International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Model of the Effect of Advanced Sea Water in Lamong Bay Due to Global Warming on the Drainage System in Surabaya City

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***Abstract*—** *The Lamong Bay area of the city of Surabaya is one of the areas with frequent inundation. The lamong bay area has several primary channels from the drainage system which where the primary canal empties into the lamong bay. The West Surabaya area, especially in the lower reaches of Tandes Rayon, has a high level of inundation due to several factors, one of which is the influence of sea level rise. So that times in the Tandes Rayon area it is unable to accommodate the tide from the sea. Therefore a puddle map is needed which is one of the efforts to minimize the impact of inundation that occurs in the downstream area of tandes Rayon by using 4 scenario conditions that occur in the field, namely the scenario when the existing conditions, second, the scenario when the water level rise is low, third is the scenario at the time of rising middle water level, fourth is the scenario when the water level rise is high. Data on global warming changes that occur in Indonesia are obtained from several studies on global warming, so that we get a change in sea level per year. Hydrological data processing can use HEC-HMS software and for hydraulic data processing requires primary channel profile data and can be processed in HEC-RAS 1D. Inundation map modeling in the Lamong bay area uses 2D HEC-RAS which is used to determine flood-prone locations caused by sea level rise in 4 simulated scenarios .From the results of this study, an analysis of sea level rise on global warming using IPCC data with predictions in 2030 with sea level rise as high as 8 cm for low, 18 cm for middle, and 29 cm for high Sea Level Rise. The effect of backflow from the sea greatly affects the conditions in the channel section. When the highest tide occurs 2.10 m, the water from the sea enters the channel cross section and causes the cross section of the channel not to be able to accommodate the discharge from rainwater and tide. In conditions at the Balong, Kandangan, and Sememi channels, they have a water depth of 1-3 meters. The largest inundation area is in the third scenario, which is high Sea Level Rise and 10 year return period of 9.24 km2. From the results of this simulation it can be seen that the inundation that occurs is strongly influenced by sea level rise and return period discharge. Especially in the downstream area it has a very large puddle and is very influenced by the tide of sea water.*

***Keywords*—** *Inundation, Global Warming, Sea Level Rise, Surabaya, HEC-RAS.*

I. INTRODUCTION

North Surabaya is one of the areas prone to floods. With economic growth and rapid development in the city of Surabaya, it causes environmental changes due to the volume of water that is not able to withstand flooding. Other causes that affect the occurrence of flooding in North Surabaya are the topography of the terrain in North Surabaya which is relatively low <10 masl and the slope of the surface is only <3%. The composition of the land is in the form of saturated soil so that parts of North Surabaya are never flooded, temporarily flooded, and constantly flooded.

Surabaya City Government has overcome flooding that occurred in several regions by normalizing, repairing channels, making box culverts, flood pumps, bozem, and especially in North Surabaya for 10 km of sea dikes and flood gates for flood management. However, there are still some areas that still have special overflow and surface runoff in the North Surabaya area around the Sememi, Kandangan, and Balong canals which still overflow in several locations which have caused some locations to be flooded.

In general, sea level rise is the impact of global warming that has hit the entire hemisphere. Based on the IPCC (International Panel On Climate Change) report that the average global surface temperature has increased from 0.3 to 0.6 oC since the end of the 19th century and until 2100 the earth's temperature is expected to rise by around 1.4 - 5.8 oC (Dahuri , 2002 and Bratasida, 2002). As for some studies that estimate sea level rise in Indonesia from 1984-2003 around 0.38-14.1 mm / year (Muhammad Zikra et al., 2014).

The condition of sea level rise around Lamong Bay will also cause waterlogging in coastal areas that have relatively low morphology. The level of damage caused to various regions may differ in the carrying capacity of the region or capacity of the coastal ecosystem.

To see changes in sea level, a simulation approach is needed to obtain information or measurements from objects using the HEC-RAS 2D application, which can find out the location of the inundation, length of inundation, area of inundation and depth of the inundation.

Sea level rise generally results in impacts such as (a) increasing frequency and intensity of floods, (b) changes in ocean currents and widespread destruction of mangroves, (c) widespread sea water intrusion, (d) threats to socio-economic activities of coastal communities, and (e) reduced land area or loss of small islands (Diposaptono 2002). With the effect due to the occurrence of backwater effects from the Teluk Lamong area to land. According to research (Kimpraswil, 2002) the frequency and intensity of flooding is predicted to occur 9 times greater in the next decade where 80% of the increase in flooding occurs in South and Southeast Asia including in Indonesia with a flood inundation reaching 2 million square miles. So that an increase in the volume of water in the coastal area will provide an accumulative effect if the sea level rise

Rezky Karuru and Umboro Lasminto, “Model of the Effect of Advanced Sea Water in Lamong Bay Due to Global Warming on the Drainage System in Surabaya City,” *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 3, pp. 236-240, 2019.

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and increase in the frequency and intensity of the rain occur in the same time period.

A. Runoff

Surface runoff, which is rainwater flowing in the form of a thin layer above the surface of the land, will enter the ditches and gutters which then merge into tributaries and eventually become river streams (Bambang Triatmodjo, 2010).

B. Rainy Period (PUH)

From the calculation of the suitability test, it will be known the type of distribution that will be used in determining the planned rainfall. Then the rainfall of the plan is changed to PUH (Rainy Period) which will be used as input to HEC-HMS.

C. Flood Debit Plans

The so-called flood plan here is the discharge that is used as the basis for calculating the channel dimensions to be planned. As for this writing, the calculation of the design flood discharge that will be used is the rainwater discharge. In this plan the planned flood discharge is calculated using the US-SCS (Soil Consolidation Service) method with the HEC-HMS auxiliary program.

D. HEC-HMS

The HEC - HMS model can provide hydrological simulations from the peak of the daily flow for the calculation of planned flood discharge from a watershed. The HEC-HMS model packs a variety of methods used in hydrological analysis. In operation, it uses a Windows system base, so that this model becomes easy to learn and easy to use, but it is still done with deepening and understanding of the models used.

E. Analysis of Sea Level Advances on Global Warming

Changes in acceleration of sea level rise that will cause further impacts such as submerging small island islands, increasing flooding, coastal erosion, seawater intrusion and changes in ecological process processes in coastal areas. Changes that occur in the biological-physical aspects will also have an impact on the socio-economic aspects of communities in coastal areas such as loss of infrastructure, decreasing ecological values and economic value of coastal resources (Klein and Nicholls, 1999).

F. Hydraulics Analysis with HEC-RAS 1D

Unsteady Flow Simulation. This module is able to simulate one-dimensional non-permanent flow in rivers that have complex grooves. Initially, the HEC-RAS non-permanent flow module can only be applied to the sub-criticism stream, but since the launch of version 3.1, the HEC-RAS non-permanent flow module can also simulate mixed flow regimes (sub-criticism, super-criticism, water jumping, and draw-downs).

Initially the unsteady flow was only designed to model subcritical flow, but the latest version of the HEC-RAS version 5.0.6 can also be used to model supercritical flow, critical, subcritical or mixed and hydraulic jumps. In addition, the calculation of energy loss in channel friction, turns and cross-section changes is also taken into account.

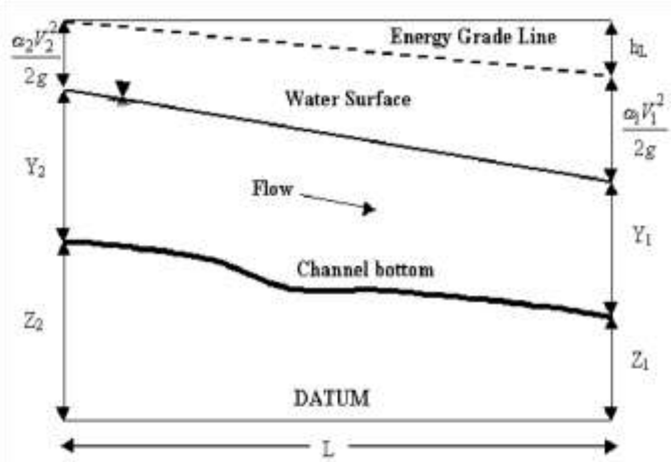

Figure 1. Depiction of energy equations in open channels (Istiarto, 2014)

G. Analyzing Hydraulics with 2D HEC-RAS

2 Dimensional Flow (2D) all particles are considered to flow in a plane along the flow, so that there is no perpendicular flow to the plane. Two-dimensional flow if it can be assumed that flow parameters vary in the direction of flow. In 2D flow calculations there are several methods that can be used such as mass conservation, numerical methods, and saint venant.

Figure 2. 2D HEC-RAS Simulation (Bunner, 2014)

H. Modeling the Area of Inundation

HEC RAS adds the ability to display 2 D hydrodynamic flow routes unsteady. With the 2 D flow area in the HEC RAS can be used in various ways. The following is a method of processing data and processing up to 2 D flow areas with HEC-RAS modeling:

1. Geometric data input.
2. Processing geometril data for cross section data.
3. Inputting tide and debit data.
4. Processing data for tide analysis and flow type.
5. Inputting RAS Mapper data.
6. Processing data to analyze the area of inundation in 2D..

International Research Journal of Advanced Engineering and Science
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II. METHODOLOGY

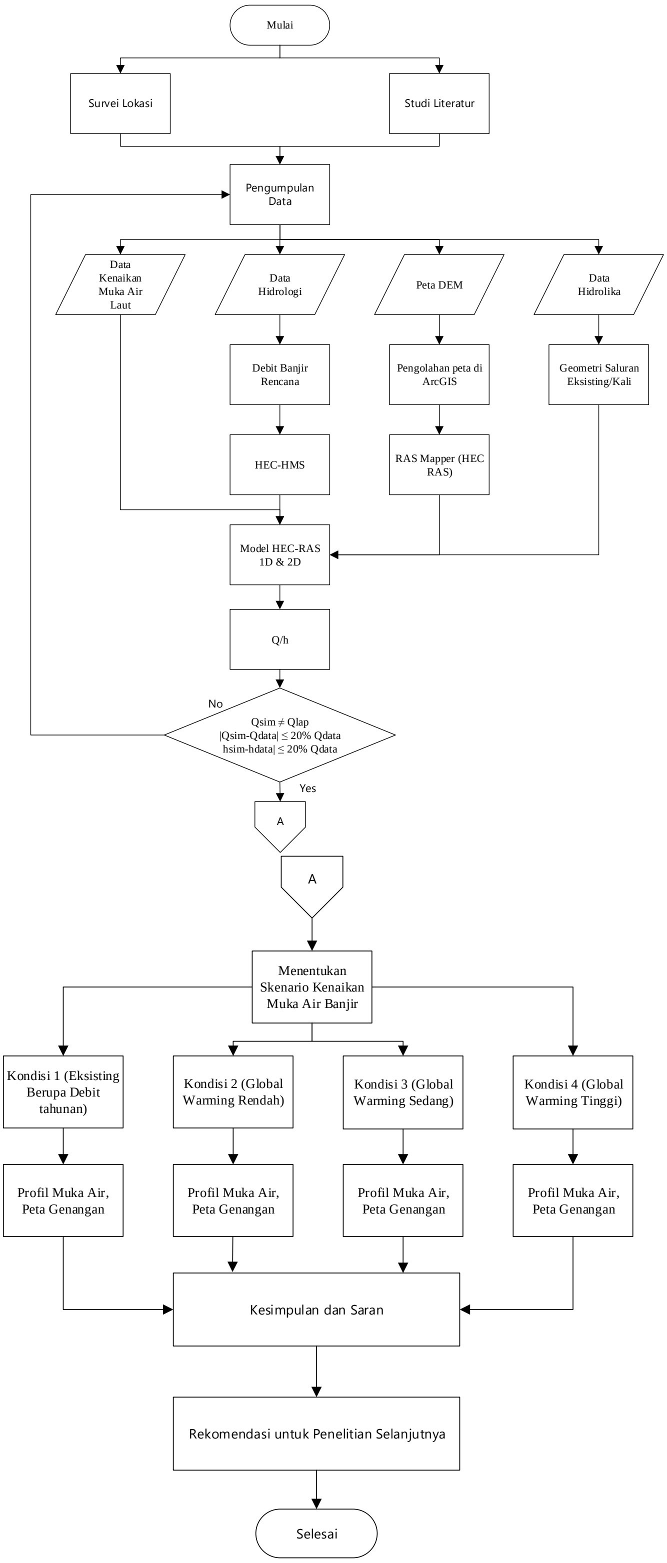

Figure 1. Flowchart of research method

In this research methodology, flood analysis that occurs on sea level rise is used to make and determine the map of flood locations caused by climate change that occurs every year which results in higher sea level rise. The stages consist of the location of research and research design in the form of data collection, identification of problems, analyzing the HEC-RAS model, calibration to adjust to field conditions, and analyzing the impact of bad, medium, and bad scenarios that will occur in the future.

III. RESULT

A. Hydrological Analysis

This analysis was conducted to determine the hydrological characterization of the Tandes drainage area. This analysis is used to determine the magnitude of the planned flood discharge. Flood Discharge Plan Period 2, 5, 10 years. 10-year rainfall data at Kandangan station, processing data using log person III method and in statistical tests.

TABLE 1. Rainfall Period

Rt'	**PUH**		
	2	**5**	**10**
jam	**mm**		
1	57.51	68.52	76.11
2	14.95	17.81	19.78
3	10.49	12.49	13.88
4	8.35	9.95	11.05

Source: Calculation

Table 1 describes the return period of rain with a high variation of rain that occurs for 4 hours. From this data can be used to calculate the planned flood discharge using HEC-HMS.

From the simulation results, HEC-HMS produces Smemi, Kandangan, and Balong channel discharge data. The biggest flow discharge is in the Balong channel because it has a larger watershed. The time interval used for the analysis of flood discharge is 5 minutes, the output of HEC-HMS is in the form of inflow and outflow.

B. Hydrologic Analysis

Analysis of drainage systems based on hydraulic modeling is intended to determine the river topography and drainage section topography. Hydraulic modeling is used to determine water level elevation, flow profile and flow velocity.

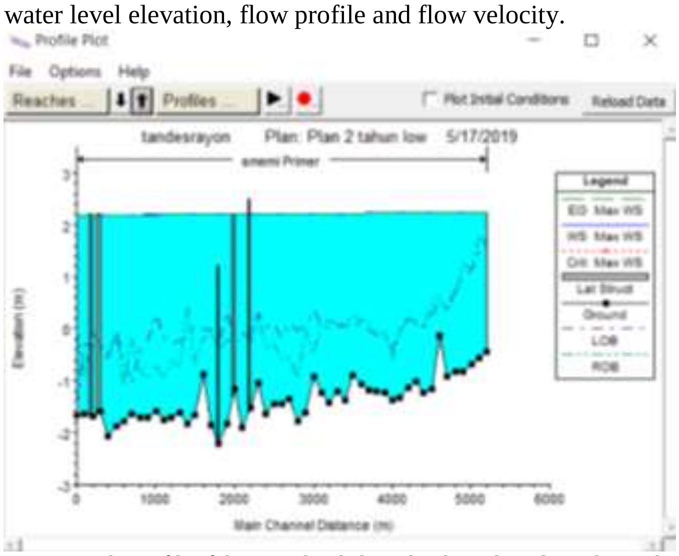

Figure 1. The profile of the water level along the channel results in the reach of the non-permanent flow to reach Sememi

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Geometric data analysis containing data on transverse profiles, channel length, watershed of each channel. The focus for the 1D model is analysis of the channel cross section profile. Analysis of topographic maps used to display 2D hydrodynamic flow unsteady.

the base slope of the channel and the slope of the critical reach on the Semi Channel is Io <Ic, yn> yc, with a slope of 0,0008, then the water level profile of Sememi is included in the Mild Slope type.

C. Scenario for Increasing Flood Water Levels

This scenario is needed to determine changes in sea level rise with several conditions.

Condition 1 displays the simulation when the planned flood discharge returns for 2 years, 5 years and 10 years.

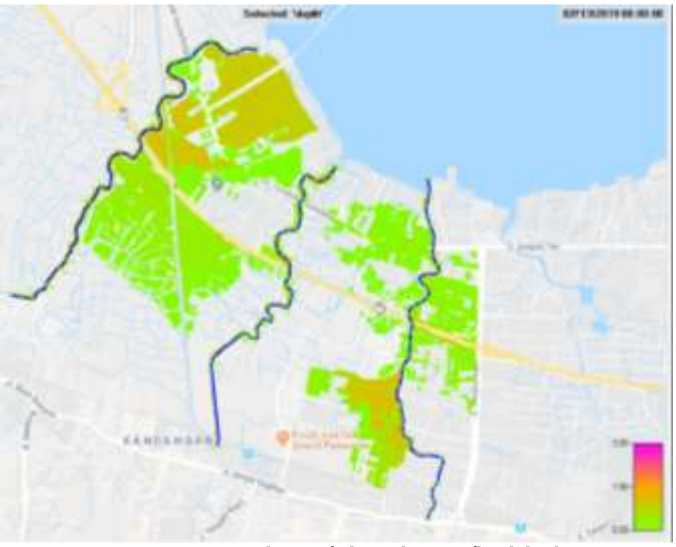

Figure 2. Existing condition of planned 2 year flood discharge

Figure 3. Existing condition of planned 5 year flood discharge

Figure 4. Existing condition of planned 10 year flood discharge

In the figure above explains the occurrence of inundation in each return period of floods. In figure 1 the 2 year return period has a depth of 0 - 1.89 m, figure 2 with a 5 year return period having a depth of 0 - 1.89 m, and figure 3 with a 10 year return period having a depth of 0 - 1.9 m.

Condition 2, This modeling is influenced by rising sea levels every year, using predictive sea level rise data that have been affected by Global Warming for 30 years. The scenario of Global Warming and sea level rise are low with an increase in 2030 as high as 8 cm. From the simulation results the water level reaches 0 - 1.9 m.

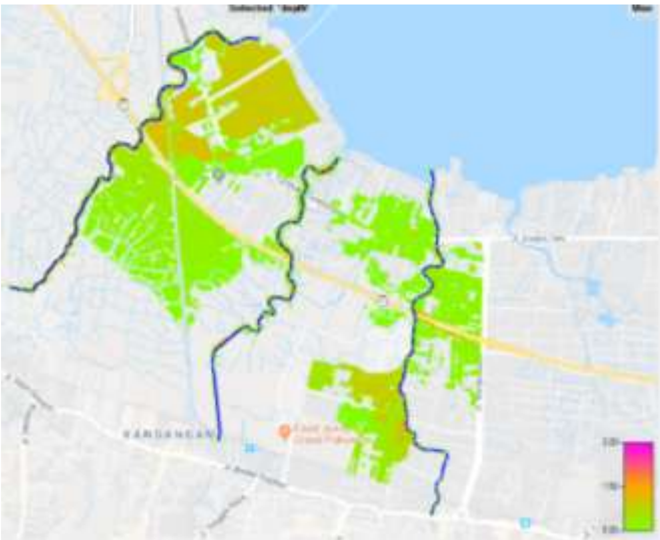

Figure 5. Global Warming Scenario Low ten years period

Condition 3, The scenario of Global Warming and sea level rise are moderate conditions with an increase in 2030 as high as 18 cm. From the simulation results the water level reaches 0 - 2.2 m.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Figure 6. Global Warming Scenario Medium ten years period

Condition 4, The scenario of Global Warming and sea level rise are moderate conditions with increases in 2030 as high as 29 cm. From the simulation results the water level reaches 0 - 2.4 m.

Figure 7. Global Warming Scenario High ten years period

TABLE 2. Depth in each scenario condition.

Periode	Skenario 1 (Eksisting)	Skenario 2 (Low SLR)	Skenario 3 (Middle SLR)	Skenario 4 (High SLR)
Plan 2 tahun	0.647	0.885	1.125	1.344
Plan 5 tahun	0.65	0.888	1.172	1.344
Plan 10 tahun	0.65	0.888	1.172	1.344

Table 2 explains that sample locations are reviewed to display depth in each scenario. so that they can find out the changes in the inundation that occurred.

TABLE 3. Area of Inundation in each scenario condition

Periode	Skenario 1 (Eksisting)	Skenario 2 (Low SLR)	Skenario 3 (Middle SLR)	Skenario 4 (High SLR)
Plan 2 tahun	5.69	6.45	8.06	8.71
Plan 5 tahun	6.64	6.51	8.33	9.08
Plan 10 tahun	6.64	6.51	8.65	9.24

In figure 3, it explains the graph in each of the scenarios and can compare the broad changes in each scenario.

IV. CONCLUSION

The results of the analysis and discussion on the thesis research The Effect of Increase in Sea Water Levels in Lamong Bay Due to Global Warming of Surabaya City Drainage System, the conclusions are as follows:

1. From the results of several reference studies analyzed about sea level rise in global warming, data from the IPCC (Intergovernmental Panel On Climate Change). Data held by IPCC is the prediction of sea level rise until 2100. Predictions for this study are taken in 2030 based on the Surabaya RTRW. For Low Sea Level Rise conditions have an increase as high as 8 cm, Middle Sea Level Rise as high as 18 cm and High Sea Level Rise as high as 29 cm.
2. Because the Balong channel, Kandangan, and Sememi downstream flow into the sea the effect of backwater from the sea is very influential. When the highest tide occurs 2.10 m, the water from the sea enters the channel cross section and causes the cross section of the channel not to be able to accommodate the discharge from rainwater and tide. In conditions at the Balong, Kandangan, and Sememi channels, they have a water depth of 1-3 meters.
3. The extent of the influences of inundation that occur at the study sites vary in each scenario and the planned flood return period. The largest inundation area is in the third scenario, which is high Sea Level Rise and 10 year return period of 9.24 km2. From the results of this simulation it can be seen that the inundation that occurs is strongly influenced by sea level rise and return period discharge. Especially in the downstream area it has a very large puddle and is very influenced by the tide of sea water.

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