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# Impact of Reclamation Development on Sedimentation and Current Pattern in East Coast Surabaya (Pamurbaya)

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## ABSTRACT

*Reclamation is an effort to establish a new land area either in coastal areas or in the middle of the ocean. In Pamurbaya area a number of property projects both housing and apartments is still continuing. Environmental impacts of the coastal reclamation project is in the potential increase of flooding. The changes include the extent of the cluster, the composition of river sediments, the tidal pattern, the pattern of ocean currents along the coast and damaging the water system. This study examines changes in current patterns, morphology, and sedimentation rate due to the reclamation modeled using Delft3D software. The pattern of current flow after the reclamation has changed. Basic surface changes that occur before and after reclamation in each crossection is by difference, crossection 1 = +0.22 m, crossection 2 = -0.19 m, and crossection 3 = +0.11 m. The sign (+) shows the occurrence of sedimentation, while (-) is erosion. The condition after the reclamation in crossection 1 is sedimentation, crossection 2 is erosion, and crossection 3 is sedimentation. The difference in intensity is very small, therefore the erosion and sedimentation which took place after reclamation is not too significant.*

**Keywords:** *reclamation, sedimentation, current, Delft3D*

## 1. INTRODUCTION

Reclamation is a way to create or to expand a new land region at shore or offshore location. The main aim of reclamation is to develop a non-developed water region and to utilize its potential for economic purpose and other strategic purpose. The new land region can be utilized as a residential area, industrial area, business and offices area, airport, cities, farming area, and highways. Other purposes are for fresh water reservoir, waste management area, embankment to protect the preserved land from abrasion, and to create a tourist attraction.

The reclamation studied herein is located in the Zone III from the North East end to the East of Surabaya, at sub-district Bulak, as shown in Fig.1. The reclamation, as explained before, is an expanded land region at the shore, by utilizing any means of engineering to create a new region that can cause erosion and sedimentation problems. Hence, a thorough study of the pattern of the current and the sediment transport, after the reclamation and before the reclamation is needed.

In this study, the main discussions are on the pattern of current and the sediment transport after the reclamation is accomplished. The sediment transport after the reclamation is modeled numerically using the Delft3D software. The results of this simulation can be used by the government and investors as a consideration on what to do when the erosion and sedimentation is happening after the reclamation.

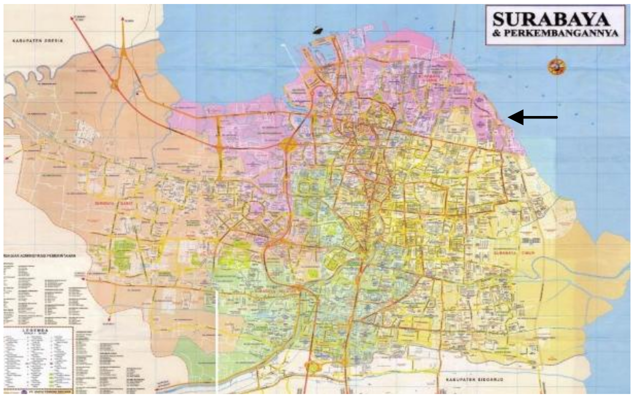


Figure 1. The location of reclamation in NE and E coast of Surabaya

## 2. THEORY

### 2.1 Reclamation

Reclamation can give advantages and can help the city to provide an area for city expansion, coastal zone management, tourist attraction development, etc. However, one must always remember that reclamation is some kind of human intervention to the balance of the natural state of shore environment. A disruption in the dynamical balance of the shore environment, will create a change in the current pattern, erosion, and sedimentation. This change will affect the balance of the environment for a long time. Indonesian Government Regulation No. 27, Article 34, 2007 explains that reclamation can only be done if the social and economic benefits are greater than the social economical costs. However, the process of reclamation should be done with careful consideration such as:

a) the prosperity of the people;
b) the balance between sustaining the environment and the people's interest; and
c) the technical requirements in excavating, dredging, and material storing [1].

### 2.2 Sediment and the Characteristics

Sediment material in an area have some benefits for the people such as, construction material, coastal restoration material, and the place marine biodiversity to reproduce. The too few sediments can create a damage in the environment. One of the examples of the damage is that which happened in Louisiana beach where it is eroded every year because of the low level of sediment transport from the Mississippi River.

Likewise, too much sediment can create damage in environment and in economic aspect. For example, if a harbor area has a large deposit of materials on its sea bed, there will be a decrement in the port's water depth. This can prevent the ship from entering and exiting the harbor, so the ship has to decrease its cargo to prevent the ship from grounding [2]. Sediment can be classified based on the size of its grain such as clay, mud, sand, gravel, cobble, and boulder.

### 2.3 Shore Sediment Transport

The transportation of sediment from a certain area to another area in the vicinity basically depends on the balance between the lifting velocity and sinking velocity on the particle. There are three (3) types of sediment transport [3]:

a) Bed Load Transport
   In this condition, the material is transported in a relatively slow current not far from the riverbed, so the transported material will only slide along the sea bed.
b) Wash Load Transport
   Wash is a transportation of fine particles such as clay and fine sand (dust). In this condition the material is transported in a relatively fast current.
c) Suspended Load Transport
   In the condition, materials such as fine grain of particles are suspended with the current. The faster the velocity of the flow, the more the particle will move.

### 2.4 Tides

Triatmodjo [4] defines the tide as a natural phenomenon that creates a fluctuation in sea water level. This fluctuation is caused by the earth gravitation and other planets. The effect of earth gravitation and other planets will create not only the tide, but also the change in earth shape (bodily tide) and atmosphere (atmospheric tide).

The spring tide happens when the earth, the moon, and the sun are in a straight line. The neap tide happens when the earth is perpendicular to the moon. In a certain region the cycle of the tide happens one time to twice in a day. The tides are classified based on the fluctuation of the water level. Figure 2 below shows the types of the tide, where: A) dual-daily, B) mix which is tend to be dual-daily, C) mix which is tend to be singular-daily, and D) singular-daily.

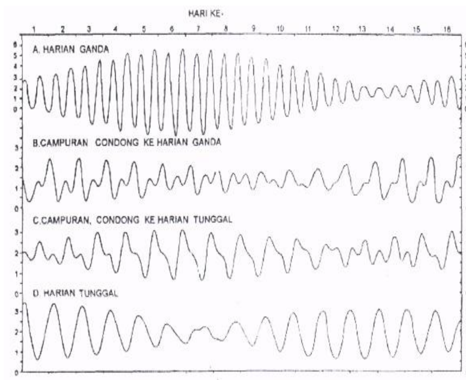


Figure 2. Tidal type [4]

### 2.5 Tide Current

Tide current is the horizontal movement of waters which is caused by the fluctuation of water level from tide. The tide current has the opposite direction with the receding current [5,6].

### 2.6 Delft3D

Delft3D is a numerical software to solve the shallow water equation in high velocity variable using the grids in two dimensions or three dimensions, as exhibited in Fig. 3 [7].

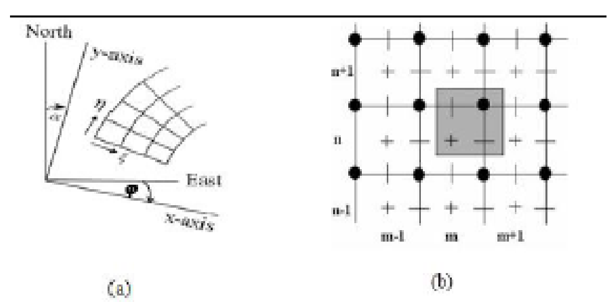


Figure 3. (a) Spherical coordinate system and (b) Cartesian coordinate system.

## 3. RESEARCH METHODOLOGY

The research methodology and procedure is as exhibited in flowchart diagram of Fig. 4.

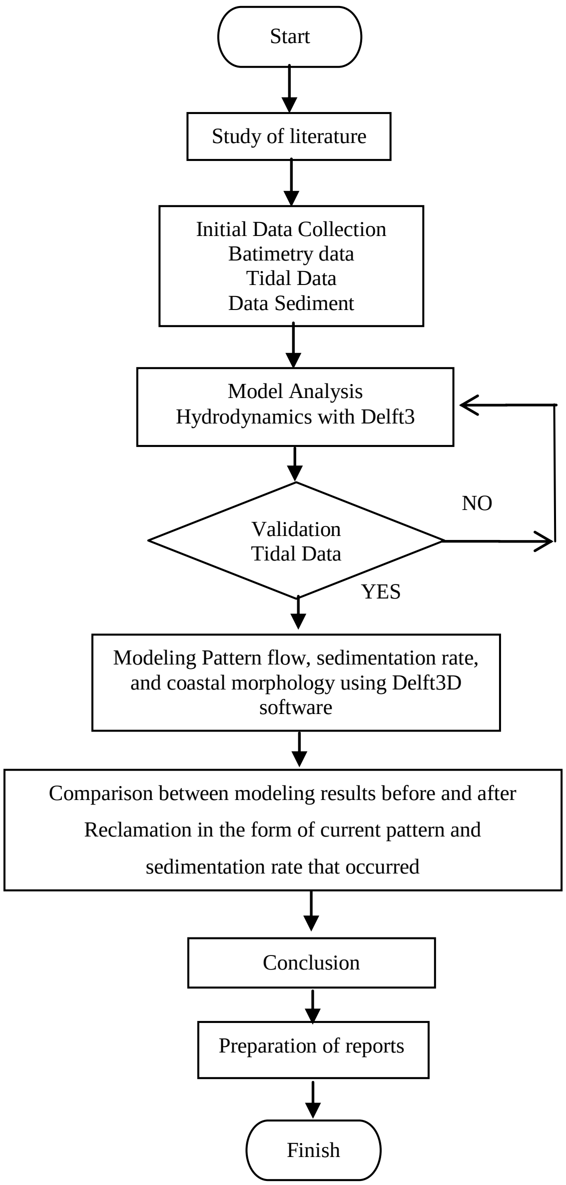


Figure 4. Flowchart diagram of research methodology and procedures

## 4. ANALYSIS AND DISCUSSIONS

### 4.1 Bathymetry

The bathymetry data used in this final project is collected from the Thesis Research of water region which expands from Juanda Airport to the Suramadu Bridge, Surabaya in East Java [8]. The bathymetry shows that the depth reached 15 m. The data shows the bathymetry in the year of 2016, which can be seen in the Fig. 5 below.

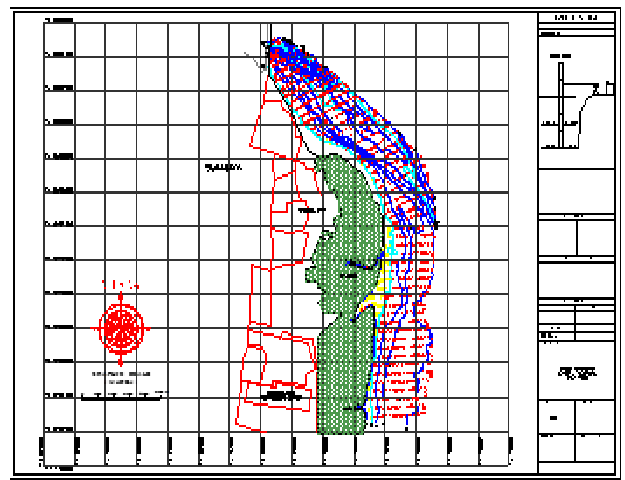

Figure 5. Bathymetry of East Coast Surabaya in 2016

### 4.2 Data of Sediment

The sediment sample collected from the location is brought to the laboratory to be tested. The grain size used for the input of the Delft3D model is D50. This is presented in Table 1 below.

Table 1. Grain size data of the corresponding sediment

| Sieve | | Sample | |
|---|---|---|---|
| **Number** | **Empty Weight** | **Number** | **Soil Weight** |
| 4 | 505.1 | 4 | 507 |
| 10 | 470.6 | 10 | 480.4 |
| 20 | 398.8 | 20 | 410.2 |
| 40 | 381.9 | 40 | 415.5 |
| 100 | 334.1 | 100 | 589.9 |
| 200 | 264 | 200 | 402 |
| **Pan** | **338.5** | **Pan** | **382.7** |

### 4.3 Tidal Data

The data used for the input of the Delft3D model is the tidal data of Juanda-Suramadu in the year of 2016 for 1 month period, ie. from June 9$^{th}$ 2016 to July 8$^{th}$ 2016. The tidal graph is presented in Fig. 6 below

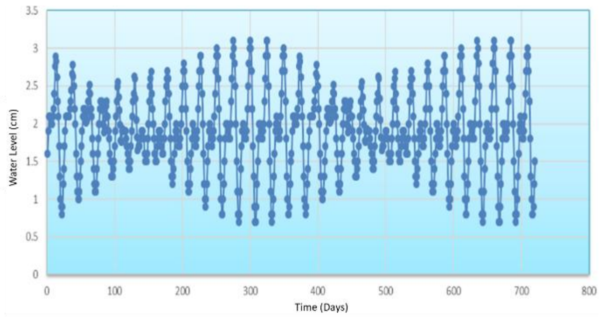


Figure 6. Tide graph of Juanda – Suramadu

### 4.4 Meshing

Meshing consists of grids that are presented with the data of the water depth. This data is collected from the exported bathymetry data in Delft3D. The meshing will show the area of interest where the study will be conducted. In this study, there are two meshing model, the first is the preserved existing model (before the reclamation), and the other is the model after the reclamation is done. This can be seen in Figs. 7 and 8 below.

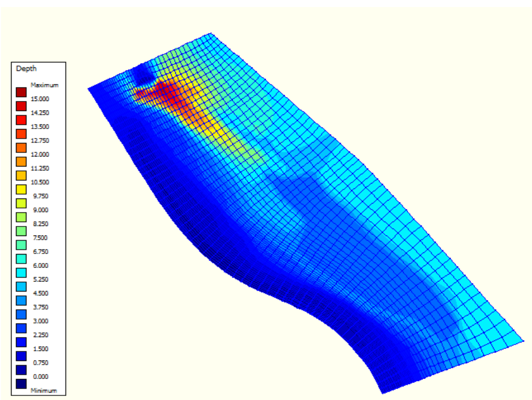

Figure 7. Meshing on existing conditions

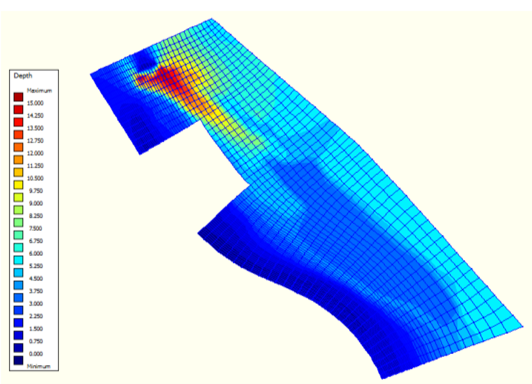

Figure 8. Meshing after reclamation

### 4.5 Tidal Data Validation

The tidal data validation is done to meet the validity of the inputted Delft3D tidal data. If the output from the Delft3D has a relatively small difference from the inputted data, then the simulation can be resumed; otherwise the simulation should not be resumed. As stated in the explanation before, the inputted tidal data is from the period from 00.00 of June 9th 2016 to 23.00 of 8th July 2016, all in Western Indonesian Time Zone. From the conducted simulation as presented in Fig. 9, the error obtained is 0.04%. This result conclude that the process of simulation is valid.

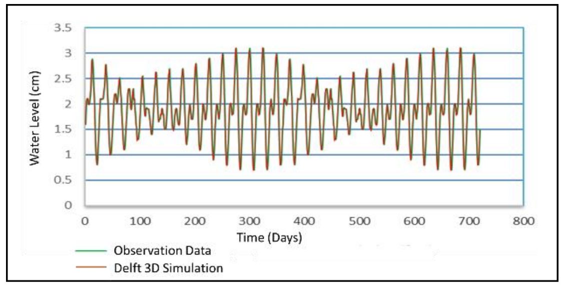


Figure 9. Tidal validation graph

### 4.6 Pattern of the Current

From the result of Delft3D simulation, the highest tide happens on June 20$^{th}$ 2016 at 10.00 Western Indonesian Time, when the current is moving from the open sea to the shore. The lowest tide happens on June 21$^{st}$ 2016 at 18.00 Western Indonesian Time, when the current is moving from the shore to the open sea. The highest tide and the lowest tide for the existing condition (before the reclamation) and for the after reclamation condition are presented in the figures below.

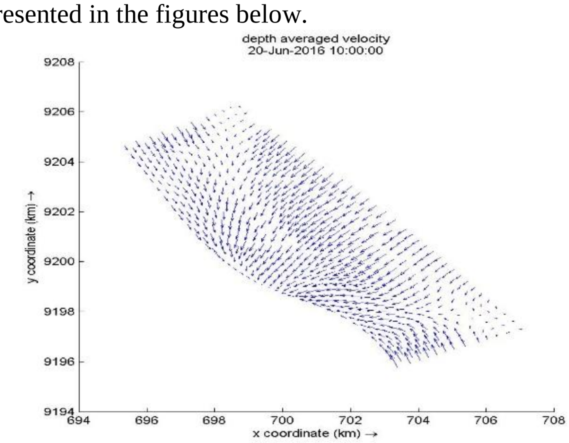


Figure 10. Highest tidal flow pattern on existing condition

From the current pattern at the highest tide for existing condition, as presented in Fig. 10, it can be observed that the current pattern moves from the open sea to the shore. This is obtained from the result of Delft3D simulation.

From the current pattern at the lowest tide for existing condition as depicted in Fig. 11, it can observed that the current pattern moves from the shore to the open sea. This phenomenon is happening at 18.00 Western Indonesian time on June 21th 2016.

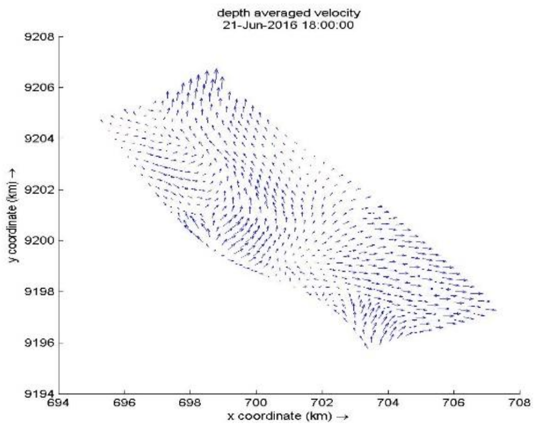


Figure 11. Lowest tidal flow pattern on existing condition

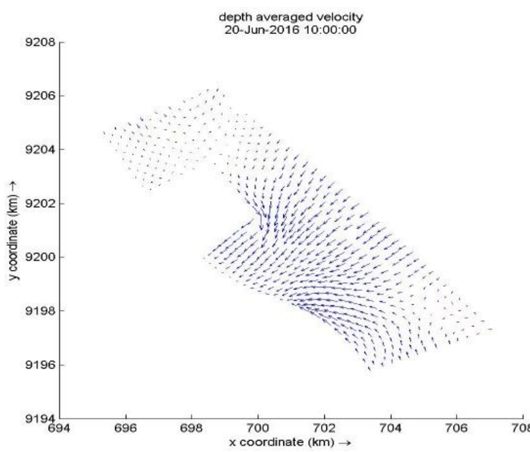


Figure 12. Highest tidal flow pattern after reclamation

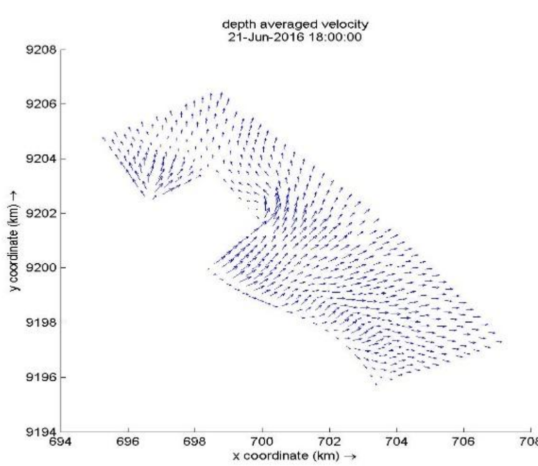


Figure 13. Lowest tidal flow pattern after reclamation

From the current pattern at the highest tide for condition the after reclamation as shown in Fig. 12, it can observed that the current pattern moves from the open sea to the shore. The pattern is different from the existing condition because of the reclamation itself. The change in the pattern is caused by the reclamation shape.

From the current pattern at the lowest tide for the after reclamation condition as exhibited in Fig. 13, it can observed that the current pattern moves from the shore to the open sea. This phenomenon is happening at 18.00 Western Indonesian Time on July 21st 2016.

### 4.7 Sediment Transport Condition

The condition of sediment transport can be used to show information about the movement of the sediment per time unit. The condition of sediment transport is evaluated at the existing condition and the after reclamation condition. From the series of simulation, the last result is used to represent all of the simulation. The simulation ends at 23.00 Western Indonesian Time on July 8th 2016. The result can be shown in Fig. 14 and 15 below.

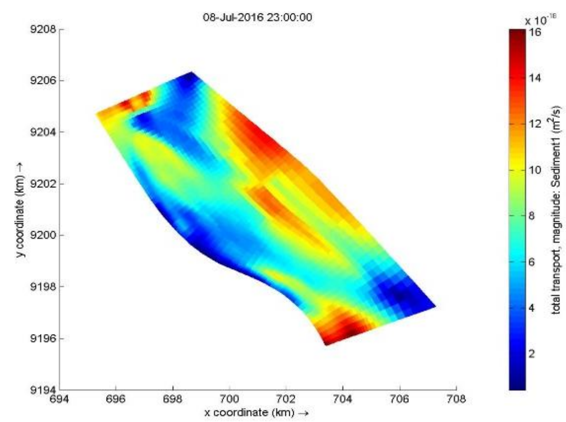


Figure 14. Total transport on existing condition

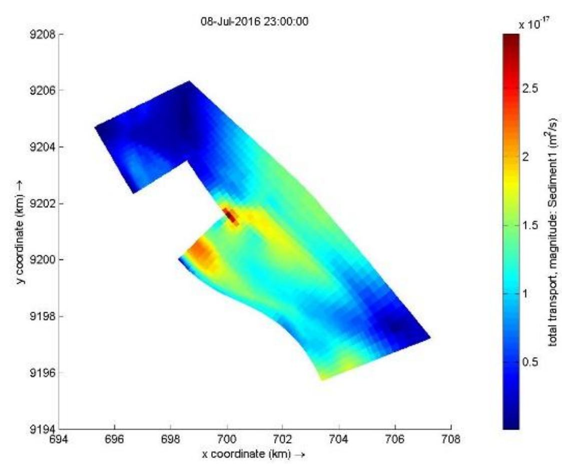


Figure 15. Total transport after reclamation

At the existing condition, as can be seen in Fig. 14, most of the sediment transports are changing. This change depends on the current pattern at that same condition. Because of the change in current pattern after the reclamation, the sediment transport around the reclamation area will also undergo some changes, as indicated in Fig. 15. On the marked area, the transport sediment is approximately 2.5 x $10^{-17}$ $m^2/s$.

### 4.8 Morphological Change

The change in morphology on the seabed is caused by the erosion and sedimentation (deposit material) on it. This is affected by a number of factors such as the sediment transport, the current pattern, and the current velocity. The change in morphology of the seabed at existing condition and the after condition are presented in Fig. 16 below.

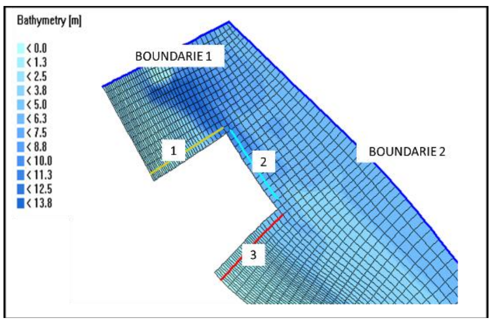


Figure 16. Location of cross section

### 4.9 The Comparison of the Morphological Change

The comparison in the change of seabed morphology is made between the morphology at existing condition and the after reclamation condition. This can be seen in Figs. 17 to 19.

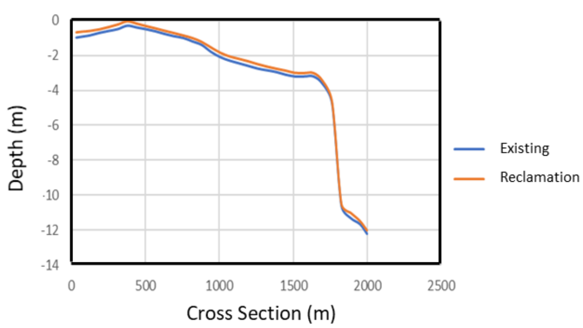


Figure 17. Graph of base surface change on cross section 1

From Fig. 17, it can be observed the graphic of seabed morphological change after the reclamation. On the cross section 1, the deposited material is found to be 0.22 m thick. This fact suggests that sedimentation is happening on the cross section 1.

From Fig. 18, it can be observed the graphic of seabed morphological change also after the reclamation. On the cross section 2, the eroded material amounted of -0.19 m thick. This fact indicates that erosion is happening on the cross section 2.

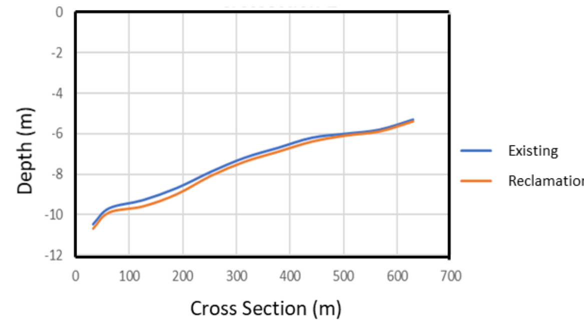


Figure 18. Graph of base surface change on cross section 2

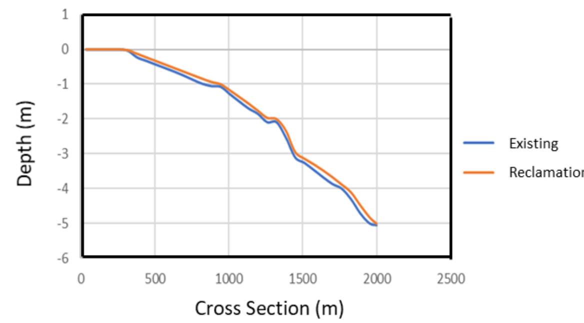


Figure 19. Graph of base surface change crossection 3

From Fig. 18, it can be observes the graphic of seabed morphological change after the reclamation. On the cross section 3, the deposited material amounted of 0.11 m thick. This fact shows that sedimentation is happening on the cross section 3, although not as much as on cross section 1.

From the comparison of the results, it can be calculated the difference between the two conditions, namely exiting and the after reclamation. Positive sign (+) shows that sedimentation is happening at that location, while negative sign (–) shows that erosion is happening at that location. These differences are recapitulated in Table 2 below.

Table 2. Comparison of morphological change

| Observation Point | Basic Surface Difference (m) |
|---|---|
| Cross section 1 | + 0.22 m |
| Cross section 2 | - 0.19 m |
| Cross section 3 | + 0.11 m |

## 5. CONCLUSIONS

A study has been carried out to observe the impact of reclamation development on sedimentation and change in the pattern of current Pattern at East Coast Surabaya. Some findings have been attained and concluded as follows:

- The current pattern at the highest tide is moving from the open sea to the shore. While at the lowest tide, the current pattern is moving from the shore to the open sea. This shows that there is a change in the current pattern which is affected by the reclamation.

- The change in seabed morphology before and after the reclamation on cross section 1 is +0.22 m, on cross section 2 is -0.19 m, and on cross section 3 is +0.11 m. The positive sign (+) shows that sedimentation is happening at that location. While negative sign (-) shows erosion is taking place at that location.
- Sedimentation happens on cross section 1 and cross section 3, while the erosion happens on cross section 2. From the simulation it can be concluded that the change in the seabed morphology before and after the reclamation is not that significant.

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