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DEVELOPMENT OF FLOOD FORECASTING MODEL AND WARNING SYSTEMS AT RIVER OF WAY RUHU - AMBON

Muhamat Marasabessy
Doctoral Student of Civil Engineering Department, Hasanuddin University, Makassar

Muhammad Saleh Pallu
Professor, Civil Engineering Department, Hasanuddin University, Makassar

Rita Tahir Lopa
Associate Professor, Civil Engineering Department, Hasanuddin University, Makassar

Muhammad Arsyad Thaha
Associate Professor, Civil Engineering Department, Hasanuddin University, Makassar

ABSTRACT

Way Ruhu river has a main river length of 11.8 km with a watershed of 17.2 km^2, and the slope of the land is steep. People in the Way Ruhu river watershed are often threatened by flash. Therefore, this study was conducted with the aim to determine the magnitude and time of flooding in the Way Ruhu river watershed, the modeling results will 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. Output from HEC-RAS is flood map, flood height, and duration of flood. The results of this study indicate that the time between 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.

Keywords: Way Ruhu river, flood, 2D modeling, HEC-RAS

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1. INTRODUCTION

Indonesia's geographical condition which is located at the confluence of the earth's plates and pacific fire circles and climatological conditions namely high rainfall, leaves Indonesia vulnerable to disasters such as floods, earthquakes, volcanic eruptions, and landslides. The Government of Indonesia has implemented a number of policies and measures to mitigate disasters by developing a structural approach, but often the loss of assets and lives is still quite large if the disaster occurs, especially disasters due to flash floods. One of the cities frequently hit by flash floods is Ambon City. Ambon City has a hilly area that has the potential for landslides in the event of rain.

Heavy rain in Ambon City, which took place from Monday 29 July 2013 evening to Tuesday 30 July 2013 afternoon, caused floods and landslides in several places. As a result, residents of settlements on the banks of rivers, and hillsides are affected by flooding. In the past few years, rivers in the city of Ambon also often overflowed and flash floods occurred which resulted in a number of residents' homes being destroyed.

The heavy rains that often occur in the Way Ruhu - Ambon watershed and relatively steep topographical conditions, have caused massive flooding and affected community activities in Ambon City. Judging from the flow of the Way Ruhu River on one side is a potential river for exploitation and on the other hand it often creates flooding problems, a program / plan has been prepared to optimize the management of the Way Ruhu River so that when excess water can be controlled and when needed to support drinking water supplies can be guaranteed its reliability . The program for making dams upstream of the Way Ruhu River is an appropriate step in optimizing the management of Way Ruhu, where the dam can not only be used for flood control and water supply. In addition to the structural approach, a non-structural approach is needed to control water damage. One non-structural approach is by forecasting flood discharge and early warning systems, which are a series of systems for notifying the upcoming discharge at certain hours in a river caused by rain in the upstream. Non-structural approaches are widely used abroad and are successful in reducing the risk of loss of assets and lives.

This research is to support the management of water resources in the Way Ruhu Watershed by developing a forecast and early warning system of flow rates using a monitoring system of rainfall that is occurring /will occur and a monitoring system of river water level fluctuations in *real time* . With this system the magnitude and time of the flood will try to be predicted /known early. This information is very useful for the community so that when climate conditions are extreme, people can and have time to evacuate from a flood inundation location before a disaster occurs.

2. MATERIAL AND METHODS

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 :

2.1. Correlation Method

1. 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.
2. 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/not linear) by determining the deviation criteria/deviation between the observation discharge and the calculation discharge from the correlation model.

2.2. Rainfall-Runoff Models

1. 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).
2. 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).
3. 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 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 hydrograp results and the hydrograp results observed. If the parameters are stable enough, the parameters of the model can be used for flood forecasting and early warning (For example: Wflow model).

2.3. Flood Routing Models

1. 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 back water.
2. 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 hydrograp discharge and the observed hydrograp discharge. If sufficient parameters are obtained, the parameters of the model can be used for flood forecasting and early warning.

At this paper, the combination of simple rainfall-runoff model (unit hydrograph) and flood routing model (HEC-RAS5.0.7) is used to identified and simulated flood hydrograph 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.

2.4. Research Method

Water Level and Cross Section Measurement

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 1. Review points in (left) Galala village and (right) Hative Kecil village

The left of Figure 1 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 talud of 2.65 meters.

Methodolgy of Forecasting and Warning System

The selection of forecast data input and flood early warning can be seen in Figure 2.

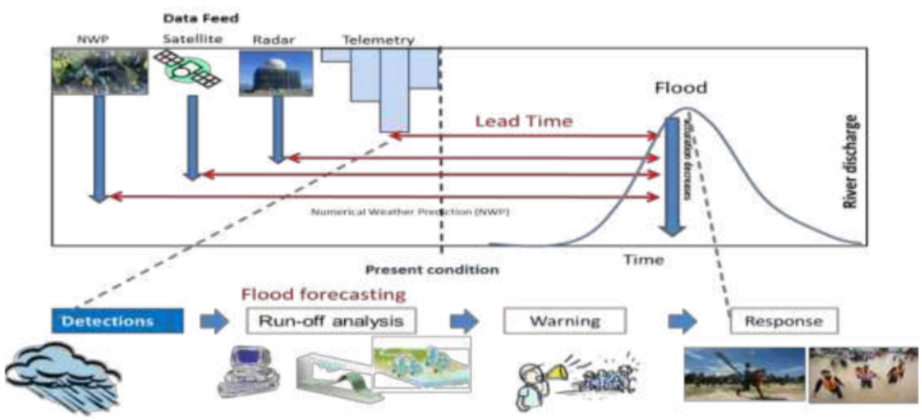

Figure 2. Selecting data inputs for flood early forecasting and warning

3. RESULTS AND DISCUSSION

3.1. Time Series and Cross Section

The results of water level profile modeling in the time series display and river cross section are shown in Figure 3 to Figure 6.

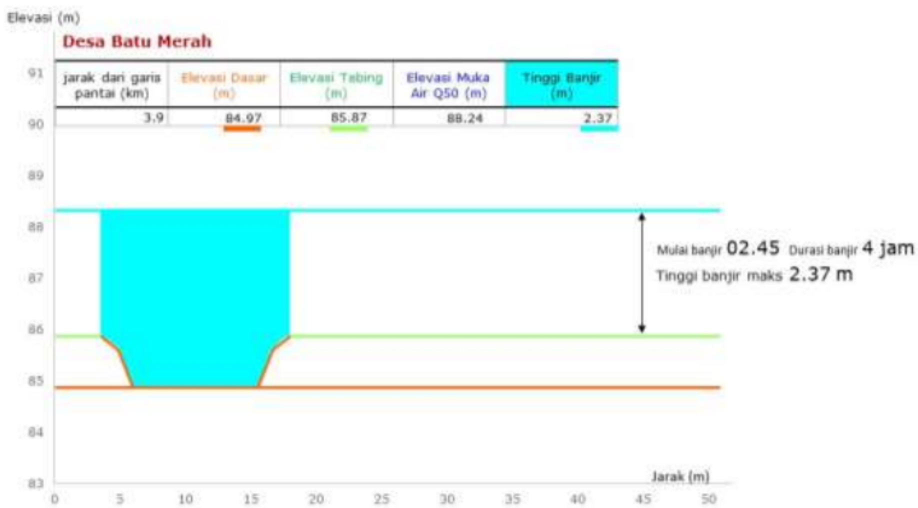

Figure 3. River cross section at the first review point

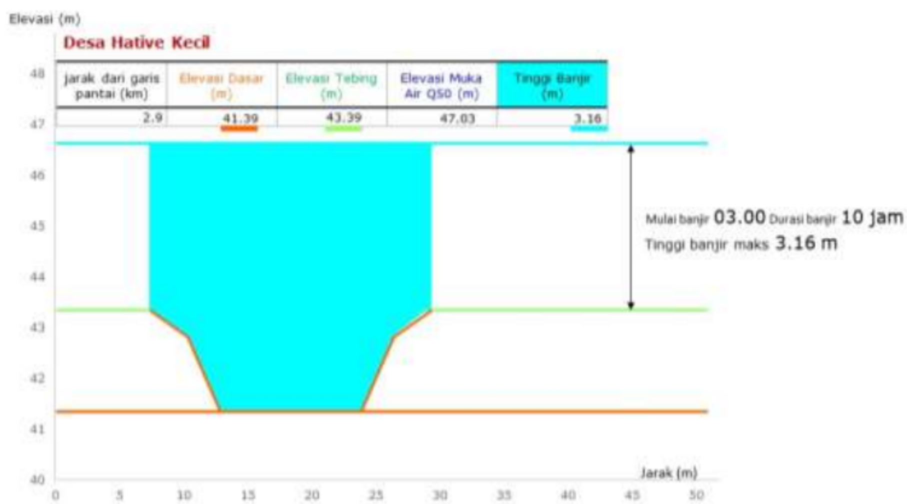

Figure 4. River cross section at the second review point

Figure 3 show 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 show 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.

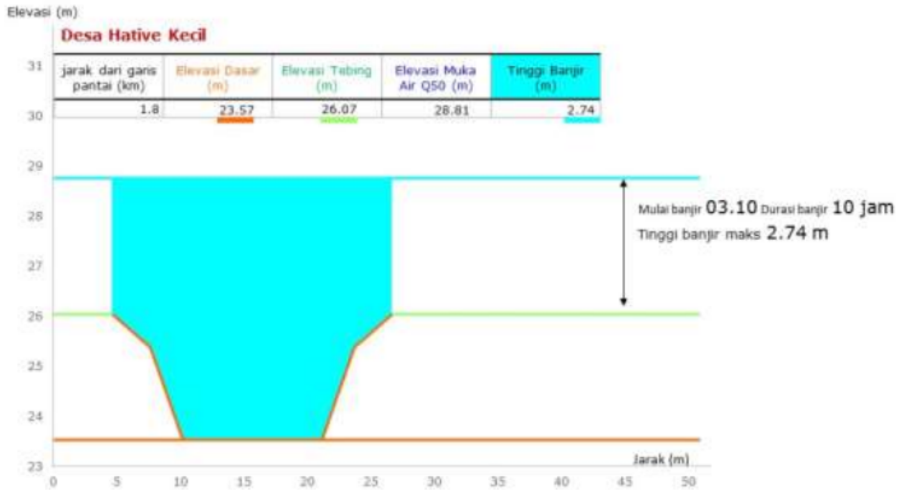

Figure 5. River cross section at the third review point

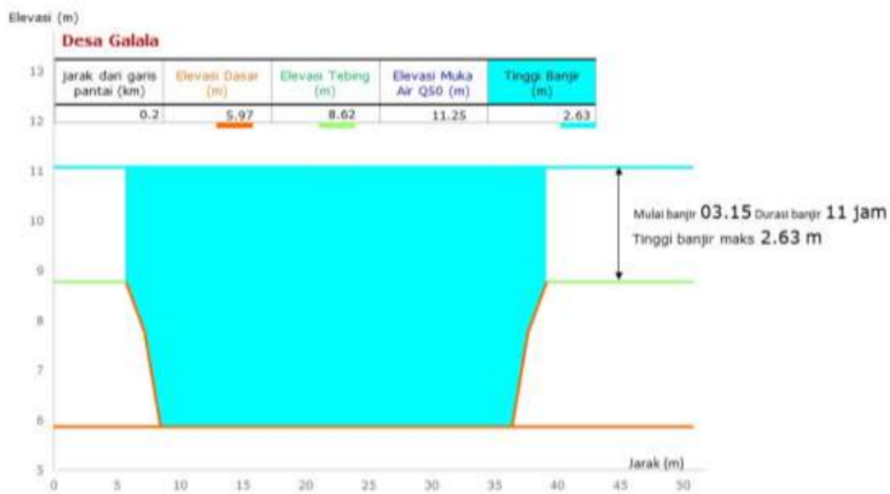

Figure 6. River cross section at the fourth viewing point

Figure 5 show 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 show 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.

3.2. Flood Routing

Figure 7 shows the water level profiles at each point of view are displayed in a shared graph so that it can be seen the course of flood water 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 9.

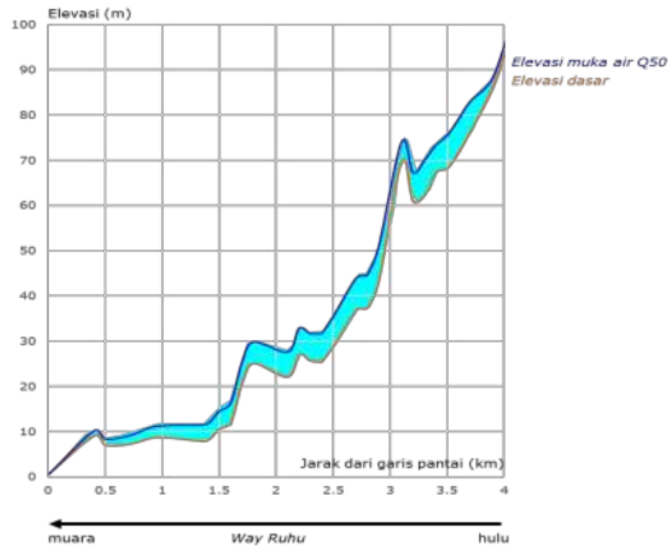

Figure 7. River cross section at the fourth viewing point

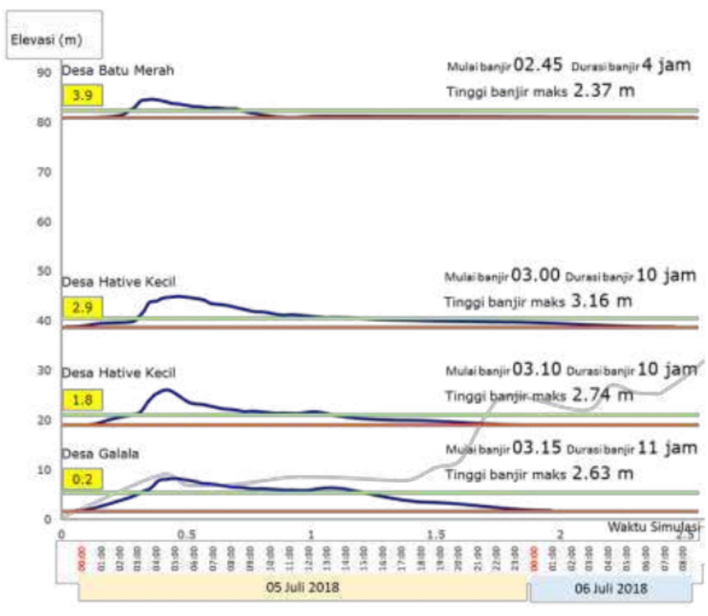

Figure 8. Flood routing in Way Ruhu with floods in 50 years

From the graph above, it can be seen that the journey of the flood takes 30 minutes with a distance of 3.7 km (the distance between the initial and final review points). This means that if the 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).

3.3. Visualization of Flood Inundation Layout

Visualization of flood inundation areas is the result of HEC-RAS 5.0.7. These results are then compared with a flood prone map issued by the local government.

Figure 9. Layout of flood inundation in 50 years

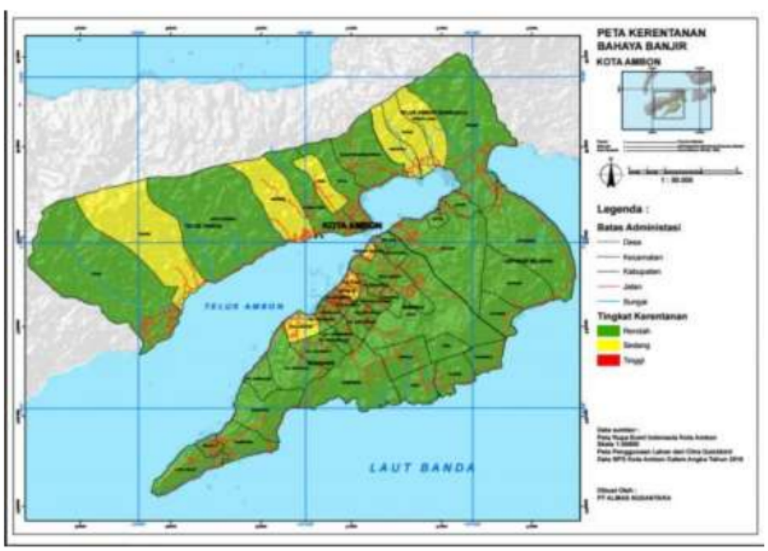

Figure 10. Map of flood hazard vulnerability

Based on Figure 9 and 10, it can be seen that Galala Village, Hative Kecil Village, up to a portion of Batu Merah Village enter the flood-prone zone with moderate vulnerability.

3.4. Analysis of Causes and Countermeasures

Based on the results of the modeling above, here are some analyzes from the author:

1. Extreme rain can often cause flash floods. If the intensity of rain in the upstream area is very high, while previously there has been rain so that the watershed is experiencing saturation. Then the extreme rain that occurred could no longer be held by the watershed and flowed rapidly downstream, there was a flash flood. Moreover, coupled with the topographic slope cram and earth profile in the form of rocks and hills.
2. Countermeasures can be done with preventive efforts by looking at the weather forecast, the community must be prepared for evacuation if the weather forecast conditions rain indicate extreme rain, settlements along the river banks are evacuated or relocated.
3. Typology of "sponge" watersheds can cause flash floods, where watersheds at the beginning of the rainy season function like "sponges" holding up almost 90% of the rain that falls on them. This rainwater is accommodated thoroughly in the form of small dams along river channels, basins, small basins etc. After reaching full condition, and the next rain is still falling, then the watershed is unable to hold anymore, thus releasing all the water it holds and causing flash floods in the downstream (Spon DAS which does not hold water, changes its nature to "as if squeezing water" that it holds. micro to medium scale dams composed of river sediments and residual vegetation are generally scattered throughout the watershed area, especially in small and medium river basins in the upstream area, because the water storage load increases, the construction of small to medium dam damages has a snowball effect. until the entire reservoir volume flows quickly downstream, so there is indeed a watershed sponge with a type of banjir bandang prone to watch out for. This explanation can be used to explain why in watersheds where forest cover is still relatively good, flash floods can occur. rubbish, pieces on-tree. If the volume of water increases and the blockage is unable to withstand it will burst and can be sure there will be a flash flood in the downstream. The flash flood was accompanied by a flow of logs, rocks and mud which was very dangerous during the flood.
4. The countermeasure is to conduct a river channel character expedition check and a downstream course. If a river channel typology is found as mentioned above, if dams are found from the remnants of vegetation, soil and rocks in various places along the river channel, it is necessary to attempt surgery of the blockages before the rainy season arrives or during the early rainy season . After a flash flood, the community does not need to be afraid of the subsequent flash floods and the real time is close to the previous flash floods. This is because waterways need time to form natural reservoirs again. However, this type of flash flood will periodically recur. A field survey is needed to ask the community about previous flash flood events in the river.
5. Damage to the river channel by landslides that will cause flash floods can also occur due to geological landslides at various points. Avalanches can be more intensive with the earthquake that occurred before, so that the stability of the river cliffs is weak. The closure by these damages causes accumulation of water volume in the upstream part of the landslide. Floods caused by dams and blockages due to landslides or residual vegetation above can be repeated several decades later (according to the characteristics of the watershed). The years after this big flash flood will generally not occur again. Subsequent flash floods may occur after the watershed has succeeded in forming small dams again.
6. Countermeasures can be done by investigating riverbank prone areas. Areas estimated to be landslides can be detained by construction of landslides or they will be reported in advance and landslide material removed before the rainy season arrives, so that the flow of water smoothly does not occur dams.
7. Flash floods can also be caused by the breakdown of dams or dykes. In general, the dam and embankment burst due to leakage or seepage and the most dangerous is over topping

(the water level in the dam flows past the peak of the dam). Seepage and leakage and over-topping generally take place very quickly and the volume of flood waters from rivers and reservoirs flowing graphically through the area in its path in a relatively short time. The community is generally late in evacuating. The collapse of the embankment can cause flash floods as long as the flow leads to a much lower area with steep slopes, within hours the area is in a flooded condition.

8. Countermeasures are carried out with an *early warning system* and evacuation as soon as possible, as well as preventive routine investigations carried out security of the dam or embankment. If there are indications of leaking or piping, they must be fixed immediately. Counter measures are *Over-topping* generally installed with emergency overflow and automatic control on overflow doors.

4. CONCLUSIONS

The time interval between the rise of river water level in the upstream and the arrival of flood water downstream is not more than one hour, with the character of 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 the future research to use Radar, Satellite or Numerical Weather Prediction (NWP).

The need for 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 land cover and cross section change from the year of research, the modeling results are certain to be different.

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