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Numerical Model of Correlation between Distance and Length of Groyne toward the Protected Coastal Areas

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Abstract— *Groin is a structure built to prevent the coastline from erosion. This structure is not built correspondingly for the placement design and the beneficial use. Groin has function to withstand sand that is drifted at the shore as the moving sand is accumulated at the both sides of updrift groin. The condition makes a changing along coastline and decreasing wave angle. While groin has a simple concept in design, the relation between groin and coastline is more complex with limited design of functional groin. Therefore, it is necessary to do a research to get the effective groin design. Numeric method will be used in this research with consideration of inadequate knowledge and functional design guide. By using MIKE21, the numeric model will result in hydrodynamic simulation and coastline changing of straight type groin. This program determines spatial discrete with cell centered finite volume method. Mike21 contains methods such as flow simulation and sediment transport, and wave propagation simulation to flow module. In this method, the data of wind velocity, wave angle, and bathymetry map will be considered to fulfill the model design. This research aims to find the relation between the distance and the effective length of groin towards coastline angle in controlling the sediment and to get the current speed and wave height value by using straight-type groin. Originally the coastal slope was around 0.0016 – 0.0029. The bottom slope of Coastal when the simulation reaches one month changes to 0.0026 – 0.0071 due to groyne installation.*

Keywords— *Groin, straight type groin, Numerical Method, MIKE21, finite volume.*

I. INTRODUCTION

Coastal erosion is one of the serious problems with coastline changes caused by natural factors, such as wind, currents and waves. This has become one of the frequent coastal dynamics phenomena called Littoral drift, where the sediment grains at the bottom of the coastal are lifted (eroded). Furthermore, the sediment grains are transported by 2 types of driving force, namely the wave energy component in the direction along the coast and the alongshore current generated by the breaking wave (Longshore Current). Then the grains will settle if the flow cannot maintain its movement. One of the countermeasures methods is the use of coastal protection structures, where the structure serves to protect the coast from damage due to wave and current attacks. One of the coastal protective structures from erosion that is commonly used is groynes.

Groin is a coastal security structure built protruding relative to the direction of the coastline. Groin construction materials are generally in the form of wood, steel, concrete, and stone. Groin installations interrupt the flow of coastal currents so that the sand is trapped on the Upcurrent Side, while on the Downcurrent Side erosion occurs, due to the movement of the coastal currents continues. If beach damage occurs due to sediment transport along the coast, then groynes can be used to prevent such damage. The groyne's function is to hold sediment transported along the coast, so that sediment does not move to other places (Triatmodjo, 2014).

Usually the protection of the beach is done by making a series of buildings consisting of several groynes which are placed a certain distance. With the groyne system, sediment transport along the coast will not come out of the space between the two groyne. Sediments will be blocked by groin which is downstream and deposited on the upstream side. If the waves are in the opposite direction, the sediment that is deposited will erode and transport to the left and will be blocked by groynes next to it. Thus the sediment will remain in the segment between the two groynes so that the coastline will be stable

Determination of the groyne layout becomes important in the groyne construction. A groin distance that is too close will provide an expensive groin system and from an artistic point of view will disturb the beauty of the beach. While the distance is too far will result in an ineffective groin system and erosion will continue, so the groin function to capture sediment is ineffective. According to Erlich and Kulhawy, the distance between groynes on sandy beaches is specifically 2 to 3 times the length of the groyne (L / P = 2 to L / P = 3).

Therefore modeling is needed to determine the effectiveness of a groyne construction by modeling the length and distance between groyne required at a certain coastline distance.

II. STUDY OF LITERATURE

A. Breaking Waves

If a wave spreads from a deep place to a shallower place, at a certain location the wave will break. Breaking wave conditions depend on the slope of the beach bottom and the steepness of the waves.

B. Wave Generators

In wave generation, there are a number of parameters that cause waves:

1. Average wind speed on the surface of the water (Uw)
2. Wind Direction
3. Fetch

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4. Duration of wind gusts on fetch

C. Wind

Wind is an ocean wave generator. Therefore wind data can be used to estimate the height and direction of waves at a location. Wind data are classified based on speed and direction, then the percentage of events is calculated. The direction of the wind is expressed in the form of eight directions of the compass (North, Northeast, East, Southeast, South, Southwest, West and Northwest). Wind speed is expressed in knots.

D. Fetch

Fetch is a region of wave formation which is assumed to have a relatively constant wind speed and direction. Wind direction is still considered constant if the change is not up to 15 °. while the wind speed is still considered constant if the change is not more than 5 knots (2.5 m / s) (Triatmodjo, 2011).

E. Tide

Tides are sea level fluctuations due to the attraction of objects in the sky, especially the sun and moon against the mass of sea water on earth. Knowledge of tides is important in the planning of coastal and harbor safety structures. The highest water level (tide) and lows (low tide) is very important to plan for these buildings (Triatmodjo, 2011).

F. Bathymetry

Bathymetry is the water depth measurement of oceans and lakes, as well as all the information obtained from such measurements. Bathimetry survey aims to get bathymetry data in the form of bathymetry maps. Bathymetry map is needed to determine the state of the depth of the sea around the work site. This map is used to determine the wave conditions at the job site (Triatmodjo, Bambang: 2011).

G. Sediment Transport

Waves and currents in the ocean can transport sediment shoreline parallel and perpendicular to the shoreline. This sediment movement can change coastal morphology such as depth and coastline. Changes in the coastline can occur due to erosion or sedimentation.

H. Groin

Groin is a coastal protective structure that is usually made perpendicular to the coastline and serves to hold sediment transport along the coast so that it can reduce or stop erosion that occurs (Triatmodjo, Bambang: 2011).

Figure 1 Types of Groynes

In general, groynes are in the form of straight buildings jutting toward the sea and perpendicular to the coastline. Groynes have several types, there are straight types, T types or L types which can be seen in Figure 1. The choice of types of groynes depends on the use and planning needs.

I. Numerical Modeling Simulation

This simulation method uses a depth-integrated 2-D sediment transport model generated by waves and currents. The Spectral wave model is used to simulate the transmission of static waves in an area in order to produce a current field (current) as input in the Hydrodynamic model. While the Hydrodynamic model is used to simulate flow circulation (water discharge at the inlet and outlet) as an input for the Sediment Transport model. Finally, the Sediment Trasnport model is running to simulate the movement of sediments (both bed sediment transport and suspended of non-cohesive sediment transport) in an area to determine the movement of sediment, especially around the structure.

J. Hydrodynamic Module

Horizontal movement of currents in 2-D is simulated with the Mike21 Flow Model FM. The governing equation in this model uses the Continuity equation and the Navier-Stokes equation. Both equations are integrated into depth to get the 2-D hydrodynamic equation in shallow water, in the form of an equation as follows:

Continuity equation

$$\frac{\partial \eta}{\partial t}+\frac{\partial uh}{\partial x}+\frac{\partial vh}{\partial y}=\frac{\partial h}{\partial t} \tag{1}$$

Navier-Stokes equation

x-axis direction:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial \eta}{\partial x}+\frac{1}{\rho h}\left(\frac{\partial S_{xx}}{\partial x}+\frac{\partial S_{xy}}{\partial y}\right)+\frac{gu\sqrt{u^2+v^2}}{C^2h}+A_H\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \tag{2}$$

y-axis direction:

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial \eta}{\partial y}+\frac{1}{\rho h}\left(\frac{\partial S_{yx}}{\partial x}+\frac{\partial S_{yy}}{\partial y}\right)+\frac{gu\sqrt{u^2+v^2}}{C^2h}+A_H\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right) \tag{3}$$

K. Sand Transport Module

The Sediment Transport Model is simulated with an additional application on the MIKE 21 Flow Model, the Sand transport module. Calculation of the sediment transport model produced by a combination of current and wave, is calculated by involving stress wave radiation and calculation of the resultant flow.

L. Modeling Using MIKE 21

There are 3 phases in using MIKE 21, including the pre-processing phase, the processing phase, and the post processing phase which are all done separately. The first phase is to use a mesh generator to create a mesh model and determine the model boundaries. And use time series to change data in the form of time series. The second phase uses a coupled model to input data and run simulations simultaneously. The third phase is the animation of the simulation results and the results of running in the form of time series

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III. METHODOLOGY

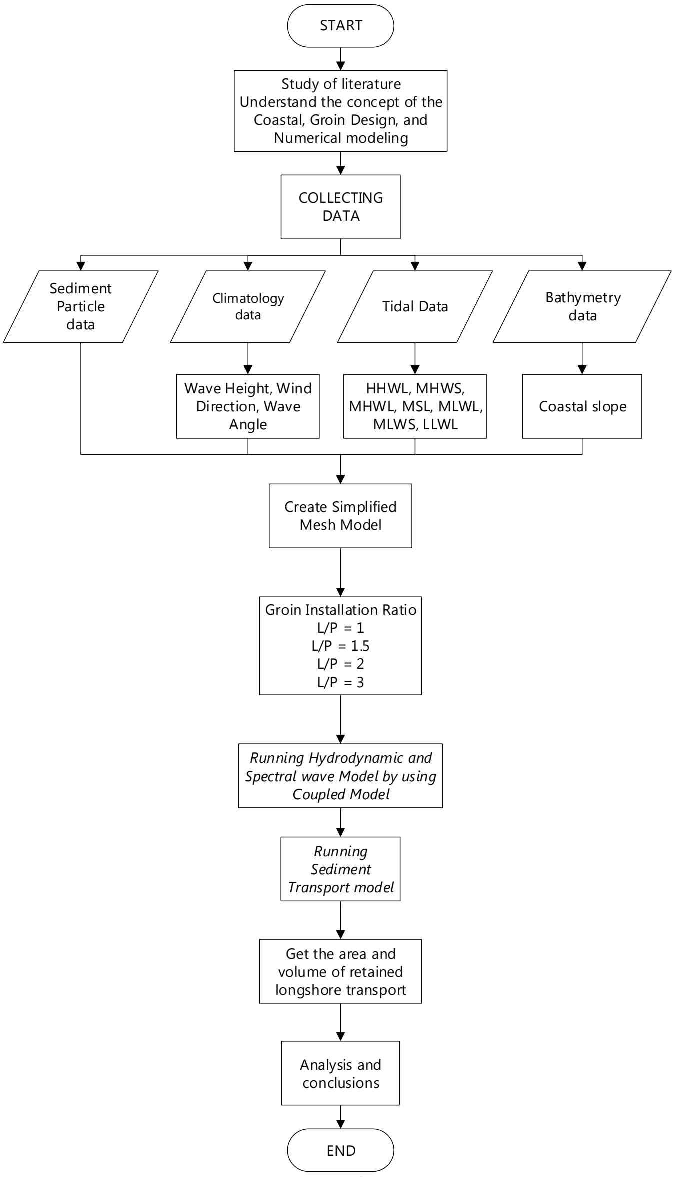

Figure 1 . Flowchart of research method

The results obtained are the area and volume of the sediment area that is protected by groyne, current speed and wave height that occur at each point of view in each scenario model. Then compare the area and volume against the groynes L / P ratio.

IV. RESULT

A. Bathymetry Analysis

From the GEBCO data, it is known that the coast of the city of Semarang to be used as a model of this study has a slope of the beach base in the range of 0.216% - 0.24%. Based on the calculation of the beach slope in the previous study ranged from 0.178% - 0.2% with the category of a sloping beach slope.

B. Wave Height and Wave Period Analysis

In the calculation of height and wave period, the data used is Wind data. In wave calculation it is better to use wave data. However, in Indonesia wave data is not available, so this wave calculation is done using wind data which is a factor in the formation of waves. In this wave calculation, the method used is the hindcasting method. This method is explained in SPM 1984 (Shore Protection Manual).

TABLE 1. Calculation of Height and Period of Waves

Year	Month	Hm0	Tp
		meter	s
2011	Januari	0.22	1.80
	Februari	1.37	6.17
	Maret	0.28	2.76
	April	0.28	2.76
	Mei	0.08	1.20
	Juni	0.08	1.20
	Juli	0.11	1.39
	Agustus	0.14	1.51
	September	0.11	1.39
	Oktober	0.11	1.39
	Nopember	0.08	1.20
	Desember	0.22	1.80

C. Sediment Parameters

In this study, sediment data input was taken from previous research data conducted by Mardi Wibowo in 2018. Floating sediment concentration values ranged from 0.028 to 0.063 gr / L in sea waters with depths of 2, 6 and 8 meters. While in the river mouths it ranges from 0.036 - 0.079 gr / L. Basic sediment is classified as fine sand with d50 ranging from 0.1 - 0.23 mm. Sediment porosity value at Semarang beach is 0.684% with sediment density of 2.446 gr / cm3. These sediment parameters are needed to input data into the sediment simulation later.

D. Simulation Output

MIKE 21/3 Integrated Models displays simulation results in the form of graphs, tables and area simulation models. Results in the form of graphs and tables are used to display detailed results in the form of numbers or values from calculations at specific locations / points. Below this will be presented the calculation results for each module with several choices of display types. The results of this output can be seen using the data viewer. In this study, the cooled simulation output is current speed, wave, and bed level change on the results of the simulation duration of 1 month and 3 months

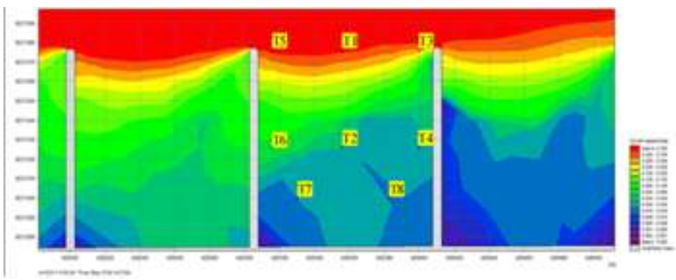

Figure 1. Scenario Point Coordinate L/P = 1 for the results of Current Speed and Wave Height

Condition 1 is a scenario where the ratio of the distance of the groyne to the length of the groyne or L / P = 1. Can be seen in the figure 1, the coordinate display to find the current speed and wave height values from the simulation model

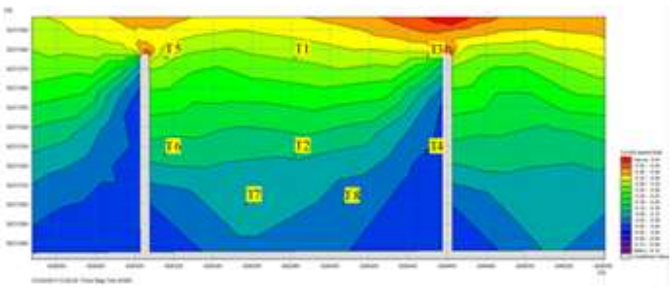

Figure 2. Scenario Point Coordinate L/P = 1.5 for the results of Current Speed and Wave Height

Condition 2 is a scenario where the ratio of the distance of the groyne to the length of the groyne or L / P = 1.5. Can be seen in the figure 2, the coordinate display to find the current value and wave height from the simulation model

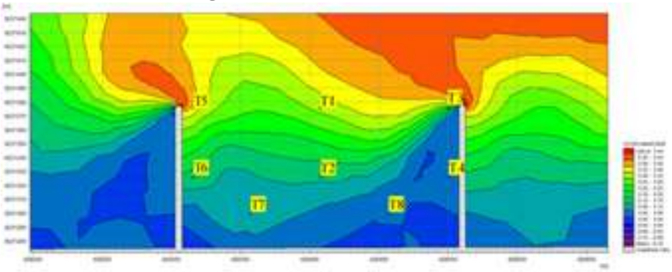

Figure 3. Scenario Point Coordinate L/P = 2 for the results of Current Speed and Wave Height

Condition 3 is a scenario where the ratio of the distance of the groyne to the length of the groyne or L / P = 2. Can be seen in the figure 3, the coordinate display to find the current value and wave height from the simulation model

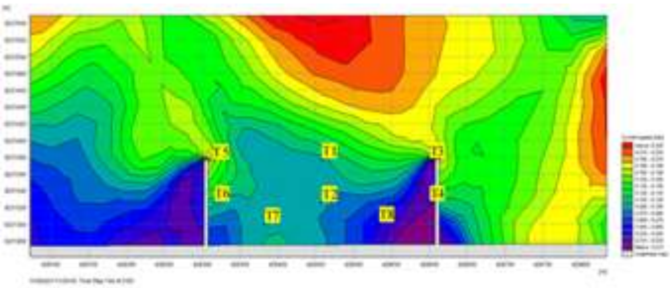

Figure 4. Scenario Point Coordinate L/P = 3 for the results of Current Speed and Wave Height

Condition 4 is a scenario where the ratio of the distance of the groyne to the length of the groyne or L / P = 3. Can be seen in the figure 4, the coordinate display to find the current value and wave height from the simulation model

E. Hydrodynamic Module Calculation Results

From each scenario, it can be seen the difference in current speed that is affected by the distance and length between groynes. Figure 5 and Figure 6 explain the graph in each scenario and can compare the current speed in each scenario. From the graph, it proves the current velocity in the groyne area, the closer to the coast the smaller the current velocity. The velocity at point T5 is greater than the speed at point T3 although both are near groynes because the direction of the current moves from east to west. Current speed at point T6> T2> T4.

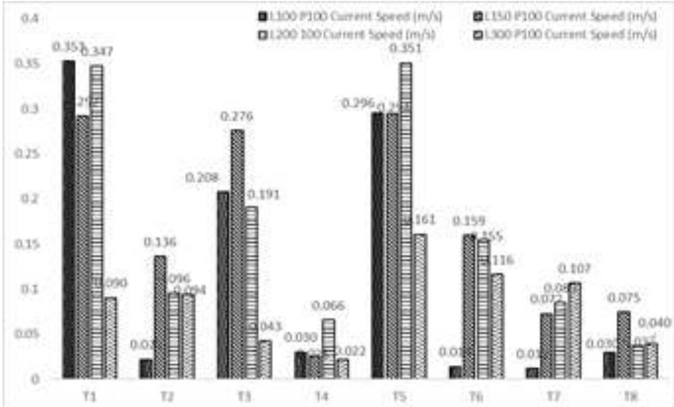

Figure 5. Current Speed Recap Chart Review Point T1 to T8 duration 1 month

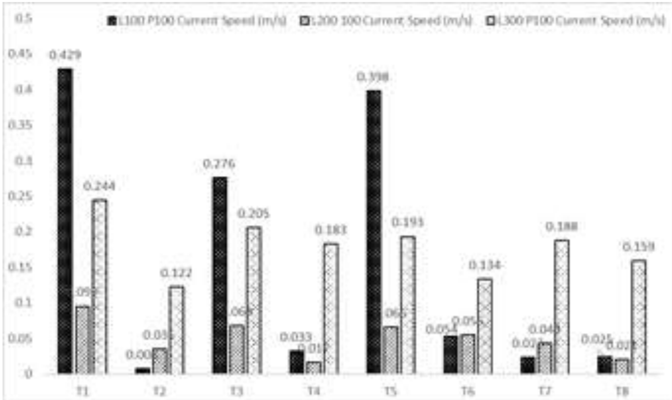

Figure 6. Current Speed Recap Chart Review Point T1 to T8 duration 3 month

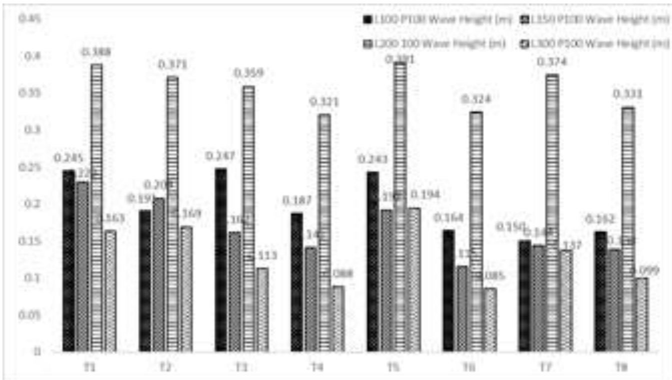

Figure 7. Wave Height Recap Chart Review Point T1 to T8 duration 1 month

F. Hydrodynamic Module Calculation Results

From each scenario it can be seen the difference in wave height that occurs which is influenced by the distance and length between groynes. Figure 7 and Figure 8 explain the graph in each scenario and can compare the wave height in

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each scenario. From these graphs prove, the closer the beach is, the smaller the wave height. Wave height at point T5 is greater than speed at point T3 although both are near groynes because the direction of the current moves from east to west.

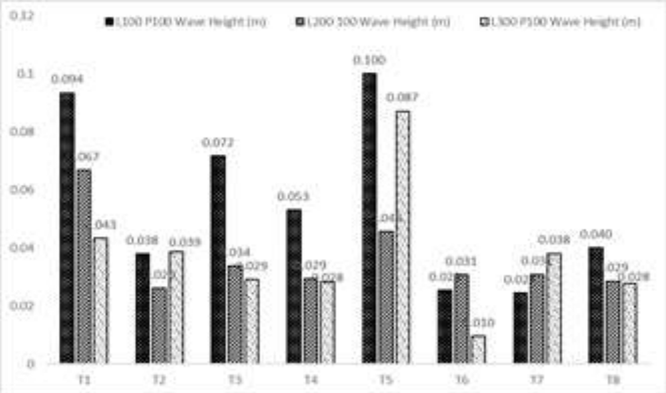

Figure 8. Wave Height Recap Chart Review Point T1 to T8 duration 1 month

G. Sand Transport Module Calculation Results

After running the simulation model is complete and the data viewer results of the Sand Transport module simulation are opened. There is an output that results from the calculation, select 'Bed Level Change' and select the desired time series. In this study, the simulation used is a simulation for 1 month and a simulation of 3 months. After that, the simulation results are processed and the relationship between the volume of sediment and the area held by the groyne building is obtained as shown in the Figure 9 and Figure 10.

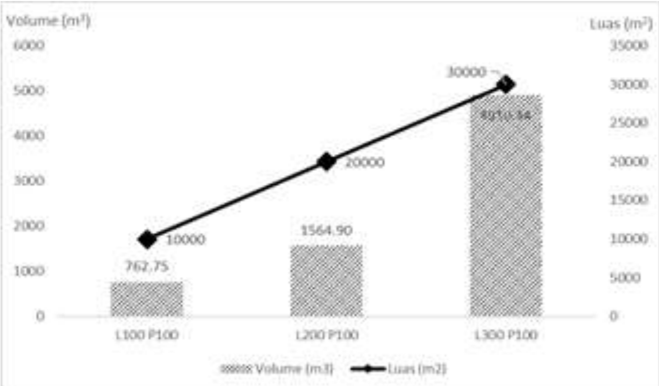

Figure 9.Graph of Relationship between Sediment Volume and Sediment Area Detained in Each Scenario (1 Month)

H. Coastal Morphology

For the scenario L / P = 1, the bottom slope of the Coastal under existing conditions is 0.0016. The bottom slope of the Coastal when the duration in the first month and third month are 0.0071 and 0.015, respectively. For the scenario L / P = 1.5, the bottom slope of the Coastal under existing conditions is 0.0018. The bottom slope of the Coastal when the duration in the first month is 0.0062. For the scenario L / P = 2, the bottom slope of the coast under existing conditions is 0.0022. The bottom slope of the Coastal when the duration in the first month and third month are 0.0027 and 0.0067, respectively. For the scenario L / P = 3, the bottom slope of the Coastal under existing conditions is 0.00285. The bottom slope of the Coastal when the duration in the first month and third month are 0.0026 and 0.0075, respectively.

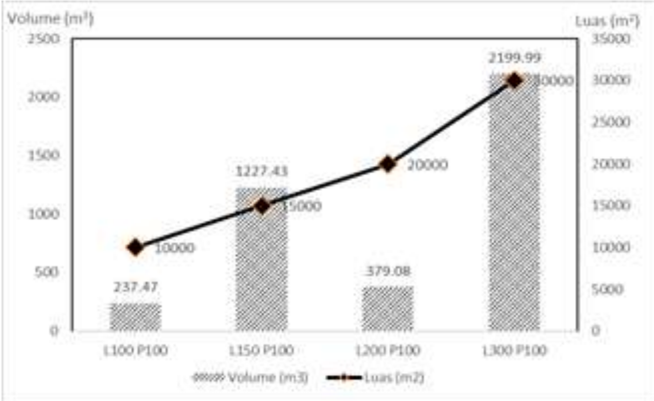

Figure 10. Graph of Relationship between Sediment Volume and Sediment Area Detained in Each Scenario (3 Months)

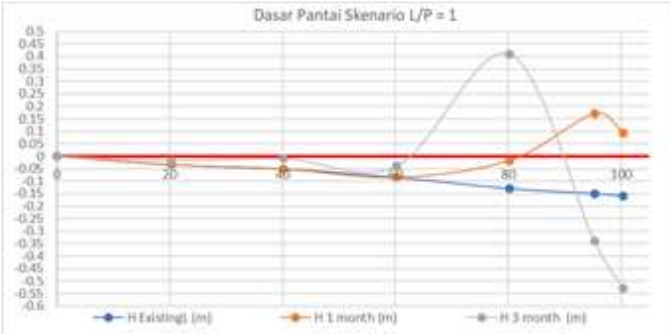

Figure 11. Coastal Bottom Line Scenario L / P = 1 Duration 1 Month and 3 Months

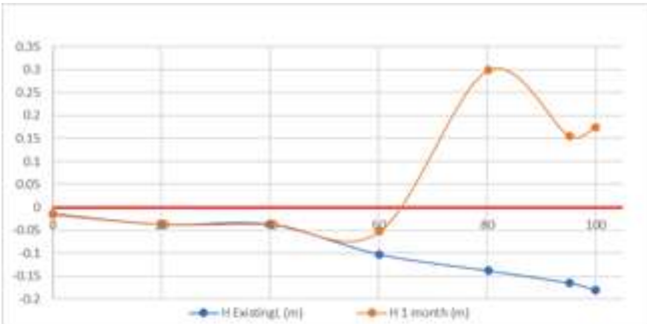

Figure 12. Coastal Bottom Line Scenario L / P = 1.5 Duration 1 Month and 3 Months

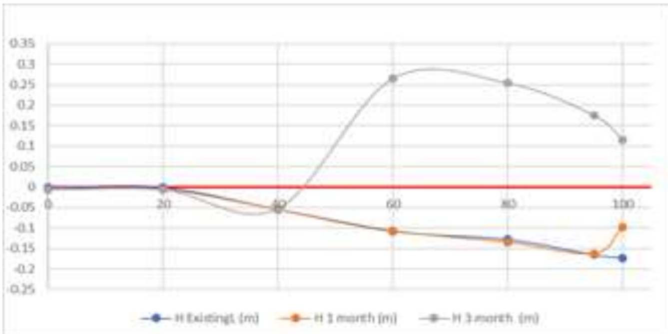

Figure 13. Coastal Bottom Line Scenario L / P = 2 Duration 1 Month and 3 Months

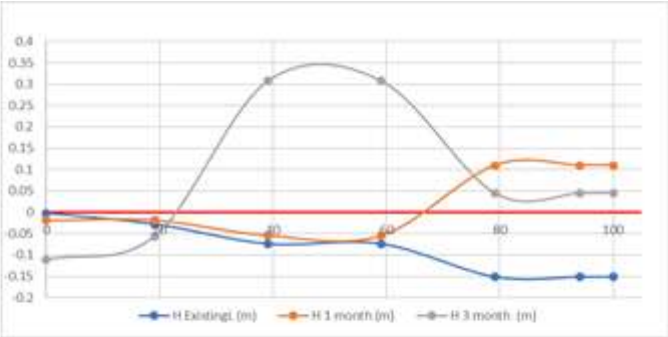

Figure 14. Coastal Bottom Line Scenario L / P = 3 Duration 1 Month and 3 Months

V. CONCLUSION

The Based on the results of the analysis and discussion of the thesis research of the Numerical Model of the Relationship Between the Distance and Length of the Groin To the Protected Beach Area, the following conclusions are obtained:

1. The more sediment area increases or the greater the groin installation ratio, the greater the volume retained in the groyne building. The effect of L / P on the volume and area of retained sediment is not linear (unstable). On a one-month calculation (Time Series), the increase in sediment area is not supported by an increase in sediment volume. There is a large difference in volume from the scenario L / P = 1 to L / P = 2 and from L / P = 2 to L / P = 3. For calculations (time series) 3 months, the increase in sediment area with an increase in sediment volume is more stable. The value of the scenario volume L / P = 2 is twice the volume of the sediment scenario L / P = 1 and the volume of the scenario sediment L / P = 3, 3-4 times the volume of the scenario L / P = 2.
2. The greater the distance between the installed groynes, the current velocity and wave height in the middle or L / 2 from the distance between the groynes and what happens at the points of view T3, T4, T5, and T6 will decrease. This is due to energy loss or reduction such as friction in the speed of the current with groynes.
3. Changes in the beach floor in each scenario are different. The slope of the beach base was originally around 0.0016 - 0.0029. The bottom slope of the beach when the simulation reaches one month changes to 0.0026 - 0.0071. When the simulation reaches 3 months, the bottom slope of the beach changes to around 0.0067 - 0.015. The bottom slope of the beach is obtained from the simulation with speedup factor 3 which means that the entire value after running is multiplied by 3, both for current speed, wave height and sediment transport.

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