

STUDY OF TOTAL SUSPENDED MATTER TRANSPORTATION AND CIRCULATION IN JAKARTA BAY USING NUMERICAL SIMULATION AND SATELLITE DATA

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ABSTRACT

Jakarta Bay lies in the north of Jakarta and receives freshwater run off from thirteen rivers that run through the Jakarta metropolitan area, a conurbation that is home to some 20 millions people.

Total discharges of organic water pollution have experienced a rapid increase from 214 tones per day in 1980 to over 537 tones per day in 1993. This is resulted to the high nutrient levels and eutrophication of coastal waters. Input pollutant in Jakarta Bay change the natural environment condition. Eutrophication has severe local impacts in the Jakarta Bay (GEF, 2008).

Study of TSM in Jakarta Bay was conducted during September 2008 to June 2009. The aims of this research were to investigate the transportations of TSM in Jakarta Bay MODIS satellite data was used and the current pattern circulation in Jakarta Bay.

Methods applied were MODIS satellite data analyses from 2003 to 2005 and numerical model 2-dimensional, for the in-situ data of total suspended matter secondary data from LIPI in September 2004 was applied. To validate the result regression method was used.

Validation research results using MODIS satellite analysis showed the regression coefficient is $R=0.72$. Vector of current in Jakarta Bay in September 2004 experienced of the change direction and speed at each condition during spring condition at flood tide 1.23 m/s, highest tide 0.77 m/s, ebb tide 0.83 m/s, and lowest tide 1.31 m/s and during neap condition at flood tide 0.71 m/s, highest tide 0.69 m/s, ebb tide 0.90 m/s, and lowest tide 0.34 m/s. Transportation of TSM in Jakarta Bay are dynamic, in dry season transportation of TSM higher than rain season.

Key words: Remote sensing, Total Suspended Matter, Jakarta Bay

ABSTRAK

Teluk Jakarta terletak di sebelah utara kota Jakarta dan merupakan muara dari tiga belas sungai yang mengalir melewati kota Jakarta, yang memiliki jumlah penduduk sekitar 20 juta jiwa.

Jumlah pencemar bahan organik mengalami peningkatan yang sangat cepat dari 214 ton perhari (1980) menjadi 537 ton perhari (1993). Hal ini menyebabkan meningkatnya kandungan hara dan eutropikasi sehingga mengubah kondisi alami yang berdampak buruk bagi lingkungan Teluk Jakarta.

Studi mengenai total padatan terlarut di Teluk Jakarta dilaksanakan dari bulan September 2008 sampai bulan Juni 2009. Studi ini bertujuan untuk mengetahui transportasi dari total padatan terlarut di Teluk Jakarta dan untuk mengetahui pola arus di teluk Jakarta.

Metode yang digunakan berupa analisis data satelit MODIS tahun 2003 sampai 2005 dan model numerik 2-dimensi, sedangkan untuk data in-situ dari total padatan terlarut menggunakan data sekunder bulan September 2004 (LIPI) dan untuk validasi digunakan metode regresi.

Validasi yang telah dilakukan dengan menggunakan data satelit MODIS diperoleh nilai koefisien regresi $R=0,72$. Arah dan kecepatan arus di Jakarta Teluk pada bulan September 2004 selalu berubah-ubah pada tiap kondisi dan kecepatan pada masing-masing kondisi selama bulan penuh yaitu saat pasang naik 1.23 m/s, pasang paling tinggi 0.77 m/s, pasang menuju surut 0.83 m/s, dan pasang terendah 1.31 m/s dan pada saat bulan mati saat pasang naik 0.71 m/s, pasang paling tinggi 0.69 m/s, pasang menuju surut 0.90 m/s, dan pasang paling rendah 0.34 m/s. Transportasi TSM di Teluk Jakarta selalu berubah, dimana konsentrasi TSM lebih tinggi pada musim kemarau dibandingkan musim hujan.

Kata Kunci: Penginderaan jauh, Total Padatan Terlarut, Teluk Jakarta

INTRODUCTION

Background

Jakarta Bay lies in the north of Jakarta and receives freshwater run off from the thirteen rivers that run through the Jakarta Metropolitan Area, a conurbation that is home to some 20 million people. With the expansion of the Jakarta Metropolitan Area during the second half of the 20th century, the environment of Jakarta Bay has been significantly affected by a range of human activities (Arifin, 2004).

Urban expansion and industrialization in Jakarta Bay have resulted in water pollution from industry, sewage, and contaminated air. Municipal and industrial wastewater is discharged virtually untreated into the waterways causing rapid deterioration of water quality, particularly in the large urban centers. Total discharges of organic water pollution have experienced a rapid increase from 214 tones per day in 1980 to over 537 tones per day in 1993. This is resulted to the high nutrient levels and eutrophication of coastal waters extending over a considerable distance as far as the Java Sea.

Input pollutant in Jakarta Bay change the natural environment condition. Eutrophication has severe local impacts in the Jakarta Bay, where massive blooms of phytoplankton several meters thick are present for several kilometers offshore. Overall, solid waste poses a severe problem, particularly around cities where waste management is unable to keep pace with production. Massive amounts of plastic bags and other waste products flow into Jakarta Bay (GEF, 2008).

The largest proportion of solid wastes released, which is predominantly organic carbon and nitrogen, settles to the seabed in the immediate vicinity of the farm. Organic enrichment of the benthic ecosystem may result in increased oxygen consumption by the sediment and formation of anoxic sediments, with, in extreme cases, out gassing of carbon dioxide, methane and hydrogen sulphide, enhanced demineralization of organic nitrogen and reduction in macro fauna biomass, abundance and species composition. There is evidence of very localized effects of reduced concentrations of dissolved oxygen in bottom and surface waters close to farm sites which are due to the considerable biochemical oxygen demand of released organic wastes and the respiratory demands of the cultured stock.

Change of natural condition in Jakarta bay can make degradation of wetland habitats. Coastal wetlands such as mangrove swamps are amongst the most productive ecosystems sustaining the ecological integrity and productivity of adjacent coastal waters, and are important breeding and nursery grounds for many commercially exploited fish and shellfish species (FAO, 2008). Based on

this description, the writer is interested to do this research with the image satellite data and model of numeric simulation.

RESEARCH METHODS

Research Scheme

This research applies *in-situ* data and satellite image. Satellite images are obtained from MODIS NASA during 2003 to 2005 and *in-situ* data of TSM was used secondary data from LIPI in September 2004. The scheme of research is shown in Figure 1.

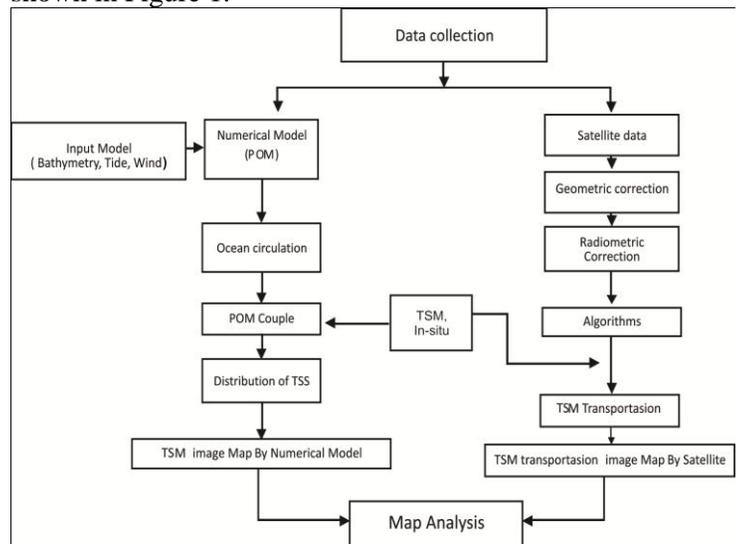


Figure 1. Research scheme

Research Location

This research was conducted in Jakarta Bay, located in the west part of Java Island (106° 20' and 107° 03' east longitude, and from 5° 10' to 6° 10' south latitude E) 5298.03 Km². Location of Jakarta Bay is shown in Figure 2.

Data Analysis

Calculation TSM from Satellite Data

Research TSM in Jakarta Bay used data satellite which was verificated with the secondary in situ data on 18 points of samples data. As for calculation phase of image data processing was taken as follows:

- a. Bowtie correction.
- b. Image rectification.
- c. Band Combination.
- d. Contrast enhancement.

After passing the step hereinafter image data serve the purpose of elementary map and substance analyze to continue (Zhou *et al.*, 2005). For image MODIS-Aqua used algorithm from Tassan,1994 that is :

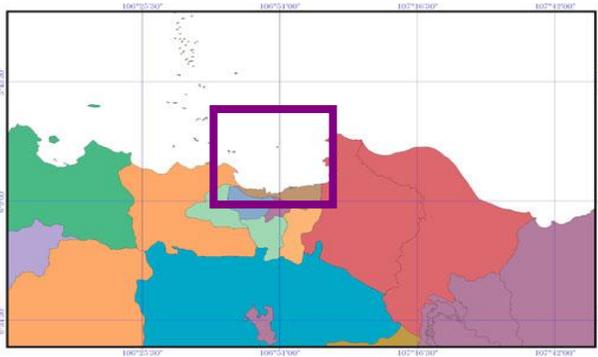


Figure 2. Location of Jakarta Bay

$$t_{bx} = rru\sqrt{(u^2 + v^2)}$$

$$t_{by} = rrv\sqrt{(u^2 + v^2)}$$

With the price of the coefficient of the basic friction around $r = 3 \times 10^{-3}$.

Eddy's viscosity coefficient horizontal (A_h) stated the level of turbulence of the water body. The value determination was from this coefficient matched with the measurement grid and the model and the depth bathymetry the area of the model.

The horizontal grid is in the Cartesian coordinate system and the staggered grid arrangement for the external mode is depicted in Figure 3.

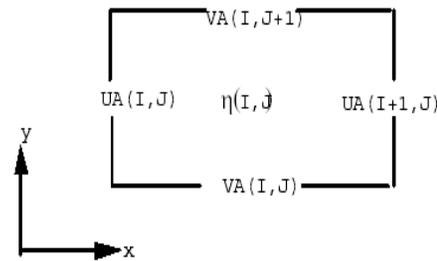


Figure 3. The 2-dimensional external mode grid

$$\log(S) = 1.83 + 1.26 \log(X_s)$$

$$X_s = [R(\lambda_5) + R(\lambda_6)] [R(\lambda_3) / R(\lambda_5)]^{-0.5}$$

Where :

$\lambda_3 = \text{spectral.region.green}$

$\lambda_5 = \text{spectral.region.yellow}$

$\lambda_6 = \text{spectral.region.red}$

S = TSM Concentration

Numerical Simulation of Sediment Distribution

The Hydrodynamics Model

The movement of the water mass in the area of the coast that was generated by the rise, fall tide and the wind generally depicted with the eternity law of the momentum and the eternity of the mass. In the coordinate system kartesian two dimensions, the condition for hydrodynamics could be in the area of the coast depicted with the equality of the continuity:

$$\frac{\partial h}{\partial t} + \frac{\partial (uh)}{\partial x} + \frac{\partial (vh)}{\partial y} = 0$$

The equality of the movement in the direction of x and y:

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = fv - g \frac{\partial \eta}{\partial x} + \frac{\tau_{sx} - \tau_{bx}}{\rho h} + A_h \left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right]$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = -fu - g \frac{\partial \eta}{\partial y} + \frac{\tau_{sy} - \tau_{by}}{\rho h} + A_h \left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right]$$

Where :

u = the speed of the flow in the direction of x (m/s)

v = the speed of the flow in the direction of y (m/s)

η = sea surface elevation (m)

h = the depth of the total waters (m)

f = coriolis parameter (sec-1)

A_h = eddy's viscosity coefficient horizontal (m²/s)

g = the acceleration of earth gravitation (m/s²)

ρ_0 = the density of water (kg/m³)

τ_{sx} and τ_{sy} = stress their respective surface for the direction x and the direction y (N/m²)

τ_{bx} and τ_{by} = stress their respective foundation for the direction x and the direction y (N/m²)

The form of the equality of the basic friction that was used in the model was:

In this research, the horizontal grid contained 72 x 110 grid points and value of $dx = 500$ M, $dy = 500$ M.

RESULTS AND DISCUSSIONS

Results of TSM distribution in Jakarta Bay during 2003 until 2005 by using MODIS Satellite data, in rainy season and dry season can shown in Figure 4.

The result of research using MODIS satellite data shown that highest concentration of TSM mostly in near coastal area. It's indicated that pollution of suspended mostly near coastal area

Tide

In current process, four point movement periods was selected. Those are flood tide, highest tide, ebb tide and lowest tide. The result is shown as follows:

Current pattern (Spring)

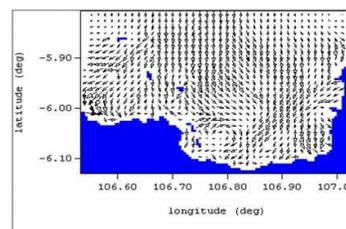


Figure 5. Current Pattern in Flood Tide with Maximum Velocity 1.23 m/s

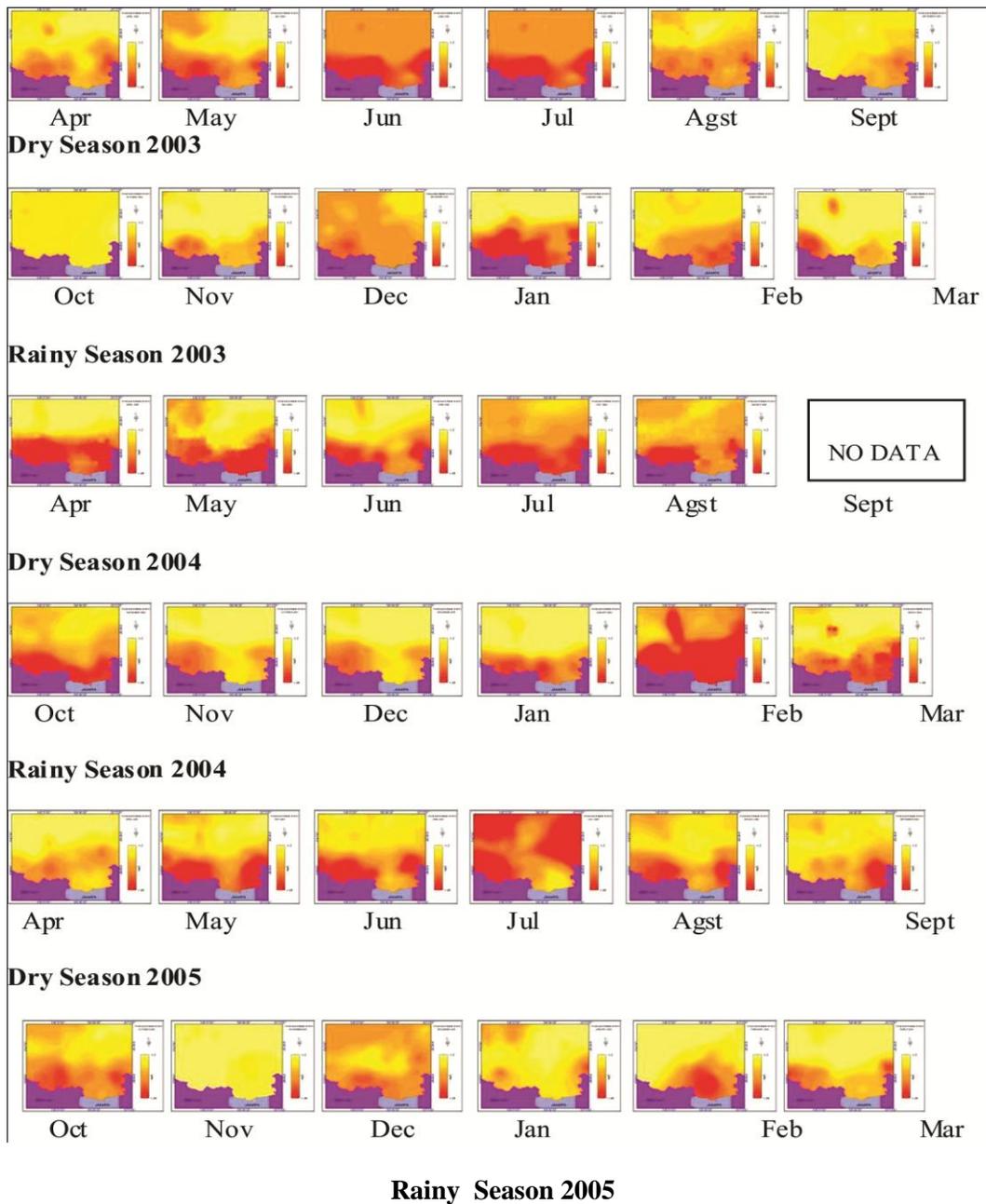


Figure 4. Transportation of TSM In Jakarta Bay

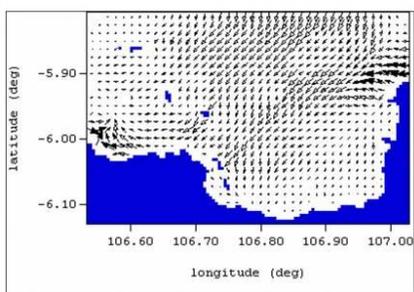


Figure 6. Current Pattern in Highest Tide with Maximum Velocity 0.77 m/s

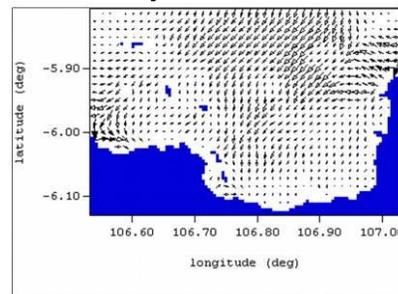


Figure 7. Current Pattern in Ebb Tide with Maximum Velocity 0.83 m/s

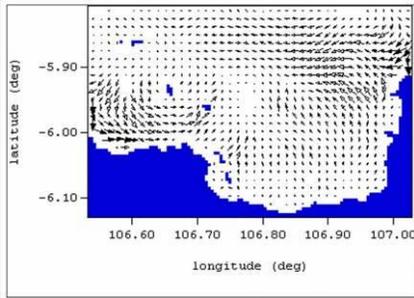


Figure 8. Current Pattern in Lowest Tide with Maximum Velocity 1.31 m/s

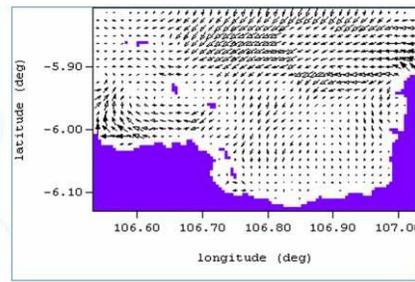


Figure 12. Current Pattern in Lowest Tide with Maximum Velocity 0.34 m/s

The current condition in Jakarta Bay when spring indicated that detection of current mostly from northeast and maximum velocity when spring condition was in Lowest Tide are 1.31 m/s.

The current condition in Jakarta Bay when neap indicated that detection of current mostly from northeast but the direction different with spring condition and maximum velocity when spring condition was in Ebb Tide with Maximum Velocity 0.90 m/s

Current pattern (Neap)

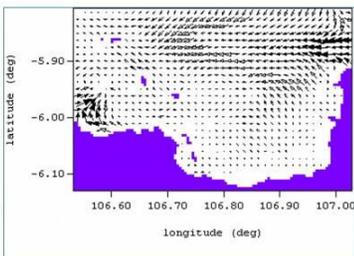


Figure 9. Current Pattern in Flood Tide with Maximum Velocity 0.71 m/s

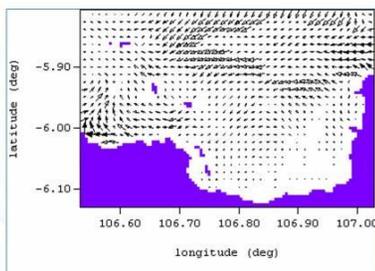


Figure 10. Current Pattern in Highest Tide with Maximum Velocity 0.69 m/s

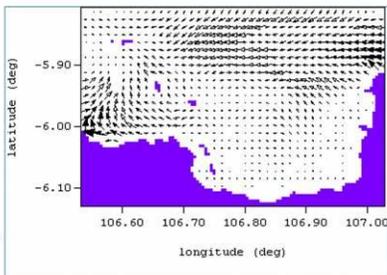


Figure 11. Current Pattern in Ebb Tide with Maximum Velocity 0.90 m/s

Pattern of TSM from Satellite Data

Using MODIS satellite TSM distribution in Jakarta Bay Observed shows that the highest concentration distribution of TSM, accumulate mostly near coastal area because, of many industrial in coastal area and because the river accumulate in coastal area

Result of observation revealed that concentration TSM range from 9.200 mg/L until 37.167 mg/L, in which the tolerant limit of sediment specified by the government is 70 mg/L. The result indicate that TSM concentration in Jakarta Bay in September 2004 were under limitation and still can tolerance

Distribution of TSM using satellite MODIS by comparing result of perception with the satellite and result of secondary data (LIPI, 2004), obtained a relatively good correlation the value of regression coefficient are $R=0.72$

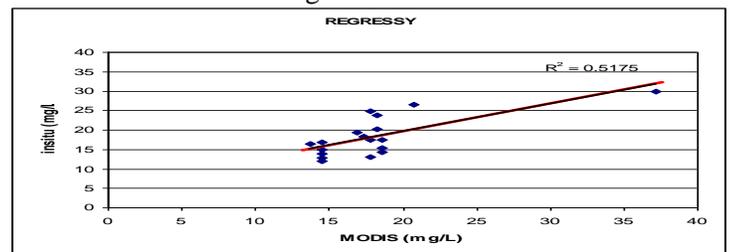


Figure 13. Regression of TSM with In-situ Data

CONCLUSION AND SUGGESTION

Based on the result of this research, the conclusion could be suggested as follows:

Based on the results of this research, the conclusion could be as follows:

1. The highest TSM transportation in Jakarta Bay was in coastal area and the regression coefficient (18 sample

points) was $R=0.72$. Total suspended matter distribution using modis satellite showed the concentration of TSM was high during dry season (April-October) and low during rainy season (October-April).

2. Vector of current in Jakarta Bay in September 2004 experienced of the change direction and speed at each condition during spring condition at flood tide 1.23 m/s, highest tide 0.77 m/s, ebb tide 0.83 m/s, and lowest tide 1.31 m/s and during neap condition at flood tide 0.71 m/s, highest tide 0.69 m/s, ebb tide 0.90 m/s, and lowest tide 0.34 m/s.

Suggestion

1. MODIS Satellite with the resolution of 4 km could examine the environment condition well, but in the narrow area it is not really possible, so for a better and more accurate result the highest satellite accuracy should be used.
2. The result of the research is expected to give a contribution to Jakarta government in determining policies about the environmental monitoring and pollution control such as:
 - a. For the further research should be used the latest satellite image, to improve the level of accuracy data.
 - b. Pollutant better be processed before thrown to environment.

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