Flood modelling of Air Bengkulu Watershed, Indonesia, using SUH and HEC-HMS

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Abstract. This study aims to develop a flood forecasting model for Air Bengkulu based on Synthetic Unit Hydrograph and HEC-HMS. Rainfall data were obtained from the River Region VII Regional Office of Bengkulu Province, from 2000 to 2021. The Synthetic Unit Hydrograph (SUH) method used to estimate the discharge was a synthetic unit hydrograph, namely GAMA-1. Flood simulation was carried out using HEC-HMS software. The peak discharge value produced by HEC-HMS is 690 m s⁻¹ while the peak discharge value from SUH GAMA-1 is 319.23 m s⁻¹. The peak discharge value of the Air Bengkulu flood produced by both SUH GAMA-1 and HEC-HMS has been able to represent the value of the flood discharge of the Air Bengkulu Watershed. This study concludes that SUH GAMA-1 and HEC-HMS have been able to model the flood event on April 29, 2019, that occurred in the Air Bengkulu watershed. Validation of the model needs to be studied continuously so that it can produce a model that can represent the actual flood events in Air Bengkulu.

1. Introduction
Flooding is the number one natural disaster in Bengkulu province. Flood events happen every year, even if floods hit an area more than once a year. Floods inundated various locations in every district in Bengkulu province. The impacts that have been caused by floods in the form of economic losses, ecological damage, and loss of life. These losses cannot be valued in money and the recovery time is also long. Therefore, all people must give serious attention to solve the problem of flooding.

Flood discharge can estimate using synthetic unit hydrograph such as Snyder, Nakayasu, and Soil Conservation Service [1-3]. GAMA-1 and GAMA-2 were carried out by Sri Harto [4], ITB-1, and ITB-2 were carried out by Dantje K Natakusumah [5], ITS-1 and ITS-2 by Lasidi, et al. [6], Limantara by Lily Montarcih Limantara (2009) [7]. US Army the Corps of Engineers has also developed a flood discharge estimation model. HEC-HMS can be used to calculate runoff volume, direct runoff, baseflow, and channel flow [8-12].

Each model that examines the relationship between rainfall and runoff has various advantages and disadvantages. Efforts to find an appropriate model for predicting flooding in a watershed can be done by trying various existing models and then validating them. A good model is a model with a high level of accuracy. This study aims to develop a flood forecasting model for Air Bengkulu based on Synthetic Unit SUH and HEC-HMS.

2. Method
2.1. Research Site
Geographically, the location or position of the Air Bengkulu watershed is between 5 ° 40'2 "south latitude to 100 ° 40" 104 "east longitude. This Air Bengkulu river flows through seven districts along with the river flow [13]. The research location is presented in Figure 1.
2.2. Data
Rainfall data were obtained from the Balai Wilayah Sungai Sumatera VII, Bengkulu Province. Rainfall data is presented in Figure 2.

![Rainfall Data of Rainfall Station on Watershed of Air Bengkulu](image)

**Figure 2** Rainfall Data of Rainfall Station on Watershed of Air Bengkulu

2.3. Synthetic Unit Hydrograph (SUH)
Hydrologists have widely used the SUH method to estimate flood plans in watersheds that do not have automatic water level recording devices. In this study, the synthetic unit hydrograph tested to estimate the discharge in the Bengkulu watershed is GAMA-1. The equations used for the synthetic unit hydrograph of GAMA 1 are presented in the equation.
a. Peak Time (Tp)

\[ T_p = 0.43 \left( \frac{L}{100SF} \right)^3 + 1.0665 \text{ SIM} + 1.2775 \]  

Where:
\[ L = \text{River Long (km)} \]

**SF is the time of resource (dimensionless), the equation of SF is:**

\[ SF = \frac{X}{Y} \]

Where:
\[ X = \text{total length of river of ordo 1 (km)} \]
\[ Y = \text{total length of river of all ordo (ordo 1, 2, n) (km)} \]

SIM is symmetry factor, using the equation as:

\[ SM = WF x RUA \]

WF is width factor (dimensionless). The equation using for estimate WF is:

\[ WF = \frac{W_u}{W_l} \]

Where:
\[ W_u = \text{the width of the watershed measured at the point of the river which is 0.75 river length from the hydrometric station (km)} \]
\[ W_l = \text{the width of the watershed measured at the point of the river which is 0.25 river length from the hydrometric station (km).} \]

b. Peak Discharge (Qp)

\[ Q_p = 0.183 A^{0.5886} JN^{0.2381} TR^{-0.4008} \]

A is watershed area (km²), JN is total of river joint, TR is time of Rise (jam)

c. Base time (Tb)

\[ T_b = 27.4132 TR^{0.1457} S^{-0.0996} SN^{0.7344} RUA^{0.2574} \]

\[ S \text{ is average river slope, SN is source frequency. RUA equation is:} \]

\[ RUA = \frac{Au}{A} \]

RUA is relative watershed area upstream (dimensionless). Au is watershed area upstream (km²). A is watershed area (km²)

2.4. Hydrologic Engineering Centre-Hydrologic Modeling System (HEC-HMS)

The Air Bengkulu Watershed, a part of the Bengkulu River Basin located in Bengkulu Province. The primary conveyance system of this 515 km². Watershed includes the following streams: Susup, Rindu hati, and Bengkulu Hilir. Bengkulu Hilir is downstream of the confluence.
Flood events in 1978, 1989, and 2019 in this region are considered in this model. Parameters of the HEC-HMS model are basin model, meteorological model, control specification, time-series data, model evaluation, deficit, and constant loss method, and SCS unit hydrograph transform method. The model was applied to the Air Bengkulu watershed. It has three sub-watersheds. The area of each Air Bengkulu sub watershed are Rindu Hati (192.08 km²), Susup (98.9 km²) and Bengkulu Hilir (224.02 km²). It has a total of three rain gauge measurement stations: Bajak, Tabu Mutung, and Tanjung Jaya.

The method used to estimate peak discharge is the SCS method. Initial abreaction 20.75 mm, curve number 71, and initial discharge 1.61. Processed results for Air Bengkulu Watershed were imported to HEC-HMS software for simulation present in Figure 3.

Figure 3 shows the concept of Bengkulu flood modeling using HEC-HMS 4.8 software. HEC-HMS is designed to simulate the rainfall-runoff processes of watershed systems to identify drainage and forecasting floods based on the resulted hydrograph. The physical representation of a watershed is made with the basin model. Yet, hydrologic elements (sub-basin, reach, junction, reservoir, diversion, source, and sink) are connected in a dendritic network to simulate runoff processes [12].

3. Result and Discussion
3.1. The synthetic unit hydrograph.
The estimation results using the synthetic unit hydrograph GAMA 1. The final superposition result in the form of GAMA -1 SUH is shown in Figure 4.
Figure 4 The GAMA 1 Synthetic Unit Hydrograph in the Air Bengkulu Watershed

The figure 4 shows the peak discharge is 319.23 m³/second, with a peak time (Tp) of 4.5 hours. This estimation result is greater than the result of the design discharge estimate using the Log Pearson Type III method. The discharge value for the 100 year return period is 193.34 m³/second.

3.2. The hydrograph in the Air Bengkulu Watershed from HEC-HMS

HEC-HMS model consists of 3 Sub Basin, 4 reaches, 1 junction, and 1 sink. Sub Basin contains data about sub-basins losses, SCS Curve Number method, transform model is unit hydrograph method, and baseflow is recession method. This data is used for the transformation of rainfall into runoff. The Rindu Hati and Susup sub-watersheds are upstream of the Air Bengkulu River. The normal discharge of the Rindu Hati Sub-watershed and the Susup Sub-watershed are 26.4 m³/s and 21.4 m³/s. The hydrograph of them shown in Figure 5.

Figure 5 Hydrograph in the Susup and Rindu Hati sub-Watershed

Flooding occurs in the downstream area, namely in the Air Bengkulu Hilir sub-watershed. The contributing factors include very high rainfall with a long duration of rain and its distribution evenly from upstream to downstream. The Peak discharge of Air Bengkulu Hilir sub-watersheds is shown in Figure 6.
Figure 6 shows the flood discharge in the Air Bengkulu River Basin of 690 m³/second. Peak discharge occurs at 12:50 with a peak time (Tp) of 5 hours 50 minutes. The factor causing the high flood discharge in the Air Bengkulu River Basin is caused by high rainfall and occurs for a long time. Another contributing factor is the rain that is evenly distributed from upstream to downstream so that the Air Bengkulu River is no longer able to accommodate all the rainwater that enters the river.

4. Conclusion

Based on the results of synthetic hydrograph modeling that has been carried out in the watershed using synthetic hydrographs (GAMA-1) and HEC-HMS software, it can be concluded that the flood calculation distributed with HEC-HMS Software, apparently provide an earlier flood peak time and peak flood discharge which is higher than the yield calculation of a single (lumped) watershed flood using Gamma-1.

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