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# MODELING OF BEACH CHANGE AND TOTAL SUSPENDED SOLID DISTRIBUTION BASED ON REMOTE SENSING DATA BEFORE AND POST RECLAMATION IN LAMONG BAY PORT

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**Abstract**

Teluk Lamong Harbor is one of the reclamation areas which is affecting the marine environmental resources. Therefore, an analysis of shoreline changes, current pattern modeling, Total Suspended Solid (TSS) modeling based on remote sensing data is used to see the results of the development of the Teluk Lamong Multipurpose Port Terminal. The objectives of this study are analysing the shoreline changes in the Multipurpose Port Terminal in Lamong Bay in 2012 (before reclamation) and 2020 (after reclamation), analyzing the modeling of current patterns in the Multipurpose Port Terminal in Lamong before and after reclamation, analyzing the use of TSS analysis in the Multipurpose Port Terminal in the Lamong Bay before and after reclamation. Stages of the method are analyzing shoreline changes using the Digital Shoreline Analysis System (DSAS) software before and after reclamation, modeling the flow pattern using Mike 21 software before and after reclamation, and modeling the use TSS uses Mike 21 software based on remote data sensing using Google Earth Engine (GEE). The EPR values are 107.5 meters/year, 59.63 meters/year and 10.38 meters/year. The remote sensing TSS values which need to be considered are on the condition of very low values (0-20 mg/L), low (20.1-40 mg/L), moderate (40.1-80 mg/L), high (80.1-120 mg/L) and very high (>120.1 mg/L). For the total suspended solids, informs that the highest value is at a point near the Teluk Lamong Port based on the in-situ data where the high TSS values at stations 2, 3, 4, 22 and 23 with values of 142 mg/L, 119 mg/L, 115 mg/L, 112 mg/L, and 116 mg/L. However, comparing with the remote sensing data in 2020 using GEE TSS software shows the values on 167 mg/L, 122 mg/L, 120 mg/L, 128 mg/L and 120 mg/L. In 2012, TSS in low tide reaches 320-360 mg/L and in high tide reaches 325-350 mg/L. In 2020, TSS in low tide reaches 360-400 mg/L and 440 mg/L in high tide. Both previous papers and the recent analysis on this research give a similar result. Therefore, it may consider that the recent result as the updated condition from the development of Teluk Lamong Harbour.

Keywords: Coastal change, Flow pattern modeling, Teluk Lamong harbor, Total suspended solid modeling.

## 1. Introduction

Indonesia has a coastal region that stretches from Sabang to Merauke which is rich and a variety of natural resources that have been utilized by the community as one source of economic income. In addition to providing a variety of resources, Indonesia's coastal area has various other functions, such as transportation in the form of a port, industrial estate, agribusiness and agro-industry, recreation and tourism, residential areas, and waste disposal sites. One of the development ideas that is being discussed by many Indonesians is the concept of reclamation. Reclamation can be defined as an effort to improve, utilize, restore capacity, and improve the quality of land through the empowerment of various technologies and community empowerment focused on land that is naturally of low quality or as a result of human influence that makes the land less productive.

Reclamation is utilized to accommodate human activities in Megacity such as Surabaya and Jakarta. Proper standard procedures in the process of Reclamation have to be observed to maintain environmental sustainability [1]. The effect of population pressure, and improved knowledge, science, and technology giving the possibilities in maintaining the sustainability of environments [2, 3]. It seems that reclamation will be one of the alternatives in developing a megacity and its surrounding facility.

One of the activities that have a considerable influence on the coastal environment is the operational activities of ports built based on the coastal reclamation process. Australia and Indonesia investigated the issues surrounding major investment in infrastructure, focusing attention on the ways by which both countries seek to enhance the services offered in and around their seaports. As Surabaya and East Java are having many industry activities, therefore, the need and demand for having larger ports are very high [4]]. Teluk Lamong Harbor with its geographical location in the city of Surabaya has become a trading city and a port city [5].

Teluk Lamong Bay (Fig. 1) is located in the border area among Madura Strait on the north and east sides, Sidoarjo Regency on the south side, and Gresik Regency on the west side. Therefore, the port's role as one of the gateways of trade traffic is necessary for the City of Surabaya. Based on data released by the Central Statistics Agency of East Java, one of the contributors to economic growth in East Java is the trade sector by contributing 22.3 percent. This makes Tanjung Perak Harbor the main route for the distribution of goods and containers from East Java to other regions, especially eastern Indonesia. That causes the density of goods and container flows that occur in the second largest port in Indonesia, increasing even now the port is experiencing overcapacity. Port construction is needed to assist the distribution of goods at the Port of Tanjung Perak, namely by building the Port of the Lamong Multipurpose Terminal which has been built in phase 3. Teluk Lamong Port will be part of the solution for the port capacity need of the Tanjung Perak Port of Surabaya, but also a positive trigger for positive competition among Ports in the eastern part of Indonesia [6].

The development of the Lamong Bay Multipurpose Port may have an impact on the condition of the natural ecosystem around the coast due to the changes in environmental conditions [7].The changing of those contours correlates with the sedimentation and erosion processes in those regions as well as in the areas of Teluk Lamong (Bay of Lamong). In general, the impact of reclamation on river mouths can cause vulnerability to coastal sedimentation, which makes it difficult for fishermen to dock at the beach. Reclamation in Lamong Bay can lead to sedimentation which could have an impact on silting the shipping lanes in the Madura Strait [8]. The water depth is a crucial property for ship's accessibility to the Port. In having water depth maintainability for the Teluk Lamong Port, a suggestion was given by utilizing numerical modeling [9].

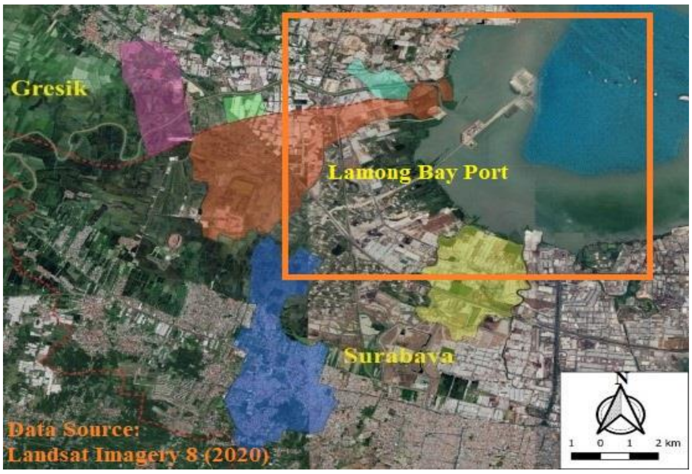


**Fig. 1. Location of Teluk Lamong Harbor.**

Coastal vulnerability around the reclamation area will experience erosion or sedimentation, due to hydrodynamics in the area [10]. The changing of hydrodynamic processes in the area will make a change such as current flow patterns, tides, and sediment transport. Those changes will have impacts on sedimentation and abrasion and influencing coastal change. The most influencing process is waves. When moving towards the beach, the waves undergo a transformation which then generates currents near the coast. Currents moving along the coast move sediments, causing shoreline changes. In offshore areas only transport to or leave the coast occurs, whereas in nearshore areas there are two types of sediment transport [11]. The change in the shoreline is related to sediment transport that occurred at Teluk Lamong port. Changes in the shoreline are caused by changes in coastal sediment which can come from the erosion of the shoreline itself, from river flows, and from deep seas that are carried along with currents towards the coast. It is important to study the nature of coastal sediments to determine the erosion and sedimentation processes. These properties are in the form of particle size and distribution of sediment grains, mass density, shape, and velocity of sediment [12].

The most significant rate of sedimentation occurs on the shore of Lamong Bay [13]. The rate of sedimentation increases, so siltation at the Port of Teluk Lamong will have an even faster impact on other problems. Therefore, knowledge about aquatic hydrodynamics is very important to understand to predict the distribution of sediment after reclamation. In recent studies, soft engineering solutions or non-structural methods of protecting the area from erosion have become popular [14]. Modeling of sea currents and sediment flow keeping the water depth of the Teluk Lamong Port, maintainability may be carried out by the method of prediction and the process may be carried out by dredging, etc.[15]. The results of the model that have been validated and have shown correlations or similarities with actual conditions in the field can be used to predict the dynamics of various processes that occur in the waters. This research was conducted to compare the effect of the sedimentation process before and after reclamation at Teluk Lamong Harbor which is influenced by factors of sea depth, wind, and tides. This research uses satellite imagery remote sensing and mike 21 modeling to get an overview of distribution of total suspended solids before and after reclamation of Teluk Lamong port.

## 2. Coastal Area Dynamics

Coastal areas consist of confluence between land and sea which has high environmental dynamics with many physical processes, sea-level rise, land subsidence, and erosion-sedimentation. The interaction between physical processes and human activities in the coastal zone determines the characteristics of the coastal environment. It is estimated that around 38% of the world's population occupies an area not further than 100 km from the shoreline [16].

Although shoreline changes are sometimes beneficial, such as additional land for purposes of land use, nevertheless shoreline changes can also result in losses with loss of land due to abrasion. An analysis of shoreline information is needed in the design of coastal protection, to calibrate and verify numerical models, to assess developing hazard zones, to formulate policies to regulate coastal development, and research on the coast [17].

### 2.1. Coastal reclamation

Land needs for various types of needs today are increasing, along with the pace of development throughout the world, including in Indonesia. For this reason, many attempts have been made to convert land that is not yet ready for use into land that is ready for use. The land that is not ready for use can be a puddle area, swamp or brackish area, a former open mining area, or the ocean.

Coastal reclamation is carried out taking into account the socio-economic conditions of the population, given the increasingly rapid growth rate, which causes the land for development to increasingly narrow. Reclamation makes watery areas that are damaged or of less value better and more useful. The new area is usually used for residential, industrial, business, and urban areas, ports, and tourist attractions. In the theory of urban planning, coastal reclamation is one step in city expansion.

#### 2.1.1. Objectives and benefits of coastal reclamation

The purpose of the reclamation according to the PERMENPUPR Number: 40/PRT/M/2007 is to make a damaged or untapped watery area become a new area that is better and more useful [18]. The new land area can be utilized for residential, industrial, container shipping ports, business and urban areas, airports, agriculture, alternative transportation routes, coastal freshwater reservoirs, integrated waste management, and environmental areas, and as an old land protection embankment from the threat of abrasion as well as to become an integrated tourist area. The objectives of the reclamation program are [19]:

a. To recover land lost due to ocean waves.

b. To acquire new land in the front line of the shoreline to erect a building that will function as a shoreline protection fortress.

c. For economic reasons, construction or to erect construction on a larger scale.

According to PERMENPUPR Number: 40/PRT/M/2007, basically, beach reclamation activities are not recommended but can be done by taking into account the following matters [18]:

a. Represents the need for developing existing cultivation areas on the land side;

b. Is part of an urban area that is quite dense and requires the development of the land area to accommodate existing needs;

c. Located outside the mangrove forest area which is part of a protected area or national park, nature reserve, and wildlife reserve and;

d. It is not an area that borders or is used as a reference for territorial borders with other regions or countries.

### 2.1.2. Impact of coastal reclamation

Based on PERMENDAGRI No. 1 of 2008 concerning coastal reclamation, the implementation of coastal reclamation must pay attention to environmental interests, ports, mangrove forest areas, fishermen, and other functions in the coastal area and the sustainability of the surrounding coastal ecosystem [20]. Planning in reclamation activities should be aligned with the city's spatial plan. The new city spatial planning must pay attention to the social and ecological carrying capacity of the city.

Reclamation project activities around the coastal area require a scientific feasibility study through a technical study of how much environmental damage will be caused and then conveyed openly to the public. It is important to remember that reclamation is a form of human intervention in the balance of the natural environment of the coast. In a coastal ecosystem that has long been formed and arranged as it should, it will lose its balance due to reclamation activities. The effect of these impacts is one of which affects the lives of the surrounding communities. Many fishermen and workers in the fisheries sector will lose their livelihoods due to the declining number of fish due to damage to the ecosystem due to runoff from sediments [21].

## 2.2. Simulation model

Hydrodynamic (HD) is a mathematical model for calculating the HD's behavior of water against various kinds of force functions, for example, certain wind conditions and water levels that have been determined in the open model boundaries. HD simulates differences in water levels and currents in the face of various style functions on the beach.

The current pattern in waters is very important to understand because it affects sediment transportation. The simulation of water flow and its variations in elevation can be simulated with several equations. This equation is an HD equation as 2D unsteady flow in one layer which is considered vertically the same. The basic principle of the conservation equation of mass and momentum which includes equations that are vertically integrated continuity, momentum, and dispersion-advection equations can explain fluid flow in-depth variations.

Y-axis momentum equation:

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial y}\left(\frac{p^2}{n}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{n}\right) + gh\frac{\partial \zeta}{\partial y} + \frac{gp\sqrt{p^2-q^2}}{C^2 h^2} - \frac{1}{pw}\left(\frac{\partial}{\partial x}(h\zeta_{\gamma\gamma}) + \frac{\partial}{\partial y}(h\zeta_{\chi\gamma})\right) - \Omega p - fVV_{\gamma} + \frac{h}{pw}\frac{\partial}{\partial_{\gamma}}(pa) = 0 \quad (1)$$

Bed shear stress in the *x* and *y* directions can be calculated using Eq. (2) [22]:

$$\zeta bx = pCf\ U\sqrt{U^2 + V^2}\ (1 + (\frac{\partial zb}{\partial x})^2 + (\frac{\partial zb}{\partial y})^2)\frac{1}{2} \quad (2)$$

Sediment transport equation (dispersion-advection)

$$\frac{\partial \acute{c}}{\partial t} + \mu\frac{\partial \acute{c}}{\partial x} + V\frac{\partial \acute{c}}{\partial y} = +\frac{1}{h}\frac{\partial}{\partial x}\left(hDx\frac{\partial \acute{c}}{\partial x}\right) + \frac{1}{n}\frac{\partial}{\partial y}\left(hDy\frac{\partial \acute{c}}{\partial x}\right) + QL\ CL\ \frac{1}{h} - S \quad (3)$$

For basic shear stresses, $\zeta b$ (N/m²) can be calculated against the interaction of current and wave:

$$\zeta c = \frac{1}{n}pfw\ (Ub^2 + U\delta^2 + 2UbU\delta\cos\beta \quad (4)$$

The approach used in sediment transportation in this module is the development of Teisson formula [23]. The equations used in this module are:

$$\frac{\partial \acute{c}i}{\partial t} + \mu\frac{\partial \mu}{\partial x} + \frac{\partial v\acute{c}i}{\partial y} + \frac{\partial w\acute{c}i}{\partial z} - \frac{\partial ws\acute{c}i}{\partial z} = \frac{\partial}{\partial x}\left(\frac{vTx}{\sigma iTx}\frac{\partial \acute{c}i}{\partial x}\right)\frac{\partial}{\partial y}\left(\frac{vTy}{\sigma iTy}\frac{\partial \acute{c}i}{\partial y}\right) + \frac{\partial}{\partial z}\left(\frac{vTy}{\sigma iTz}\frac{\partial \acute{c}i}{\partial z}\right) + Si \quad (5)$$

## 2.3. Model validation

After doing the modeling simulation, then the data is validated to determine the accuracy of the model made. Model validation is done by comparing current and tidal data from secondary data that already exists with data from modeling simulations. Flow velocity and water level elevation elements that are useful for data validation are obtained using the data extraction (.dxfm) program. The validated location points of the current speed at coordinates 112039’30 E - 112043’30 E and 7010’30 S - 7013’30” S.

Accuracy formula is needed in the validation of current and tidal pattern purposes so that the margin error that occurs can be controlled and can be accepted. In this case, the MAPE (Mean Absolute Percentage Error) and RMSE (Root Mean Square Error) formulas are used in this research. Mean Absolute Percentage Error (MAPE) is calculated using absolute error in each period divided by the real observation value for that period. Then, average out the absolute percentage error. This approach is useful when the size or size of the forecast variable is important in evaluating the accuracy of the forecast. MAPE indicates how much error in predicting compared to the real value. By using the formula below, the percentage of average current speed error is obtained between the secondary data and the modeling results.

$$MAPE = \left(\frac{1}{n}\sum\frac{|Actual - Forecast|}{|Actual|}\right)x\ 100\% \quad (6)$$

MAPE formula has a classification range that is an indication of the accuracy of modeling data using the results of an error presentation obtained from the formula [24]. Accuracy formula (Table 1) is needed in the validation of current and tidal pattern purposes so that the margin error that occurs can be controlled and can be accepted. In this case, the MAPE (Mean Absolute Percentage Error) and RMSE (Root Mean Square Error) formulas are used.

To find out how much the error value occurs, we need an error deviation formula that is Root Mean Square Error (RMSE). RMSE is an alternative method for evaluating forecasting techniques used to measure the accuracy of the forecast results of a model. RMSE is the average value of the sum of the squares of the error, it can also state the size of the error generated by a forecast model. The formula used is:

$$RMSE = \sqrt{\left(\frac{1}{n}\sum(Forecast - Actual)^2\right)} \quad (7)$$

**Table 1. Table of accuracy indicators using the MAPE formula.**

| [APE | Forecasting Power |
|---|---|
| **<10%** | Highly accurate forecasting |
| **10% ~ 20%** | Good forecasting |
| **20% ~ 50%** | Reasonable forecasting |
| **>50%** | Weak and inaccurate forecasting |

Source : Lewis [24]

This research was starting with the study literature (Fig. 2). It is important to get the information from previous research and filling the gap of the analysis for further steps. Collecting the data including bathymetry, wind, and tides at the port of Teluk Lamong were the further process in order to get the input for the metocean analysis. The data is processed using the mike 21 software such as editing the mesh, simulating current movement and current velocity, and simulating TSS movement. The data that has been formulated is then re-analysed with validation data based on previous research field data related to sediment transport.

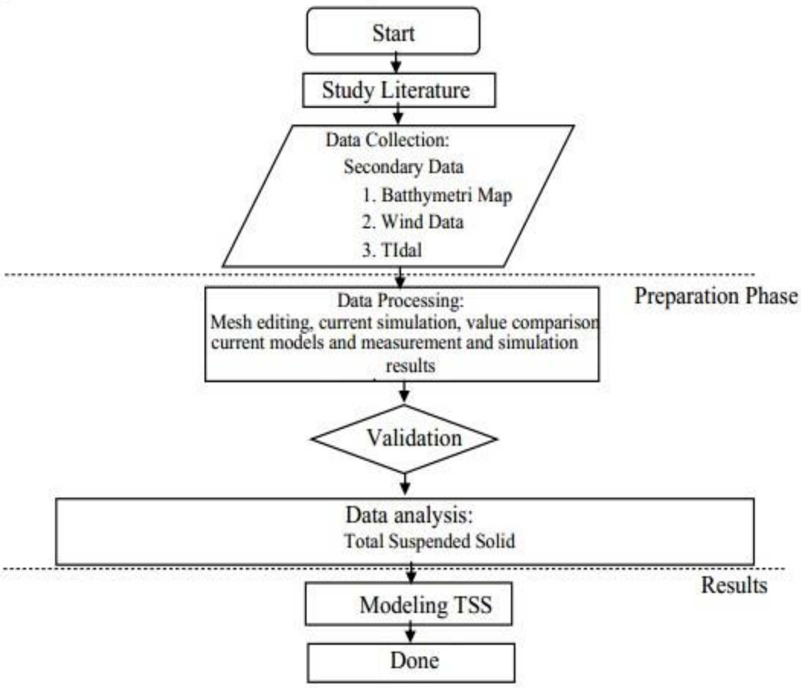


**Fig. 2. Flow Diagram modeling TSS.**

## 3. Results and Discussion

### 3.1. Changes to the shoreline of Teluk Lamong harbor

In this study, shoreline monitoring was carried out using the DSAS method. The shoreline change Net Shoreline Movement (NSM) and End Point Rate (EPR) shoreline calculation methods used in the DSAS is calculated. Observations of shoreline changes take time before and after port reclamation using data for 2012 and 2020. The purpose of this study is to determine the trend of shoreline changes during the period before and after port reclamation and predict future shoreline changes using DSAS.

The NSM method is used to calculate the longest shoreline distance in 2012 and the latest shoreline in 2020, where a positive distance has an advanced shoreline meaning, and negative data has a backward shoreline meaning. The EPR method is used to calculate the rate of shoreline change in the years before and after beach reclamation, namely in 2012 and 2020, where positive value data experiences accretion and negative value data experiences abrasion. DSAS calculation results were observed based on the phenomenon of accretion and abrasion of the Teluk Lamong Port.

Net Shoreline Movement (NSM) is a method of analysis by looking at changes in the longest shoreline distance to the latest shoreline. In the analysis using the NSM method, it will be seen the value of changes in the shoreline experiencing accretion and erosion, where accretion will be indicated by a positive value and erosion shown by a negative value, calculated from the baseline. Based on the picture below that the Lamong Bay Port area seen from the shoreline in 2012 and 2019 experienced a lot of accretion. The results of the NSM analysis above there are 3 colour variations that identify accretion, light blue with the highest value around 670-950 m, red with a moderate value of 470-530 m, and black with a low value of 60-90 m.

The profile of this transect (Fig. 3) is to have a distance between transects of 100 meters and a maximum length of 80 meters, 500 meters, and 1000 meters from a 15.3 km shoreline with a baseline as the length of the transect. Transects are used to calculate differences in the location of the shoreline each year by cutting the direction perpendicular to the shoreline analysed. The transect is then used to calculate the average of each Net Shoreline Movement and End Point Rate analysis of the study. In the analysis results, it is known that the distance of shoreline change from the baseline is from 60 to 950 meters which is indicated by 3 different colour lines in the map with a length of 3 namely 80 meters, 500 meters, and 1000 meters long transect form. As seen in the picture there was a significant addition of the shoreline to the north of the Gresik Port in the area which was the result of the coastal reclamation up to 960 meters. The addition of the shoreline also looks quite large near the Karang Kiring Coast area, reaching up to 480 meters. In the southern part of the Port development, there was a significant addition of the shoreline in the Tambak Langon area to 450 meters.

End Point Rate (EPR) is an analysis of shoreline changes by calculating the rate of shoreline change by collecting NSM analysis with time intervals in 2012 and 2020.

$$EPR\ (\frac{m}{year}) = \frac{Net\ Shoreline\ Movement\ results\ (m)}{(Latest\ and\ Oldest\ Coastline\ Intervals\ (years)} \quad (8)$$

The results of the NSM analysis above there are 3 colour variations that identify accretion, light blue based on the region of the highest change line with EPR value 107.5 meters/year, red colour based on the area of change in the moderate shoreline with EPR value 59.63 meters/year, and black colour based on the region low shoreline changes with an EPR value of 10.38 meters/year.

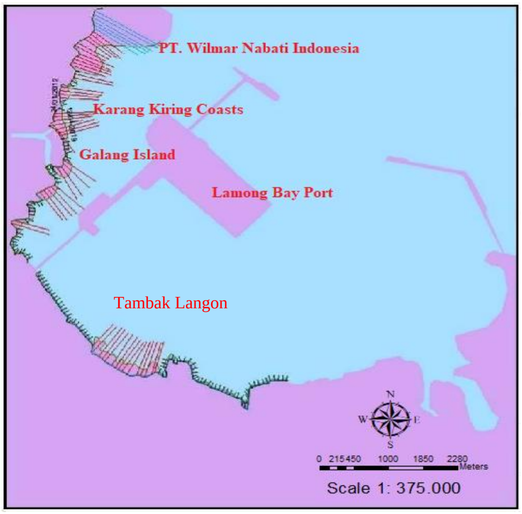


**Fig. 3. Map of NSM And EPR transect analysis before and after reclamation.**

Based on observations of changes in the shoreline in 2012 and 2020 (Fig. 4) in the area of the Port of Teluk Lamong has experienced sedimentation or land acquisition in the form of beach reclamation with a length of shoreline change reaching 950 meters and sedimentation in the Karang Kiring Coast region with a length of shoreline 480 meters [25]. There is an increase in the area of Galang Island with a length of shoreline to 430 meters. To get a comprehensive analysis, the TSS remote avoidance and TSS modeling are needed with a tidal, wave, and current data input to see the area that has an impact on sedimentation at Teluk Lamong Port. Therefore, TSS remote avoidance and TSS modeling are needed with a tidal, wave, and current data input to see the area that has an impact on sedimentation at Teluk Lamong Port.

## 3.2. Remote sensing total suspended solid

TSS is a suspended material that causes water turbidity consisting of mud, fine sand, and microorganisms mainly caused by soil erosion or water-borne erosion [26]. TSS is one of the important factors to measure water quality based on physical aspects including the addition of solids both organic and inorganic material into the waters to increase turbidity which will further inhibit the penetration of sunlight into water bodies. The amount of TSS that is in the waters can reduce the availability of dissolved oxygen. So the high TSS can also directly disrupt aquatic biota. To identify the TSS of Teluk Lamong Port, TSS remote sensing was carried out using Sentinel 2A imagery in 2020 and Landsat 8 satellite imagery in 2017 and 2019. Figure 4 shows the effect of nose shape on $C_{D0}$ with cylindrical afterbody as a function of Mach number. The drag of the cone-cylinder combination was the lowest at the considered Mach numbers. The bluntness of the nose causes the drag to increase.

TSS analysis uses the 2020 algorithm, i.e. TSS var =cut. the expression '(8.1429×(exp (23.704×0.0001×B4))', the algorithm was chosen because it was based on several experimental results that resembled in situ conditions based on the paper Concentration Change Analysis Total Suspended Solid (TSS) in Lamong Bay Using Multitemporal Landsat Imagery [8].

Based on the TSS chart and remote sensing image, the highest value is at a point near the Teluk Lamong Port In Situ data obtained in the paper explained high TSS values at stations 2, 3, 4, 22, and 23 (Fig. 4) with values of 142 mg/L, 119 mg/L, 115 mg/L, 112 mg/L, and 116 mg/L (Fig. 5). When compared to remote sensing data in 2020 using the highest GEE TSS software 167 mg/L, 122 mg/L, 120 mg/L, 128 mg/L, and 120 mg/L.

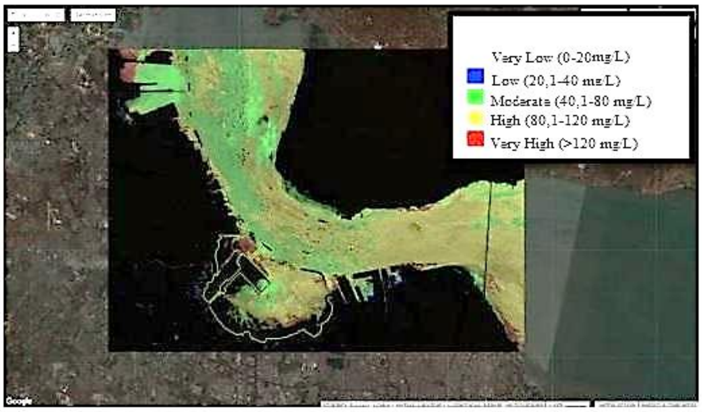


**Fig. 4. Map TSS Teluk Lamong bay.**

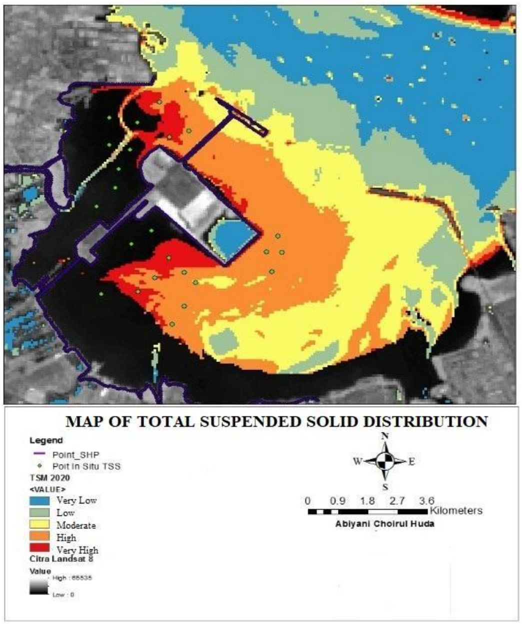


**Fig. 5. TSS Distribution map and in situ survey points.**

This analysis has a determination coefficient ($R^2$) of 89% (Fig. 6). In the validation test, correlation calculations were carried out by comparing the processed image data with the TSS ground truth results in the field. This is used to see how close or good the image data. It is considered a strong condition based on the algorithm Budiman where 0.6 is categorized as very strong [27], based on research [28]. Explains that the value of $R^2$ is very good because it exceeds the value of 0.6. In the second calculation of the TSS value, the algorithm from the research [27] will be used. The algorithm formula used is as follows:

$$ETSS\ (mg/l)\ =\ 8.1429\ (exp\ (23.704 \times 0.94 Band4)) \tag{9}$$

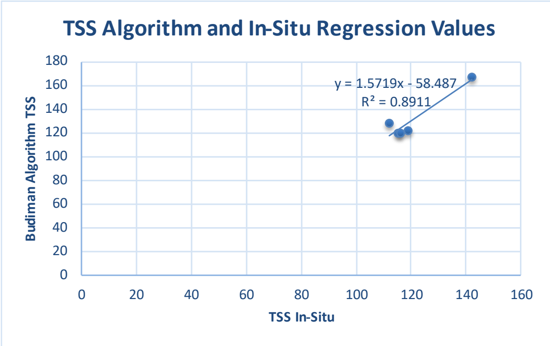


**Fig. 6. TSS observation regression chart.**

## 3.3. Pre and post modeling of TSS

### 3.3.1. Wind Condition

One that influences the speed and direction of the current is the wind factor. In Mike 21 modeling, the use of wind data as input wind forcing data contained in the hydrodynamics module. In addition to influencing the pattern of the current movement, wind can influence wave generation, so that in relation to sediment transport these three factors are intermittent. Wind data input used in March 2012 and March 2020 was adjusted for the timestep modeling simulation conducted. The following diagram of the rose wind shows the dominant direction coming from west to southeast. The following diagram of the rose wind shows the dominant direction coming from west to southeast (Figs. 7 and 8).

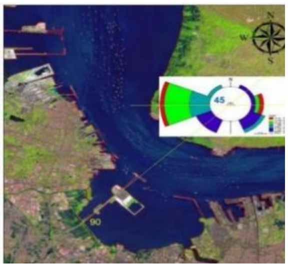

**Fig. 7. March 2012 winds.**

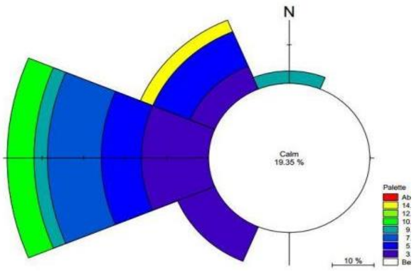


**Fig. 8. 2012 wind conditions.**

As shown on the windrose diagram (Fig. 8) and mentioned earlier that the dominant wind direction was the west part. It is forecasted from the wind frequency during 2012. The wind velocity for the dominant direction is around 3.8 m/s to 12.7 m/s.

### 3.3.2. Bathymetry

Data on seabed depth is a supporting data used in this study, so it is necessary to know the seabed condition of the waters of the Gulf, using topex satellite imagery with file format in the form of SRTM in 2011 to create a year boundary depth of the Teluk Lamong Port in 2012. The data is managed using software Global Mapper 14 generated counters with a 0.1-meter contour interval. Furthermore, the data plot has been processed in Surfer 11 software to get a bathymetry contour map in the form of 2D maps.

Figures 9 and 10 explain that the condition of the water depth in 2012 (Fig. 9) and 2020 (Fig. 10). Based on the depth data, it is used as a simulation of the current and tidal models to determine the distribution of sediment distribution.

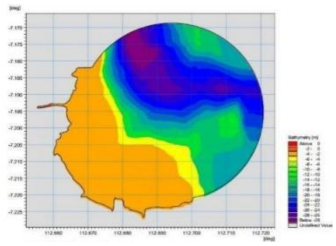

**Fig. 9. Display interpolation of bathymetry data for study locations before reclamation.**

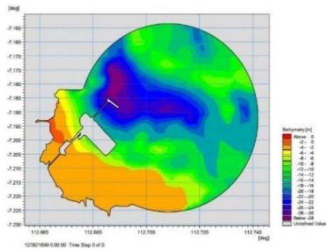

**Fig. 10. Display interpolation of bathymetry data for study locations after reclamation.**

### 3.3.3. Tidal modeling

The simulation model of this research was carried out for 15 days from 1 March 2012 at 00.00 to 15 March 2012 at 23.00 for modeling before the construction of the Teluk Lamong Port and for 15 days from 1 March 2020 at 00.00 to 15 March 2020 at 23.00 for post-development modeling Teluk Lamong Harbour. The time interval for each timestep is 3600 seconds, resulting in a total of 359 timesteps.

The model of the current pattern at the lowest seen in Fig. 11 occurred in timestep 115 on 5 March 2012 at 19.00 with the water level at low tide being -0.1448 meters at coordinates 112039'30 E - 112043'30 E and 7010'30 S - 7013'30" S and the direction of the current at low tide have the same direction as the current-to-tide pattern, but the speed of the current has decreased around 0.1-0.2 m/s. This happens because, at the lowest ebb, the water will reverse direction from the high seas to the mainland. When reversing direction, the current will stop before returning to move in the opposite direction. Thus, on one occasion, the outflow came out of the waters of Lamong Bay. On September 7, 2014, the maximum altitude was 0.77 meters, and the current velocity was 0.03-0.18 meters/s [15] and in 2006 the low tide velocity was 0.1 meters/s [13].

The current tide pattern model in Fig. 12 occurs on timestep 191 on March 8, 2020, at 23:00 with the maximum water level at low tide conditions is -1.09 meters at the red point and -1.06 meters at the black point, the current speed at this condition range between 0.01 m/s for both points.

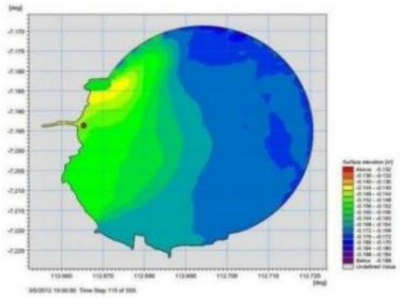

**Fig. 11. Flow modeling at the lowest tide before reclamation.**

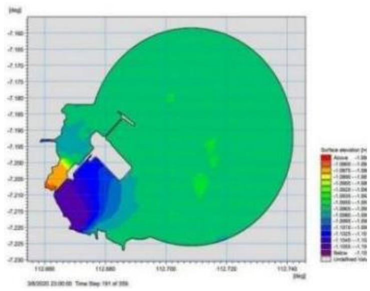

**Fig 12. Flow modeling at the lowest tide after reclamation.**

The highest current tide pattern model in Fig. 13 occurred on timestep 161 on March 7, 2012, at 17:00 with the maximum water level at the tide condition is 0.63 meters, the current speed in this condition ranged from 0.2 to 0.4 meters/s at coordinates of 112039’30 E - 112043’30 E and 7010’30 S - 7013’30” S. The direction of the current at high tide has similarities with the current leading to high tide, but in this condition, the current in the waters of the Port of Teluk Lamong starts to turn to the west side.

Thus, collected at high tide, the current flows from the east to the waters of Lamong Bay and towards the north. On September 8, 2014, the maximum height of the water surface was 1.74 and the current velocity was 0.05-0.19 m/s [15], in 2006 the tide velocity was 0.25 m/s [13].

For the current tide pattern model in Fig. 14 occurs on timestep 184 dated March 8, 2020, with the maximum water level height at tide conditions is 0.77 meters for the yellow point and 0.76 meters for the black point, the current speed in this condition ranges from 0.008 meters/s for the yellow dot and 0.008-0.02 meters/s for the second black.

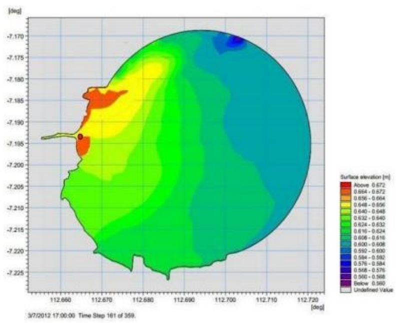

**Fig. 13. Flow modeling at high tide before reclamation**

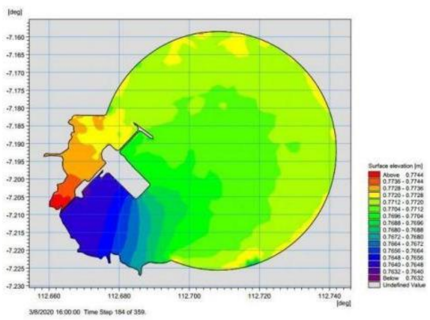

**Fig. 14. Flow modeling at high tide after reclamation.**

### 3.3.4. Total Suspended Solid modeling

Sediment transportation is important to know the speed of sediment, especially supine sediment. For non-cohesive sediments, such as sand, sedimentation velocity depends on the density of sediment and water mass, water viscosity, dimensions, and shape of sediment particles [11]. Also in calculating the rate of sedimentation hydrometer analysis is needed which aims to determine the grain size of the suspended sediment intends to determine the speed of deposition of soil grains in water using Stoke's Law, with the formula:

$$V = \frac{1}{8} + \mu \frac{Dxg}{\eta} (\gamma S - \gamma w) \quad (10)$$

Based on Fig. 15 the movement of particles when heading downward. An average speed of 0.056-0.064 meters/s and TSS value 320-360 mg/L. Based on Fig. 16 the movement of particles when heading downward. An average speed of 0.0006 meters/s and TSS value 360-400 mg/L.

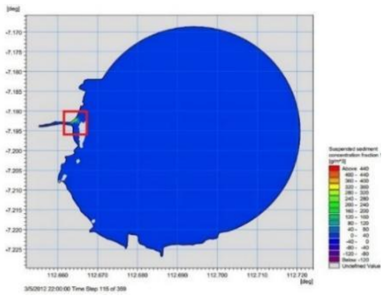

**Fig. 15. Total suspended solid modeling at low tide before reclamation.**

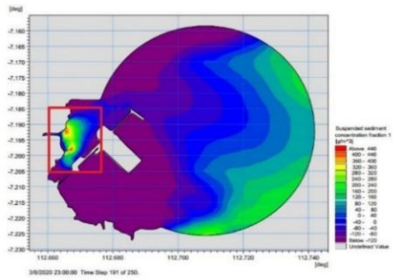

**Fig. 16. Total suspended solid modeling at low tide after reclamation**

Based on Fig. 17 the movement of particles when heading downward. An average speed of 0.040 meters/s and TSS value 325-350 mg/L. Based on Fig. 18 the movement of particles when heading downward. An average speed of 0.024-0.028 meters/s and TSS value 440 mg/L.

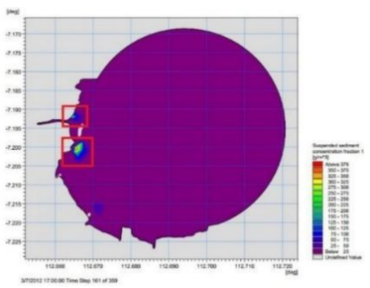

**Fig 17. Total suspended solid modeling at high tide before reclamation.**

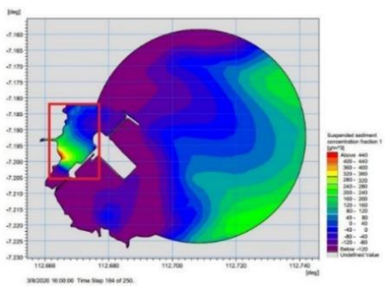

**Fig 18. Total suspended solid modeling at high tide after reclamation.**

Comparing with the remote sensing data after reclamation using GEE TSS software shows the values on 167 mg/L, 122 mg/L, 120 mg/L, 128 mg/L and 120 mg/L. Modeling before reclamation, TSS in low tide reaches 320-360 mg/L and in high tide reaches 325-350 mg/L. Modeling after reclamation, TSS in low tide reaches 360-400 mg/L and 440 mg/L in high tide.

## 4. Conclusions

Considering the analysis above, it shows that the morphology including the shoreline and the coastal process are significantly changed. Those conditions are the impact of the and use changing from the development of Teluk Lamong Harbour. Following are the detailed numbers of the changing conditions. For shoreline changes, in 2012 and 2020 Teluk Lamong Port has undergone sedimentation at coordinates 7°10'50.4"S 112°40'33.3"E with the length of shoreline changes reaching 950 m and sedimentation in the Karang Kiring Coastal area at coordinates 7°11'14.7"S 112°39'56.8"E which reached 480 m. Galang Island at coordinates 7°11'38.7"S 112°39'57.0"E from 2012 to 2020 experienced a change in shoreline reaching 430 m.

For the current pattern, it is obtained that the current in 2012 with observations to the tide speed of 0.2 meters/s, at low tide of 0.1-0.2 meters/s, when heading for the tide of 0.1 meters/s, and when the tide of 0.2-0.4 meters/s. For the current pattern it is obtained that the current in 2020 with observations when heading to recede A: 0.01-0.02 meters/s and B: 0.01 meters/s, at low tide A: 0.01 meters/s and B: 0.01 meters/s, when heading to pair A: 0.01-0.015 meters/s and B: 0.01-0.015 meters/s and at pair A: 0.008-0.0016 meters/s and B: 0.005-0.0015 meters/s.

For Total Suspended Solid (TSS), In Situ data explains the high TSS value at stations 2, 3, 4, 22 and 23 with values of 142 mg/L, 119 mg/L, 115 mg/L, 112 mg/L and 116 mg/L. When compared to remote sensing data in 2020 using the highest GEE TSS software 167 mg/L, 122 mg/L, 120 mg/L, 128 mg/L and 120 mg/L. TSS at the study site in 2012 at 320-360 mg/L at low tide and 325-350 mg/L at high tide, while in 2020 at TSS 360-400 mg/L at low tide and 440 mg/L at tide at 440 mg/L.

## Nomenclatures

| | |
|---|---|
| *Cf* | Coefficient of friction |
| *Ci* | Component *i* as a mass consultation |
| *c* | Mass concentration averaged over depth (kg / m³) |
| *D* | grain diameter (mm) |
| *Dv* | Coefficient of vertical turbulent (eddy) diffusion |
| *Dx*, *Dy* | Disperse coefficients in *x* and *y* directions |
| *h* | Water depth (m) |
| *n* | Amount of data |
| $pq\ (x, y, t)$ | flux density in the direction of the axis s, y |
| *S* | The terms source (erosion) and sink (deposition), m²/s |
| *t* | Time (s) |
| *u*, *v* | Velocity component averaged over depth, m/s |
| *u*, *v*, *w* | Flow velocity component |
| *V* | Speed of settling soil grains, cm/s |
| *Wsi* | Fall velocity, m/s |
| *x*, *y* | Coordinates, m |
| $Si$ | Source term |
| $VTx$ | anisotropic eddy viscosity |

***Greek Symbols***

| | |
|---|---|
| ʒ $(x, y, t)$ | surface elevation, m |
| ɰ | water thickness |
| $\gamma S$ | grain weigh, g/cm³ |
| $\gamma w$ | water content weight, g/cm³ |

| | |
|---|---|
| $\zeta_{XY}, \zeta_{XX}, \zeta_{YY}$ | Component of the basic shear stress due to turbulence and viscosity |
| $\sigma iTx$ | Schmidt turbulent figures |
| **Abbreviations** | |
| DSAS | Digital Shoreline Analysis System |
| EPR | End Point Rate |
| GEE | Google Earth Engine |
| KKP | Ministry of Marine Affairs and Fisheries Republic of Indonesia |
| MAPE | Mean Absolute Percentage Error |
| NSM | Net Shoreline Movement |
| PERMEND AGRI | Minister of Home Affairs Regulation in Indonesia |
| PERMENP UPR | Minister of Public Work and Public Housing Regulation in Indonesia |
| RMSE | Root Mean Square Error |
| TSS | Total Suspended Solid |

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