The Model of Shoreline Change in Estuary of Porong River after Mud Volcano

Mahmud Mustain

***Abstract*— The basic research of this paper is to produce the result of the model of extended area or/and degradasion area in estuary of Porong river after mud volcano phenomenon. The model is the part of conception of coastal management in the sector of coastal protection. This sector is concerning to the stability of shoreline change. This is obviously the extended area from sedimentation or/and degradasion area due to erosion processes in coastal vicinity. It means stable from the sedimentation and/or erosion processes that may not be wanted. This research is to create the model of shoreline change, based on the previous years to the recent condition, and then to estimate the feature condition. This model based on the conception of longshore transport (lonsgshore current) in the certain location of estuary of Porong river. The model works on the two stages. (1). Using data of year 2000 for initial condition, the model produced three difference results for next 14 years from three difference sediment transport formulations. This is to find the most apropriate result when to be compared to the existing data of 2014 among those formulatios. The formulation of Komar-Inman [6] is the best one due to getting result that have the smallest error of 7 % to the existing data 2014. (2). By using data of year 2014 as initial condition, the model have produced the estimation of shoreline change for the next period of; 5, 10, 15 and 20 years. After 20 years implementation, the model gives result of extended land area to the offshore direction in around of 1000 meters. The accuration of the result is depend on the accuration of Komar-Inman [6] formulation in the transport sediment conception.**

***Index Terms*— mud-volcano, Prorong-river, shoreline-change, Sidoarjo**

I. INTRODUCTION

The phenomenon of mud-volcano in Porong Sidoarjo makes interest for many sectors [13], [17], and [19]. This blow is existing since 2006, more than ten years. The assumsion is may not stop blowing. Mustain [12] research gives estimation of the volume of mud sours of 3.25 10^{11} m^3. This number will finish araound 8907 years if the debit of blowing is 10^5 m^3/day. If the potential energy only the half elevation of total difference elevation, so the flashing time is also half i.e 4503 years. Table 1 gives illustration of the detailed calculation. Therefore, the next interested research is to manage the mud on the surface after blowing [14].

The conception of mud turism object [15] and [16] gives inspiration to make empowering of mud flow management on the surface. This is relevan to the prospective development of coastal zone managemen around mud volcano area. Therefore, it becomes a good alternative solusion after mud blowing as development of coastal mangement area for spesific case of mud-volcano. Then, this paper is to support the ide of conception of mud turism object. This is in the topic of coastal protection [4].

Fig. 1: Study area

Table 1: Calculation of the Volume of mud source and Estimation of stop blowing [12]

The Calculation of Estimation of Mud Reservoar						
		Lengt line of B 91-169 (m) =		17000		
		Thickness (m) =		1200		
		Porosity (%) =		0.15		
		Debit of blowing (m^3/day) =		100000		
		Multiple factor of wide =		2.5		
		Multiple factor of lengt =		2.5		
Lengt of layer	Wide of layer	Volume of layer	Porosity	Volume of Mud	Time of blowing	Time of blowing
(m)	(m)	(m^3)	(%)	(m^3)	(day)	(year)
42500	42500	2.1675E+12	0.15	3.25125E+11	3251250	8907.534247

In the contect of the coastal protection of Sidoarjo after mud volcano, this research is concerning to the stability of shoreline change due to either sedimentation or erosion mainly after transportation of huge mud volcano material. The area study have been proposed in the Fig.1. Refering to the background of idea, there are two aims will be describe below;

a. To create the model of shoreline change for decision of the pattern of either sedimentation or errosion in estuari of Porong river.

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b. To estimate the shoreline profile for year of 2019, 2024, 2029 and 2034 based on the created model with initial condition of year 2014.

II. BACKGROUND THEORY

Simple definition of shoreline is the boundary line between land and sea. The shoreline may be change due to the process of sedimentation and/or erosion. To make evaluation of the sedimentation or erosion condition in the certain coastal vacinity may use the equilibreum analysis of material sediment. The equilibreum will produce the result of the balance of destructive versus constructive force [2]. Moreover, the equilibreum analysis may also be used to estimate either the deposited material due to the sedimentation process or flushed material due to the errosion process. Therefore, the condition of the shoreline depends on the either deposited material or flashed material. The existention of deposited material will make the shoreline move to offshore direction. This means that the expansion land accures. On the othe hand, the existention of flashed material will make the shoreline move to onshore direction, this is the condition of land reduction. In adition, the conception of sediment transport alongshore (longshore current) direction becomes the basic principle of the shoreline change.

The model for this research is to identify the potential shoreline change in vacinity of Porong river estuary. The indication of shoreline change is very clear due to the extra volume of the mud volcano as extra material sediment. Firstly, this model is to optimaise the determination of the pattern of shoreline change start the initial condition. The result of the model is compared to the existing condition for the folowing years. The model used the mathematical formulation of flux energy for longshore direction. Ingle [5] and bijker [1] have tested the mathematical formulation. Secondly, this research has implemented three difference formulations of sedimen transport of; CERC, Dian et al, and Komar-Inman [6] to simulate the shoreline change alongshore of the estuary area.

The main purpose of this model is to make estimation of shoreline change and then to determine the vomule of the sediment transport till year of; 2019, 2024, 2029, and 2034. This research had run the model based on the initial condition of 2000 and to make validation to data of 2014.

III. MATHEMATIC BASE OF SHORELINE CHANGE MODEL

The model in this research is *One-Line* method that refer to CERC [3] and [8]. The mathematical formulation of this model uses the conservation base of the volume of sediment alongshore line. This uses the assumsion of that the *offshore closure depth* (Dc) is constant for the shoreline profile, and the *berm crest elevation* (Db) makes the change to the shoreline profile. The *One-Line* method also illustrates the hole shoreline profile from the first sliced part move to the next slice that may figure a *single contour line* [7].

The frame of the formulation of the transported volume sediment is on the cartesian coordinat, ordinat-y is the offshore direction while the absis-x is alongshore direction. Fig.2 illustrates the frame that may support to understand; cross section of absis-x is as alongshore direction and also as shoreline, while the ordinat-y is for offshore direction and also as direction of forward or backward of shoreline change.

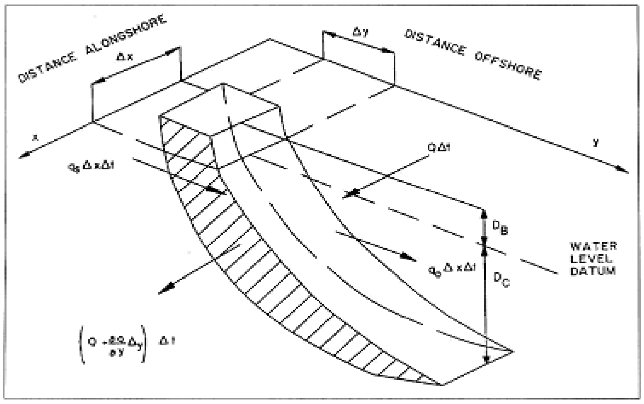

Fig. 2: cross section of the frame model [7]

The change of volume in the slice is as $\Delta V = \Delta x.\Delta y\,(db + dc)$. This depends on the amoun of material sediment (sand/mud/cay) either enter to the slece or go out from slice. The difference rate of sedment transport velocity (ΔQ) alongshore direction (*alongshore sand transportt rate)* Q for the lateral direction of each slice may change the volume. Therefore, the change of the volume is $\Delta Q.\Delta t = (\Delta Q/\Delta x)$ x.t. The other cause is the addition of material sediment from land q_s or offshore q_0 as material from lateral direction. The formulation is $q = q_s + q_0$. This gives the addition volume of $\Delta q.\Delta t$. Using the initial condition of t = 0 then the formulation becomes:

$$\frac{\Delta y}{\Delta t} = \frac{1}{db+dc}\frac{\Delta Q}{\Delta x}.q = 0 \qquad (1)$$

The process of shoreline change is a natural dynamical phenomenon. The model for this research used the formulation of Komar and Bijker [1],

$$\frac{Y}{x} = \frac{1}{db}\frac{Qs}{x} \qquad (2)$$

where:

Y : the distance between shoreline to the reference (m)

d_b : the deph of the broken wave (m)

Qs : the volume of transport sediment alongshore (m^3/day)

t : time (second)

x : the absis longshore direction (m)

The interaction of the formulation to the flux wave energy is given as:

$$Q_s = KP_1 \qquad (3)$$

$$P_1 = \frac{\rho g}{8} H_b^2 C_b \sin\alpha_b \cos\alpha_b \qquad (4)$$

where:

Q_s : the volume of transport sediment alongshore (m^3/day)

P_l : the alongshore componen of flux wave energy in the time of broken wave (Nm/d/m)

ρ : density of sea water (kg/m^3)

H_b : high wave of broken wave (m)

C_b : velocity of broken wave (m/d) = $\sqrt{(g\, d_b)}$

α_b : the angle of front wave (deg)

K, n : constants

The model uses three formulations in tyhis research:

Dian et. al : Qs=1,230xP1
Komar and Inman : Qs=0,778xP1
CERC : Qs=0,401xP1

To drive this implementation in the model, finite difference method solved eq. 2. A making slices for spesific time difference is in order to express the realisation of discrit. This is the term of conversion from partial differential to discrite condition for same amount calculations. The solusion eq. 2 is the term of explicit [21], that is expressed as:

$$f(x,t) = f_i$$
$$\frac{\partial f(x,t)}{\partial t} = \frac{f_i^{n+1} - f_i^n}{\Delta t}$$
$$\frac{\partial f(x,t)}{\partial x} = \frac{f_i^{n+1} - f_i^n}{\Delta t}$$

Therefore, the equation of *Qs* (Qs: sediment tranport alongshore direction) may write as:

$$\frac{y_i^{n+1} - y_i^n}{\Delta t} = -\frac{1}{d_i}\frac{Q_{i+1}^n - Q_i^n}{\Delta x}$$
$$y_i^{n+1} = y_i^n - \frac{\Delta t}{d_i \Delta x}(Q_{i+1}^n - Q_i^n) \qquad (5)$$

This formulation needs boundary condition of both right and left, then it available to calculate the Y_i^{n+1}(i=1,....,N). Both of right and left boundary conditions are also as a range of sediment transport alongshore direction.
For the first calculation, the data (map) may use to place the initial position (y) in the initial condition (to). For certain value of Δt and Δx, then available to calculate the value of Y_i^{n+1}. This prosedure may use for next difference periodical years.

IV. THE CONDITION OF AREA STUDY

The location of area study (Fig. 1) is the Estuary of Porong River in district (Kabupaten) of Sidoarjo, province of East Java. The previous research had calculated the wave paramaters. Table 2 below shows the previous calculation.

Table 2: The wave parameters
(Previous research not yet be publised)

T =	6.480	s	Wave Periode
g =	9.81	m/s^2	Gravitasion Accleration
$\mathbf{H_b}$ =	1.81	m	high wave of broken wave
$\mathbf{d_b}$ =	2.32	m	the deph of the broken wave
ρ =	1.025	ton/m^3	density of sea water
$\mathbf{C_b}$ =	4.77	m/s	velocity of broken wave
V =	0.923	m/s	Current velocity

V. MODEL OF SHORELINE CHANGE

The application gives result of the model of shoreline change from initial condian of shoreline profile of year 2000 (bathymetri map, Dishidros-TNI AL) in study area for along period of 14 years. This certain period is due to the recent available map of year 2014. The model had implemented three difference formulations in order to chose the best one. The sandard for validation is shoreline profile of 2014 as riil condition. Fig. 3 shows the results of these three difference formulations of; Dean *et al.* [2], Komar-Inman [6], and CERC [3] and [8].
The result of implementation of three difference transport sedimen formulations in fig. 3 shows that the formulation of Komar-Inman (purple curve) gives the best result. The refference of validation is the comparation of amount of transport sediment volume to the riil condition of 2014 (blue-light curve). The purple curve gives the amount of transport volume of 115368 m^3. This is the nearest value to the 124030 m^3 as the refferrence/standard value. This has the smallest error of 7 %. While the CERC gives result of 52% and Dean *et al.* gives 47 %. Table 3 shows the detail records. Therefore, this research decide the Komar-Inman formulation of sediment transport to be used in this implementation for shoreline change model to make estimation for next certain year.

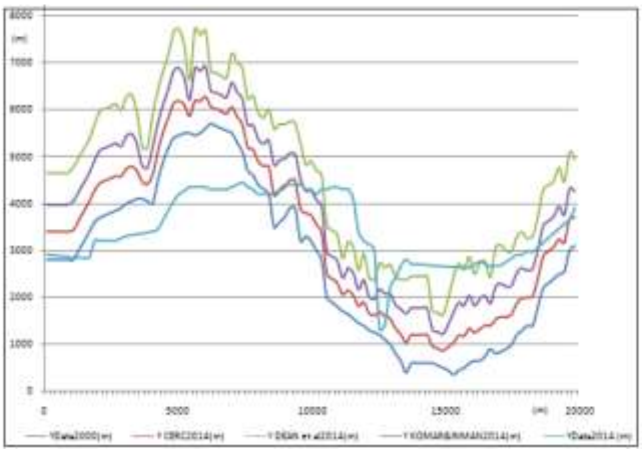

Fig. 3: The result of running model of shoreline change for three difference formulations of;
Dean *et al.* [2], Komar-Inman [6], and CERC [3] and [8]

Table 3: The result of the calculation of a mount of transport sediment volume for three difference formulations

	CERC	Dean et al	Komar-Inman	Standard
Volume of sediment transport (m^3)	59463.50	182394.27	115368.08	124030
Error (%)	52.0571662	47.0565726	6.983728853	0

Fig. 4 is the output of the model for estimation of difference next certain year of; 2019, 2024, 2029, and 2034. This output is the result of implementation of Komar-Inman sediment transport formulation using data of 2014 as initial condition. It is clear that the Fig. 4 shows the expantion of land area to the offshore direction around 1 km during 20 years. It is interested topic to make discussion in the next heading.

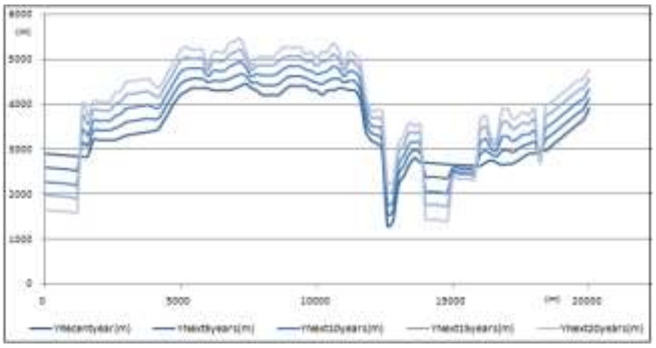

Fig. 4 the result of implementation model using Komar-Inman formulasion

VI. DISCUSSION

In the case of formulation decision from several difference terms, the idea to make main criteria is the amount of the sedimen transport volume. This is appropriate reason due to the principle of transport sediment that is as a basic conseption of the model. The model of shoreline change from 2000 to 2014 (as the first purpose of this research) is to make sure and absoluty which formulation is the best one? It uses refference data 2014 for standard validation. The result as the best one is using Komar-Inman formulation. However, it has weekness that the shape of the shoreline profile is not same. It means the material sediment move on the longshore direction. That way the reseacher concenr to make the amount of sedimen transport valume become main criteria. From this criteria, the formulation of Komar-Inman is also give a result as the most appropriate to the riil data as the standard validation.

Once more again, the validation is based on the similarity of amount of sediment transport volume among 14 years since 2000 until 2014, not in the similarity of shape of shoreline profile. In the reality condition, the recently data (map 2014) not only land expansion (sedimentation to offshore direction) when we campare to the map 2000 but also land moving (moved area) to the South direction i.e. alongshore direction. Fig. 5 clearly indicated about land moving to South direction. This is appropriate and reasonable phylosiphically due to the dominant of wave direction from the calculation of wind records that is 122^0 (South-East direction). Moreover, the current velocity and the extra material sediment from mud volcano cause the extra amount of sediment transport vomule as well [15].

Related to the second aim of this research, that the aim of model is to make estimation of shoreline profile for next certain 20 years like in fig. 4, shoreline will move forward to the affshore direction around 1000 m for next 20 years. Indeed, this is extra ordinary condition, the processed sedimentation produces land expansion of around 50 m every year. This trend can be traced from the expanded area addition in every 5 years. Fig. 6 shows the illustration of growing area or expanded land parallel to the offshore direction. The curve of growing shows a linear-positive and sharply slope. This may confirm to the fig. 4, the expansed land has similarity pattern from slice to the next slice. The shoreline change has shape of parallel to the shoreline profile except small area in the position of 14000 m.

The progress of this expanded land will change the profile of ground water elevation near shorline to the land forward direction, event not so large but significant for water quality. This is have be predicted in the previous research [13], [16], [17], and [18]. The additional land will make the ground water from the landward direction flows to seaward direction, then to move the position of interaction between frash water and saline water [9] and [10]. Therefore, the expanded area to offshore direction is importance to the ground water condition [20]. This also has simultanious effect to the position of interfase line below line of ground water [13], [17], and [18]. There are three points that may make the highlight i.e;

a. The model of shoreline change to know the erosion and sedimentation process in Estuary of Porong river works properly. The model implemented three difference sediment transport formulations; CERC, Dean *et al.*, and Komar-Inman. This research had decided the Komar-Inman formulation as the best one. This model of sedimen velocity of 4719 m^3/year gives result the total deposited sedimen of 115368 m^3 during period of 2000 to 2014 with error of 7 %.

b. The model had implemented to estimate shoreline profile for next years of ; 2019, 2024, 2029 and 2034 using formulation of Komar-Inman. This implementation gives result of information of next 20 years will extend to affshore direction araound 1000 m., as extra ordinari expansion of around 50 m/year.

c. There are four objects will get the advantages from this research as also refered to previous research [11]; University as base of next researcher, Government as regulator maker, Non Governement Organisation, and investor and industries as an other users.

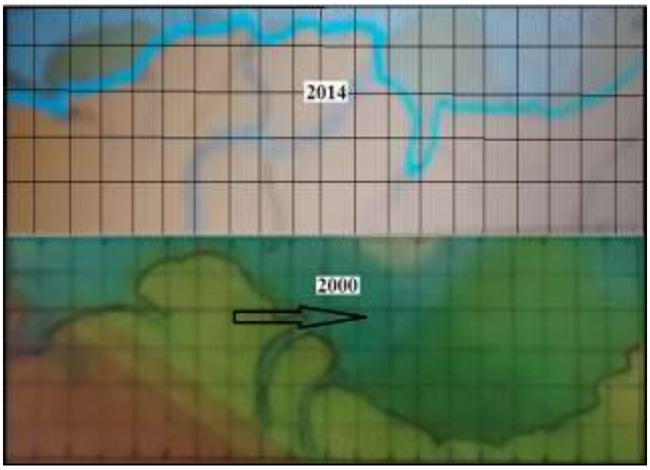

Fig. 5: the existing of shoreline moving to South direction

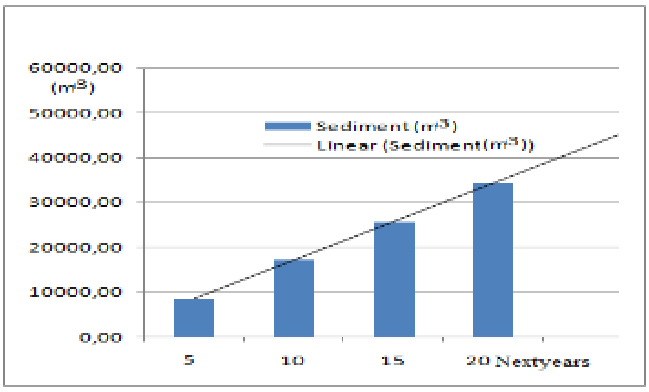

Fig. 6: The curve of growing of deposited material or expanded land to the offshore direction due to extra aditional material sedimentation from mud volcano

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