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

Model of the Effect of Sea Level Elevation on Floods in the East Semarang Area

Hanggoro Iskandar Putra Wijaya[1], Umboro Lasminto[2]
[1]Master Student, Civil Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, +62
[2]Civil Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, +62
Email: [1]hanggorowijaya@gmail.com, [2]umboro.lasminto@gmail.com

Abstract**—** *Semarang city is an area that often encounter tidal flood, particularly in East Semarang. This disaster was due to sea tides and rainwater which did not accommodated in the river/waste channel, cause overflow and inundation. The background of this study was to determine the effect of sea level on the Sringin and Tenggang drainage systems towards tidal flood in East Semarang. The analysis of inundation model in East Semarang used HEC-RAS application, in which the simulation was performed with the upstream boundary, namely the flow hydrograph with 2years, 5 years, and 10 years return periods. Simulations were carried out on the Sringin and Tenggang drainage systems until the channel downstream to the sea. Researcher performed two model scenarios influenced by mean sea level (MSL) of 1,366 . The next scenario model was influenced by the highest high water level (HHWL) of 2,048.The result of study , the inundation area height occurred in the scenario with influenced by MSL with 2, 5, and 10 years return periods is 282.036m2, 392.604m2, 450.127m2. The next, was influenced by HHWL with 2, 5, and 10 years return periods is 414.645m2, 624.075m2, 686.489m2 It is acquainted that the inundation was strongly influenced by the elevation of annual flood discharge and sea level..*

Keywords**—** *Flood; HEC-RAS 2D; Semarang city.*

I. INTRODUCTION

Semarang City is a city located on the northern coast of Java. According to Lubis et al. in Nugroho (2013) geographically Semarang City is on the 6o50' – 7o10' South Latitude line and the 109o35' – 110o50' line. The city of Semarang is traversed by the north coast transportation route (Pantura) which is very vital in the national economy. The East Semarang area is one of the main access points and is also the gateway to the city of Semarang from the east.

Ramadhany et al. (2012) in his research, the coastal area of Semarang City has a flat topography with a slope of 0-2%. Most of the coastal areas of Kora Semarang are almost the same elevation as sea level, even in some locations below it. Rob occurs directly in areas located on the coast, where the highest tides enter the land and are restrained by soil or physical structures. According to Mahesa et. al (2017), The coastal flood inundation model uses MSL and HHWL values to see the effect of sea level elevation on flood inundation.

This study aims to determine the effect of tides on the Sringin and Tenggang drainage systems, by comparing the effect of sea level tides, namely MSL and HHWL data on flooding in the East Semarang area. To obtain information or measurements from objects using the HEC-RAS 2D application. The impact of flood area for several tidal conditions can be compared from the results of inundation maps using the RAS Mapper application.

II. LITERATURE RIVIEW

A. Hydrology Analysis

1. *Calculation of Return Period Rainfall*
   The magnitude of the design rain height, depends on the use of this building, and the hazard posed by a water structure. The series of hydrological data which is a continuous variable is an illustration of an equation of the probability distribution. The mathematical model of the probability distribution that can be used is
   $$R_T = \bar{R} + K \,.\, Sd$$
2. In this study, the design flood analysis was calculated using the Nakayasu Synthetic Unit Hydrograph method. This method is a method developed by Nakayasu, who came from Japan.The equation to form the Nakayasu unit hydrograph is as follows:
   - curve up
   $$Q = Q_p \frac{t^{2.4}}{t_p}$$
   - curve down
   $$Q = Q_p \, x \, 0{,}3^{\frac{t - tp}{t_{0,3}}}$$
   $$Q = Q_p \, x \, 0{,}3^{\frac{t - tp + 0{,}5 \, x \, t_{0,3}}{1{,}5 \, x \, t_{0,3}}}$$
   $$Q = Q_p \, x \, 0{,}3^{\frac{t - tp + 1{,}5 \, x \, t_{0,3}}{2 \, x \, t_{0,3}}}$$

B. Hydraulic Analysis

1. *Steady Flow*
   If permanent flow conditions, flow modeling is done by calculating the water level profile along the channel channel which is sorted from one cross section to the next. The energy equation between the two cross-sections is calculated in the form of the following equation:
   $$Y_2 + Z_2 + \frac{a_2 V_2^{\,2}}{2g} = Y_1 + Z_1 + \frac{a_1 V_1^{\,2}}{2g} + h_e$$
2. *Unsteady Flow*
   Unsteady flow is a flow condition where the velocity, depth, and flow rate change with time (Brunner, 2016). Impermanent flow is a physical process of flow in a channel by adopting the concepts of conservation of mass and conservation of momentum

Hanggoro Iskandar Putra Wijaya and Umboro Lasminto, "Model of the Effect of Sea Level Elevation on Floods in the East Semarang Area," *International Research Journal of Advanced Engineering and Science*, Volume 6, Issue 3, pp. 266-271, 2021.

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

$$\frac{\partial Q}{\partial t}+\frac{\partial QV}{\partial x}-gA\left(\frac{\partial z}{\partial x}+S_f\right)=0$$

III. RESEARCH METHOD

A. Research Location

The location of this research is the drainage system of East Semarang region in Sringin subsystem and Tenggang subsystem.

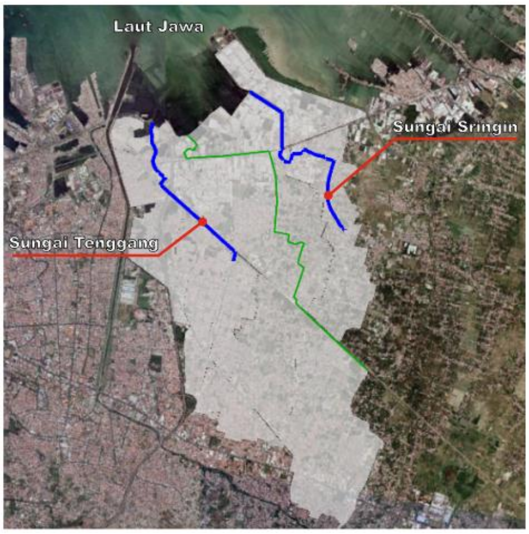

Fig. 1. Research Location

B. Research Data

The data used in this study is secondary data

1. Hydrological data used is annual rainfall data from related agencies in the form of influential rain station data, namely Maritime Station, Karangroto Station, and Pucang Anom Station. The hydrological data in this study are the data in hydrological analysis, as well as the basic planning parameters used in the HEC-RAS modeling input data.
2. Land use data derived from the Semarang City Spatial Plan for the years 2011-2031. The data includes land function criteria in the Sringin and Tenggang watersheds.
3. The hydraulic data from the Semarang City drainage master plan is the dimensions of the drainage channel in the East Semarang area and hydraulic variables related to the research. The hydraulic data in this study was used for hydraulic analysis and modeling the drainage channel using HEC-RAS.
4. DEM data is in the form of geometric or topographical data in the East Semarang area which will be processed in the ArcGIS application. This data is in the form of displaying terrain relief that resembles the actual conditions at the research site. DEM (Digital Elevation Model) data is a model that represents the topography of a surface. DEM from aerial photographs of this scale can provide more detailed information about the relief of the mapped earth's surface. This study uses ArcGIS application tools to process data into a map that is used to input data in HEC-RAS.
5. Seawater Tidal Data derived from the Semarang City drainage master plan data. The data used is the data of the average sea level elevation and the highest sea level elevation.

TABLE 1. Planned Tidal Height Semarang city

Sea Level	Elevation
(HHWL)	2,048
(MSL)	1,366

C. Research steps

The stages used in this research are:

1. Hydrological Data Processing
   - Calculation of planned rainfall. Rain data was taken from rain stations, namely Maritime Station, Karangroto Station, and Pucang Anom Station from 2005-2014. Furthermore, it is processed using the Thiesen Polygon method. The design rainfall analysis used the Pearson Type III log method.
   - In this study, the calculation of the planned flood discharge was carried out using the Nakayasu Synthetic Unit Hydrograph method. This method is a method developed by Nakayasu from Japan.
2. Geometry Data Processing and Channel Section
   The geometry and cross-sectional data of the Sringin and Tenggang channels will be inputted according to the Semarang City drainage master plan data.
3. DEM Data Processing
   DEM (Digital Elevation Model) data is a model that represents the topography of a surface. DEM from aerial photographs of this scale can provide more detailed information about the relief of the mapped earth's surface. This research uses ArcGIS application tools to process data into a map that is used to input data in HEC-RAS. The data that can be generated are TIN, contour, coordinate data (projection file), and terrain.
4. Modeling design with HEC-RAS software
   The modeling in this study uses the HEC-RAS 5.0 application developed by the U.S. Army Corps of Engineers (USACE). This application is used to simulate 2D dynamic flow flood inundation and a combination of 1D and 2D, which uses the Saint Venant equation or diffusion wave (Brunner, 2016). The software processes data up to 2D flow area with the following process:
   a) Geometric data input.
   b) Geometric data processing
   c) Input tidal data and discharge data.
   d) Data processing for tides and discharges with unsteady flow types.
   e) Input RAS Mapper data.
   f) Data processing for inundation area and height maps.

   This research is carried out in several scenarios as follows:
   1. Mean Sea Level (MSL) Scenario
      A flood modeling scenario was carried out in the Sringin River and Tenggang River channels which flow down the sea influenced by the mean sea level elevation (MSL) as the downstream condition of the channel. While in the upstream channel, the discharge

used is the planned flood discharge for return periods of 2, 5, and 10 with unsteady conditions. so that it will be simulated to determine the flooding that occurs in field conditions.

2. Higher High Water Level (HHWL) Scenario
In this scenario, flood modeling in the Sringin River and Tenggang River channels is influenced by the design seawater tide (HHWL) as the downstream condition of the channel. While in the upstream channel, the discharge used is the planned flood discharge for return periods of 2, 5, and 10 with unsteady conditions. so that it will be simulated to determine the flooding that occurs in field conditions.

IV. RESULT

A. Return Period of Rainfall

For the calculation of the return period rainfall, the Log Pearson Type III distribution is used. The following is a recapitulation of the calculation of the planned rainfall for the return period in the table

TABLE 2. Return Period Rainfall

Period	R(mm)	
	Sringin	Tenggang
2	131.55	119.28
5	153.52	133.94
10	162.93	140.40

The result of the t-hour rain height (Rt') is the input to the modeling. The t-hour is 6 hours, because the duration of the rain in the city of Semarang is not less than 6 hours. The calculation of the hourly rain is as follows;

TABLE 3. High Rainwater Sringin hour

Rt'	Period Rainfall		
	2	5	10
hour	mm		
1	72.39	84.49	89.66
2	18.82	21.96	23.31
3	13.20	15.40	16.35
4	10.51	12.26	13.01
5	8.87	10.36	10.99
6	7.76	9.05	9.61

TABLE 4. High Rainwater Sringin hour

Rt'	Period Rainfall		
	2	5	10
hour	mm		
1	65.64	73.71	77.26
2	17.06	19.16	20.08
3	11.97	13.44	14.09
4	9.53	10.70	11.21
5	8.05	9.04	9.47
6	7.03	7.90	8.28

B. Hydrograph Flood Debit Plan

The results of the hydrograph calculation of the planned flood discharge of the Nakayasu method on the Sringin River for Period Rainfall of 2, 5, and 10 years can be depicted in the image below

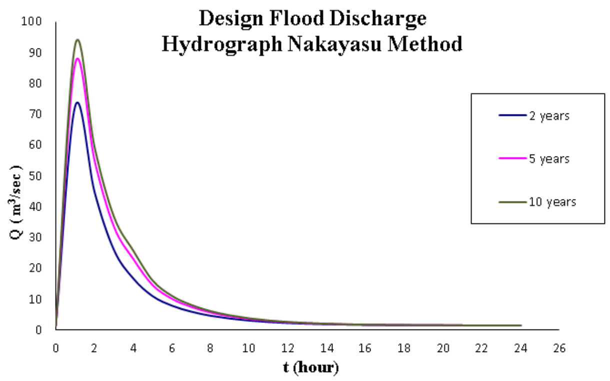

Fig. 2. Sringin Hidrograph

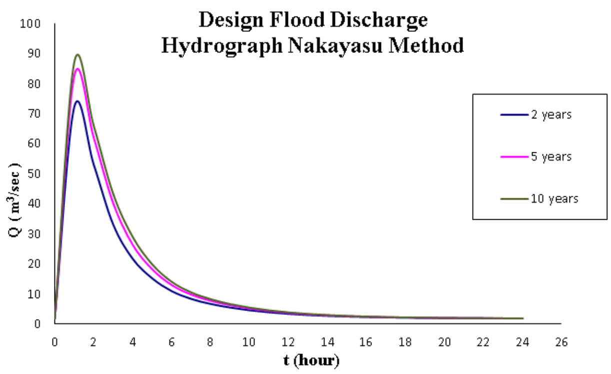

Fig. 3. Tenggang Hidrograph

C. HEC-RAS . Simulation

In this 2D HEC-RAS modeling, unsteady flow discharge analysis is used, which is influenced by changes in time. From the existing parameters used to simulate the modeling with several scenarios. The first step is to input channel geometric data on each cross section from upstream to downstream of the channel. In the data input process, input the distance between the cross sections, the manning value, and the channel embankment as shown below.

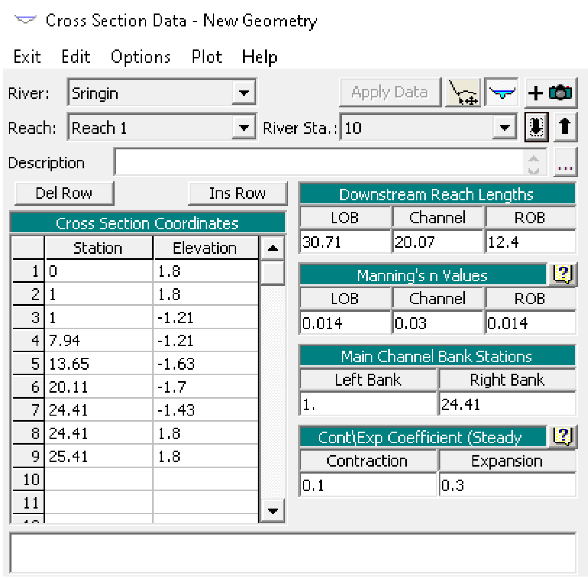

Fig. 4. Input Geometry Data

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

Next, define a 2D flow area. As an overflow channel connection, use a lateral structure. Display geometric data menu as shown below.

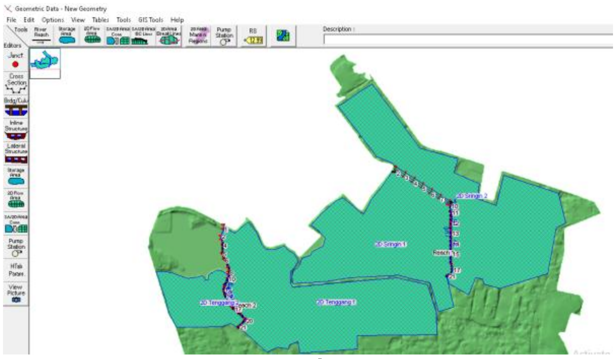

Fig. 5. Geometric data processing

Downstream of the channel is inputted with stage hydrograph scenario conditions in the form of MSL and HHWL. The upstream of the channel is a discharge in the form of a flow hydrograph for Period Rainfall of 2, 5, and 10 years. The input process is like the following picture.

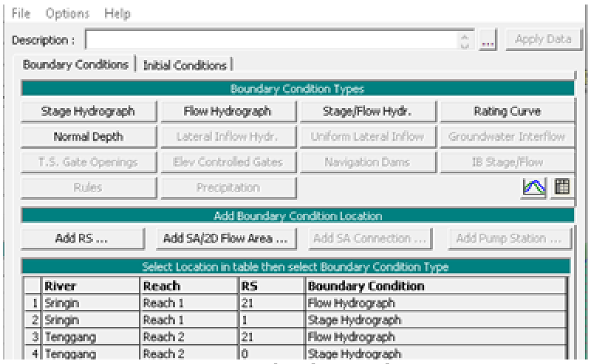

Fig. 6. Input boudary condition

This type of flow for modeling uses unsteady flow. The model is simulated for 24 hours and the running process is carried out as shown below.

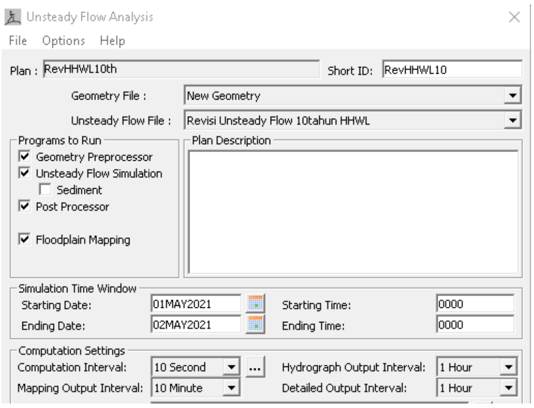

Fig. 7. Data processing for tides and discharges with unsteady flow types

The results of the simulation on the model can be seen in the RAS Mapper. The results of each scenario carried out can be seen and compared.

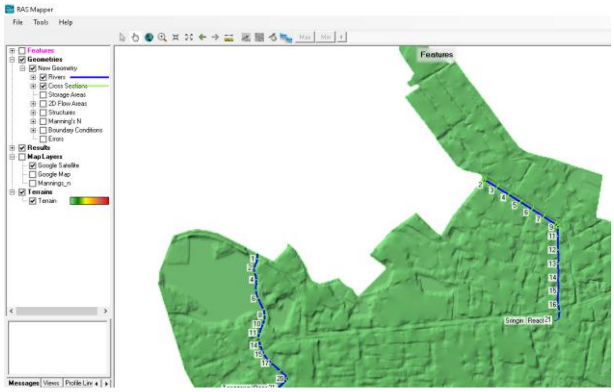

Fig. 8. Input RAS Mapper Data

The results of the inundation map for each scenario are shown in the following figures.

Fig. 9. MSL 2 years Simulation

Fig. 10. MSL 5 years Simulation

Fig. 11. MSL 10 years Simulation

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

Fig. 12. HHWL 2 years Simulation

Fig.13. HHWL 5 years Simulation

Fig. 14. HHWL 10 years Simulation

From each simulation result, the inundation area is obtained for each scenario with the help of analysis in the ArcGIS application. The results of the calculation of the inundation area can be seen in the table below.

TABLE 5. Simulation flood area

No	Scenario	Flood Area (m2)
1	MSL 2 years	282.036
2	MSL 5 years	392.604
3	MSL 10 years	450.127
4	HHWL 2 years	418.645
5	HHWL 5 years	624.075
6	HHWL 10 years	686.489

From the results of the inundation area based on the table above, it will then be seen in the comparison graph of the scenario with the inundation area as shown below

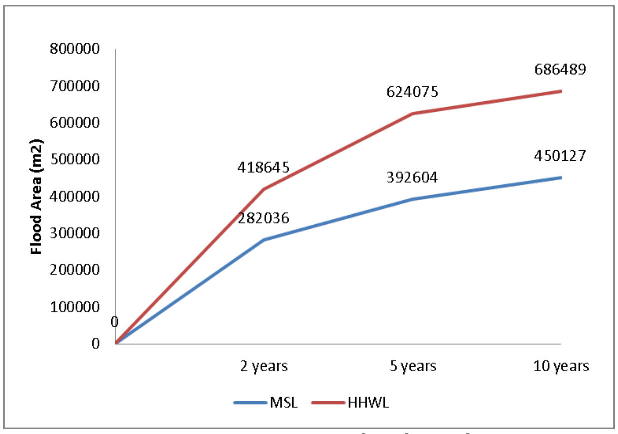

Fig. 15. Scenario Comparison Graph with Inundation Area

V. Conclusion

The flood water level in the East Semarang area for each MSL and HHWL scenario varies as follows:

1. From the MSL scenario, with the 2 years Period Rainfall, the depth is between 0-0.22m. In the infiltration pond, the deepest inundation reaches up to 1.2m. In the MSL scenario with 5 years Period Rainfall, the depth that occurs is around 0-0.34m. In the infiltration pond area, the deepest inundation reaches up to 1.5m. In the MSL scenario with 10 years Period Rainfall, the depth that occurs is around 0-0.4m. The infiltration pond area is the deepest inundation reaching up to 1.6m.
2. From the HHWL scenario, with the 2 years Period Rainfall, the depth is between 0-0.35m. In the infiltration pond, the deepest inundation reaches up to 1.5m. In the HHWL scenario with 5 years Period Rainfall, the depth that occurs is around 0-0.50m. In the infiltration pond area, the deepest inundation reaches up to 1.65m. In the HHWL scenario with 10 years Period Rainfall, the depth that occurs is around 0-0.55m. The infiltration pond area is the deepest inundation reaching up to 1.7m.

From the simulation results, it can be seen that the inundation that occurs is strongly influenced by sea level rise and return period discharge. The impact of inundation in the East Semarang area based on each MSL and HHWL scenario is as follows:

1. The result of the inundation area for the MSL scenario with the 2 years Period Rainfall is 282,036 m2. Furthermore, the inundation area for the MSL scenario with 5 years Period Rainfall is 392,604 m2. In the MSL scenario with 10 years Period Rainfall, the inundation area that occurs is 450,127 m2.
2. The result of the inundation area for the HHWL scenario with the 2 years Period Rainfall is 418,645 m2. Furthermore, the inundation area for the HHWL scenario with 5 years Period Rainfall is 624,075 m2. In the HHWL scenario with 10 years Period Rainfall, the inundation area is 686,489 m2.

REFERENCES

[1] Brunner, Gary W., "Combined 1D and 2D Modeling with HEC- RAS", *Davis: US Army Corps of Engineers Hydrologic Engineering Center*, 2014.

[2] Brunner, Gary W., "HEC-RAS River Analysis System, 2D Modeling", *User's Manual. Davis: US Army Corps of Engineers Hydrologic Engineering Center*, 2016.

[3] Hidrologic Engineering Center, HEC-RAS 2D Modeling User's Manual Version 5.0, U.S. Army Corps of Engineers, Davis CA, 2016.

[4] Nugroho, S. H., "Prediksi Luas Genangan Pasang Surut (Rob) Berdasarkan Analisis Data Spasial Di Kota Semarang, Indonesia", *Jurnal Lingkungan Dan Bencana Geologi*, Vol. 4, pp. 71-87, 2013.

[5] J Mahesa, P. D, Setiono H, dan Handoyo, G., "Peramalan Pasang Surut untuk Mengetahui Perubahan Luas Genangan Banjir Pasang di Kecamatan Kraksaan Probolinggo", *Journal of Marine Research*, Vol. 6, No. 4, pp. 543-552, 2017.

[6] J Ramadhany, A. S., Anugroho D. S. A., and Subardjo, P., "Daerah Rawan Genangan Rob di Wilayah Semarang", *Journal of Marine Research*, Vol. 1, No. 2, pp. 174-180, 2012.

Hanggoro Iskandar Putra Wijaya and Umboro Lasminto, "Model of the Effect of Sea Level Elevation on Floods in the East Semarang Area," *International Research Journal of Advanced Engineering and Science*, Volume 6, Issue 3, pp. 266-271, 2021.