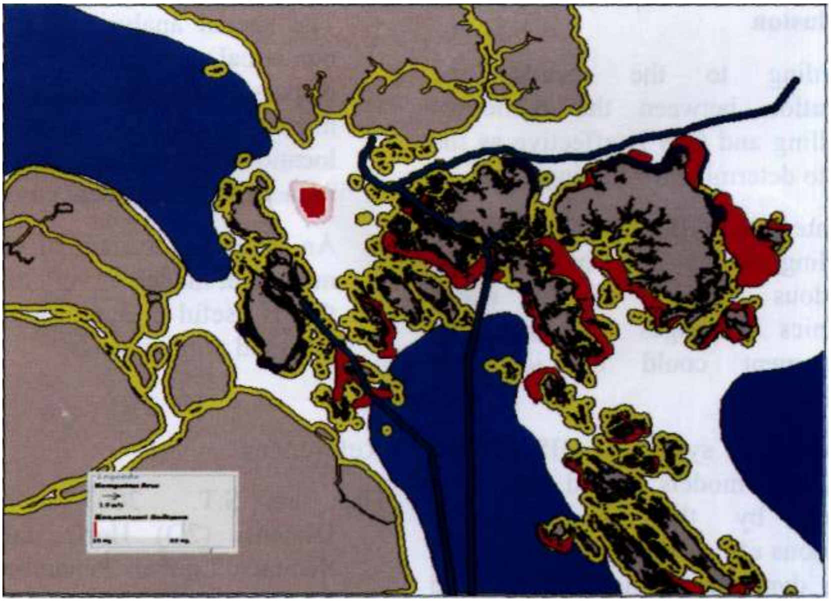

Fig. 6. The sediment dispersal with 1 mining location

Sediment dispersal with several mining zones (Figure 7)

The selection of this location is merely based on the free mining zones. This scenario is executed by the reason that the actual mining activities are made at the same time in several locations. It is clear that the spreading of sediment enters the non mining zone and the sediment concentration is far higher than the concentration in its natural state. Therefore, the forbidden zone for mining could be determined by this spatial analysis.

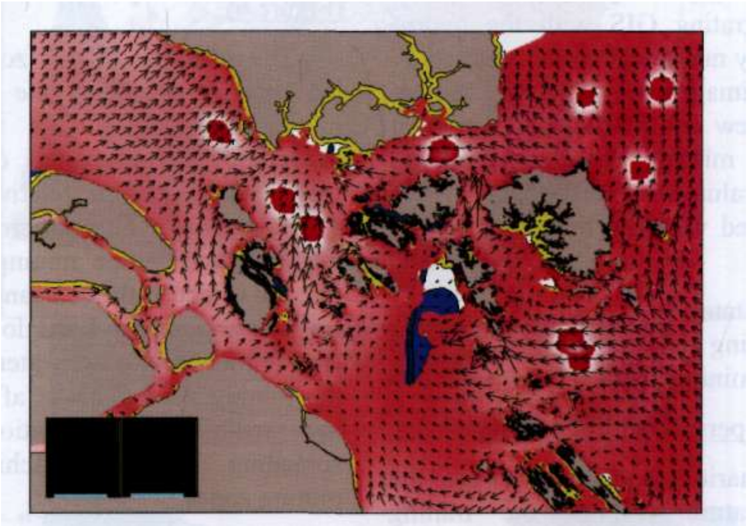

Fig. 7 The sediment dispersal with several mining locations after 8 month exploration

IV. Conclusion

- According to the results, the integration between the numerical modelling and GIS is effective as the basis to determine the mining zones.
- The integrated GIS with the numerical modeling which also indicates the hazardous impacts of the ocean dynamics changes toward the environment could be identified clearly.
- An integrated system of GIS and the numerical models could be well defined by the environmentally hazardous effects due to the alternated ocean dynamics in light of sea-sand mining.
- The spatial analysis as the result of numerical modeling in sediment dispersal reveal the suggestion that the mining could be made in several location without exerting hazardous impacts to the adjacent environments.
- An integrated system of GIS and the numerical models is very effective tool that is useful in a decision making of sea-sand mining zones.

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