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Development of flood forecasting model and warning systems at Way Ruhu – Ambon

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Abstract. Way Ruhu has a river with the slope of the land is steep. The heavy rains that often occur in the city of Ambon resulted in floods and landslides in several places thus to give a big loss to the people in the city of Ambon both the loss of property and lives. This study was conducted with the aim to determine the magnitude and time of flooding in the Way Ruhu watershed, the modeling results will be applied in android so that people can evacuate early because information can be received more quickly and the Government can prepare better mitigation programs. Modeling methods are carried out using 2D software HEC-RAS 5.0.7 which requires hydrological and topographical data as the main inputs. The output from HEC-RAS is a flood map, flood height, and duration of the flood. The results of this study indicate that the time between the upstream river rise and the arrival of floodwater in the downstream is less than one hour, with flood characteristics as high as 1-5 meters and receding within 4 to 11 hours.

1. Introduction

Ambon city has a hilly area that the potential for landslides when heavy rains. The heavy rains that often occur in the Wai Ruhu - Ambon watershed and relatively steep topography, have caused severe flooding and affected community activities in Ambon City. The river of Way Ruhu on one side is a river that has the potential to be utilized and on the other hand often creates flooding problems, then it has been arranged programs to optimize the management of the Way Ruhu River so that when excess water can be controlled and when needed to support drinking water supply, reliability is guaranteed.

The program to build a dam on the Wai Ruhu River is the right step in optimizing managed of Way Ruhu river where the dam can not only be used to control floods and water supply but with non-structural support can control the damage. One non-structural approach is to estimate flood discharge and an early warning system which is a series of systems to notify the upcoming discharge at certain hours in a river caused by upstream rain. The non-structural approach is widely used abroad and managed to reduce the risk of loss of property and lives.

This study is to support the management of water resources in the Way Ruhu River by developing a forecasting system and early warning the magnitude of flow using a monitoring system for the amount of rain that occurring or will occur and monitoring system for river water level fluctuations in real-time, with this system the magnitude and time of the flood will try to be predicted or known early. This information is very useful for the people so that when climate conditions are extreme so that people have time to evacuate from the flood site before the disaster.



2. Literature review

Damage caused by flash floods has increased in many areas due to changes in land use and the social and economic impacts of development. Increased rainfall and on a global scale as a result of global warming resulting in an increase in the frequency and severity of the impact of global climate change, resulting in an increased flood volume [1-4].

In these floods and early warning, hydrometeorological data are very important and must be monitored in a timely manner for forecasting and early warning. Not only Rainfall network stations with telemetry system in a watershed is needed to support real-time input into flood forecasting models but also Water level monitoring sensors placed on the river network can help managers to get data on flood conditions and their characteristics so that after the data collected some time will be able to plan appropriate flood mitigation techniques.

On Real-Time Surface-Water Monitoring in New Jersey, 2003 explains the real-time river water level monitoring system is used to monitor river water level elevations where data can be accessed via the internet.

A flood is an event that is influenced by random parameters both independent and related to each other. The cause of the flooding is usually due to drainage capacity (capacity) which is no longer sufficient to accommodate rain and poor drainage performance. In flood modeling, several analyzes are conducted, namely flood discharge analysis, calculating synthetic Takayasu hydrograph with the Gumbel method and system analysis using HEC-RAS.

Concentration Time is the longest time needed for rainwater that has fallen in a watershed to reach the point of output. equation is taken to predict the magnitude of t that is by the equation.

$$t = \left\{ \frac{2}{3} \times 3,28 \times L \times \frac{n_d}{\sqrt{S}} \right\}^{0,167} \quad (1)$$

Characteristics or parameters of the drainage area first, for example, time to reach the peak of the hydrograph (time to peak magnitude), base width, area, slope, length of the longest channel (length of the longest channel), runoff coefficient, and so on. Usually, we use synthetic hydrographs.

This synthetic unit hydrograph was discovered by Soemarto in 1987. From the results of his investigation, a kinetic unit hydrograph formula was made. The following is the Nakayasu synthetic unit hydrograph formula.

$$Q_p = \frac{C A R_o}{3.6 (0.3 T_p + T_{0.3})} \quad (2)$$

The unit rainfall value used in the calculation of the Nakayasu synthetic hydrograph is obtained from the calculation of the maximum unit rain using the extreme value distribution by using the Gumbel distribution method with the following formula.

$$X_{TR} = \bar{X} + \left(\frac{Y_{TR} - Y_n}{S_n} \right) S_x \quad (3)$$

3. Research method

The model to be chosen is strongly influenced by the availability of data and characteristics of watersheds, climate characteristics, flow characteristics and lead times. Calibration and verification will be carried out to obtain the model parameters of the selected model. Evaluation of the level of accuracy in each forecast compared to the magnitude of the value that occurs and the ease in the process of forecasting and early warning are two things that will be used as a basis in selecting the model. The models for forecasting and early warning that can be applied in Way Ruhu are :

3.1. Correlation method

- Linear /Non-Linear Correlation Model between Upstream and Downstream Discharge: This model is often used for forecasting of flood hydrograph when the water travel time from upstream to downstream is sufficiently long and additional discharges between upstream and downstream are observed correctly.
- Multiple Correlation Model between Downstream Discharge with its watershed characteristics: This model is often used for forecasting for watersheds that are not measured so that the discharge is correlated with rain and watershed characteristics (river length, watershed slope, land cover, soil type, of climate condition)

The parameter model is determined from the observed flood data and tries to be fit/approached with regression equations (linear /non-linear) by determining the deviation criteria/deviation between the observation discharge and the calculation discharge from the correlation model.

3.2. Rainfall-runoff models

- Empirical model: This model is the basic form of a model consisting of simple relationships without regard to the physical conditions of a hydrological cycle. (for example Unit Hydrograph)
- Black box model: This model basically deals with input and output in the process of the relationship between rainfall and discharge without clearly modeling the physical process. This model can be viewed as a semi-empirical model and can model a complete flow hydrograph. (For example Tank Model)
- Simulation models: This model tries to clearly model the physical processes of rain and discharge. This model assumes a watershed in several storage models while the parameters of the model define the dimensions of the basin and the flow rate of each basin. (Ex: Sacramento Model)

Model parameters are obtained from the model calibration results by matching the hydrograph calculated from the rain with the observed hydrograph from the discharge. The parameters of this model need to be observed constantly whether it is still consistent in the verification process, meaning that by using the parameter model obtained from the calibration results, the results are quite good between the reconstitution of the calculated hydrograph results and the hydrograph results observed. If the parameters are stable enough, the parameters of the model can be used for flood forecasting and early warning (For example W flow model).

3.3. Flood routing models

- Flood Routing model for steady flow conditions: This model is often used for flow forecasting if the flood hydrograph observation is upstream of the watershed and the flow in the river is not affected by backwater.
- Flood Routing models for unsteady flow conditions: These models are often used for flood forecasting when observations of flood hydrograph are upstream and cross-sections upstream to downstream are present and flow is often affected by tidal or backwater conditions (eg HEC -RAS 5.0.7).

Model parameters are obtained from the model calibration results by matching the calculated hydrograph discharge with the observed hydrograph discharge. The parameters of this model need to be observed constantly whether it is still consistent in the verification process, meaning that by using the parameter model obtained from the calibration results, a fairly good result is obtained between the reconstitution of the calculated hydrograph discharge and the observed hydrograph discharge. If sufficient parameters are obtained, the parameters of the model can be used for flood forecasting and early warning.

In this paper, the combination of a simple rainfall-runoff model (unit hydrograph) and flood routing model (HEC-RAS5.0.7) is used to identified and simulated flood hydrographs from upstream to downstream of flood flow in way Ruhu river.

The method used is a combination of HEC-RAS 5.0.7 with HEC-RAS 4.1 because the channel scheme is not visible on the USGS map, so it must be made manually in HEC-RAS 4.1 then imported into the HEC-RAS Mapper RAS 5.0.7.

The data used are topographic measurement data, geometry data, tidal measurement data, hydrological data as input of lasting flow data on boundary conditions. The type of flow being modeled is the unsteady flow model because the data is used as input is data whose value changes with time. The research flow is shown in figure 1.

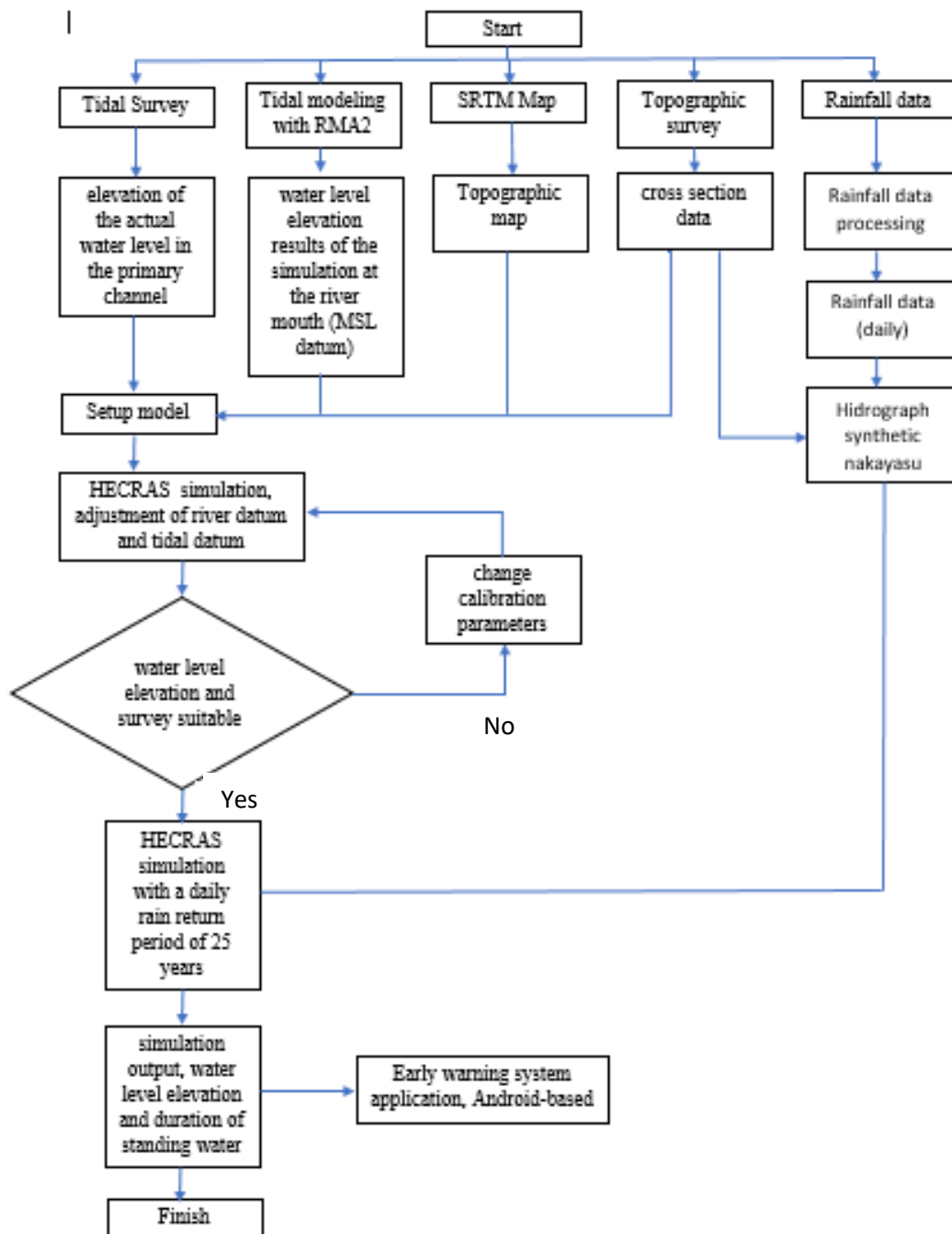


Figure 1. Research flow.

4. Results and discussion

The research sites are located in 4 locations, namely Galala Village with a distance of 200 meters from the estuary, Hative Kecil Village with a distance of 1.8 km and 2.9 km from the estuary, and 1 location in Batu Merah Village with a distance of 3.9 km from the river estuary.



Figure 2. Review points in (left) Galala Village and (right) Hative Kecil Village.

The left of figure 2 is the normal water level elevation at a distance of 200 meters from the estuary, which ranges from 15 cm to 47 cm from the riverbed. While the right-hand side is a cross-sectional condition in Hative Kecil Village, which is 1.8 km from the estuary, with a cross-section width of 21 meters and a height of value of 2.65 meters. The results of water level profile modeling in the time series display and river cross-section are shown in figure 2 to figure 9.

Figure 3 shows that flooding in Batu Merah Village can reach a height of 2.37 meters from the river bank and gradually recede within 4 hours. When viewed from the bottom of the river, the water level reaches 3.27 meters.

Figure 4 shows that flooding in Hative Kecil village can reach a height of 3.16 meters from the river bank and gradually recede within 10 hours. When viewed from the bottom of the river, the water level reaches 5.64 meters.

Figure 5 shows that the flood in Hative Kecil village can reach an altitude of 2.74 meters from the river bank and gradually recede within 10 hours. When viewed from the bottom of the river, the water level reaches 5.24 meters.

Figure 6 shows that flooding in Galala Village can reach a height of 2.63 meters from the river bank and gradually recede within 11 hours. When viewed from the bottom of the river, the water level reaches 5.28 meters.

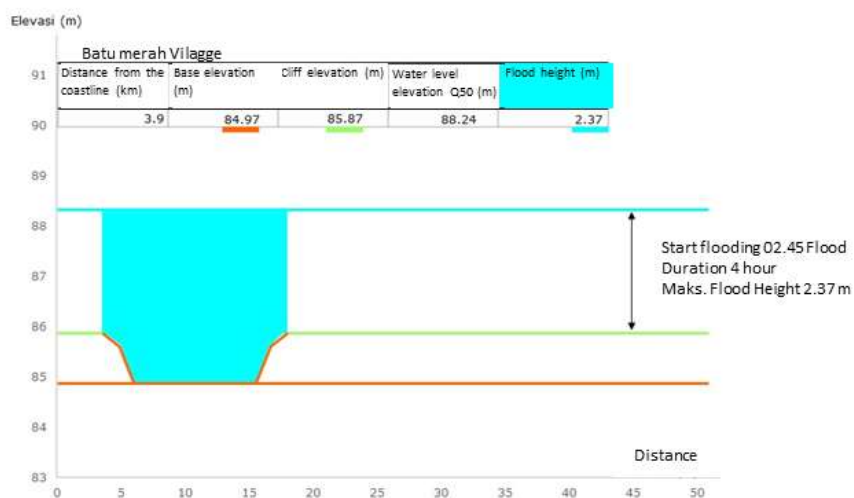


Figure 3. River cross-section at the first review point.

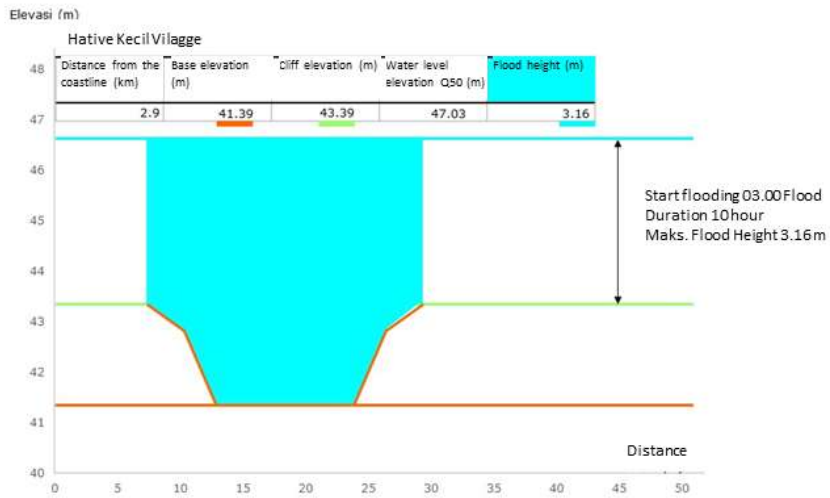


Figure 4. River cross-section at the second review point.

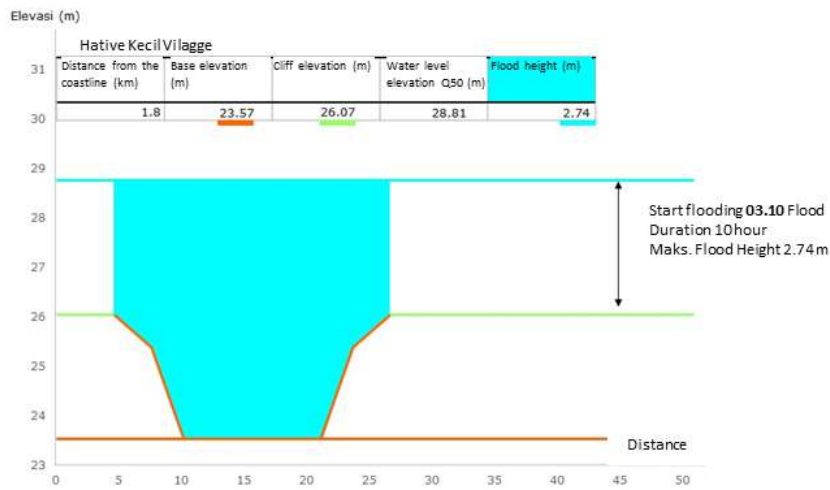


Figure 5. River cross-section at the third review point.

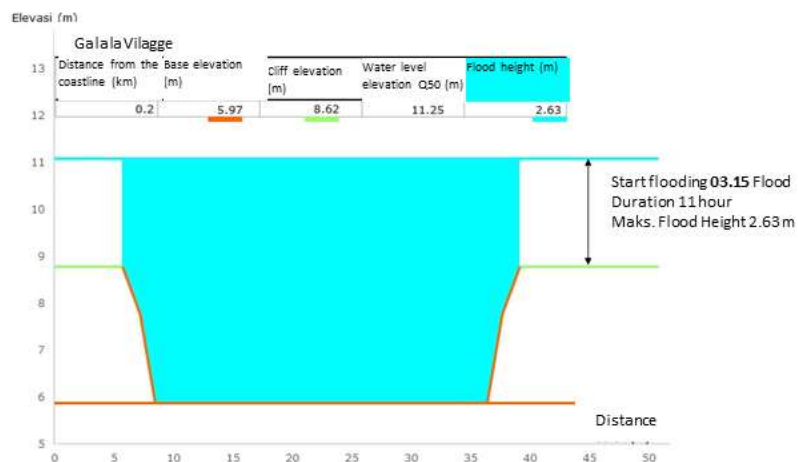


Figure 6. River cross-section at the fourth viewing point.

Figure 7 shows the water level profiles at each point of view are displayed in a shared graph so that it can be seen in the course of floodwater from upstream to downstream.

The flood routing takes 30 minutes with a distance of 3.7 km (the distance between the start and end review points). This means that if people in Batu Merah Village (a distance of 3.9 km from the estuary) start flooding at 02.45, then residents in Galala Village (a distance of 200 meters from the estuary) will receive flooding less than 30 minutes later (03.15), the flood routing shown in figure 8.

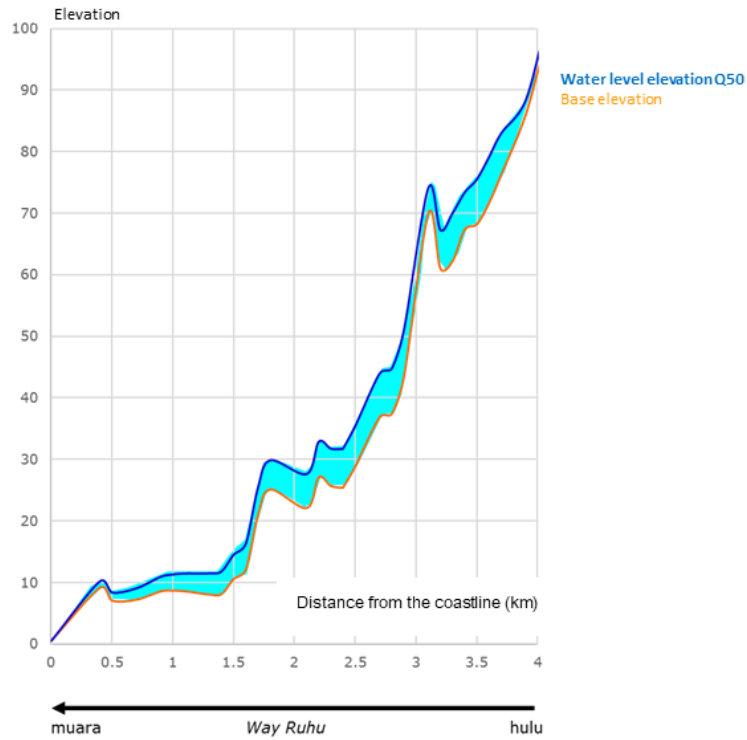


Figure 7. River cross-section at the fourth viewing point.



Figure 8. Flood routing in Way Ruhu with floods in 50 years.

5. Conclusions

The time interval between the rise of river water level in the upstream and the arrival of floodwater downstream is not more than one hour, with the character of the flood as high as 1-5 meters and receding within 4 to 11 hours.

The results of the study can be used as a basis for input in formulating a policy relating to the handling of non-structural flooding in flood-prone areas with similar characteristics, specifically with the Early Warning System application.

To provide a longer lead time so that it can provide sufficient time for evacuation it is recommended that the input data to the flood forecasting model in the Ruhu river catchment for future research use Radar, Satellite or Numerical Weather Prediction (NWP).

The need for the routine recording of river information by the local government so that the profile of the Way Ruhu cross-section and water level of the river is always observed and reported. If the land cover and cross-section change from the year of research, the modeling results are certain to be different.

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