Determination of Correction Value Curve Number (CN) on Watershed With Shape Oval Using HEC HMS Models

Nanang Saiful Rizal*, Kus Farukah
* Departement of Civil Engineering, University Of Muhammadiyah Jember
*nanangsaifulrizal@unmuhjember.ac.,id, **kusfarukah_civil@gmail.com**

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ABSTRACT

Hydrological analysis to obtain surface runoff in watershed with oval shape (form factor> 8) in large errors (more than 20%) of field observations. This is because the determination of the parameters used the same as the normal watershed without any correction factor. Some influential parameters, including topographic forms of watersheds, land use, soil types, soil moisture. So for the estimation as well as correction of these factors used approach with HEC HMS model. In the HEC HMS model, influencing factors such as soil properties, geological formation and land use have been simplified by the name of the Curve Number (CN) factor. The value of the CN (curve number) varies from 100 (for waterlogged surfaces) to 30 (for non-watertight surfaces with high infiltration values). The CN factor correction value that will be recommended in this research is yielding the smallest error with the largest correlation coefficient. After performing hydrological analysis by comparing field observation results, the watershed with oval shape was obtained by CN correction number of 1.2, with relative error (11.5%) and correlation coefficient (82%).

Corresponding Author:

Kus Farukah
Departement of Civil Engineering,
University Of Muhammadiyah Jember,
Jl. Karimata 49 Jember, Jawa Timur, Indonesia 65144
Email: **kusfarukah_civil@gmail.com**

1. INTRODUCTION

The results of the hydrological analysis to obtain surface runoff in the oval-shaped watershed often result in large errors (more than 20%) of field observations. This is because the determination of the parameters used the same as the watershed with the normal form without any correction factor. Though the flow characteristics in the watershed with oval shape is very different, the peak flood time is shorter than the normal form of watershed [3]. Some influential parameters, including topographic forms of watersheds, land use, soil types, soil moisture [2]. The form factor of the watershed is obtained from the ratio of the watershed and the length of the main river [3]. Besides form factor, the supporting factor which also influences is geological formation [4]. The ability to deliver reliable water resources to a growing population and effectively forecast flooding, drought, and surface/groundwater water contamination represent increasingly difficult and interrelated challenges to water resource managers, engineers, and researchers [6]. The results are only as good as the accuracy of the data and in most cases the resolution of the data may not be high enough to draw conclusions from it. This limitation cannot be overcome by complex software, because it is inherent in the data or the database itself [7].

This model is often used because it is more accurate, counting operation is easier and its output can be combined with other software used in water availability, urban drainage, urbanization impact prediction, spillway design, reduction of flood damage, flood handling regulations, and hydrological operation system [1] . A modified curve number (CN) approach has been employed to simulate streamflow and water yield at sub-catchment scale over hundred years utilizing Soil and Water Assessment Tool (SWAT) [8]. Nash–Sutcliffe efficiencies (NSE) for discharge on a daily basis were 0.50 during calibration (0.42 during validation) for the curve number and 0.45 (0.39) for the Green and Ampt method. Tile flow was predicted with NSE values of 0.35 during calibration (0.36 during validation) for the curve number and 0.33 (0.62) for the Green and Ampt method [10]. In this model, influencing factors such as soil properties, geological formation and land use have been simplified by the name of the Curve Number (CN) factor. CN (or, potential maximum retention, S) values showed a higher degree of dependence on the physically [9]. The value of the CN (curve number) varies from 100 (for waterlogged surfaces) to 30 (for non-watertight surfaces with high infiltration values). The error value is still large (error> 10%), then there needs to be an analysis for the determination of correct correction factor CN value. The way to obtain CN factor correction value is by inserting some correction value of CN value on HEC HMS model, then result of calculation of surface runoff value compared with observation discharge. The CN factor correction value that will be recommended in this research is yielding the smallest error with the largest correlation coefficient.

Bedadung River is the main river that passes in the middle in Jember Regency. Bedadung River flow has a length of 141 km with watershed area of 2,271 km^2, which is geographically located 6 ° 27'9 " - 7 ° 14'33 " East Longitude and 7 ° 59'6 " - 8 ° 33 ' 56 " South Latitude. Bedadung River is topographically divided into three parts, the top land with the slope of the land > 10%, the middle section between 3% - 10% and the bottom with a slope of < 3%. At the top of the watershed is selected as a research area that most of the land use in the form of plantations and moor. Average annual rainfall is about 1800 mm. The highest monthly rainfall occurred in November with a monthly average rainfall of about 200 mm, while the lowest monthly rainfall occurred in June with a monthly average rainfall of about 150 mm.

2. MATERIAL AND METHODS

The Curve Number (CN) factor determined based on soil properties, geological formations and land use has been simplified by the name of the Curve Number (CN) factor with values varying from 100 (for waterlogged surfaces) to about 30 (for non- High infiltration). CN values are also affected by AMC (Antecedent Moisture Categories) or previous moisture values. The AMC values affect the volume values and the surface flow rate. The soil classification is hydrologically divided into 4 groups:

a. Characteristic of soil with sand texture and deep profile, with infiltration rate > 0.75 cm/hour.
b. Sandy soil and shallow profile.
c. Loose clay soil and little BO content.
d. Clay texture and infiltration rate <0.15 cm / hour.

The stages performed for this research are: a). Calculate the maximum daily rainfall by polygon thiessen method, b). Calculate the value of the curve number using the soil geological map approach and land use map, c). Calculate the runoff SCS Curve Number (CN) and Hydrograph SCS Units, d). Make HEC HMS Component Models, e). Make Time Series Data, f). Creating and filling the Basin Models, g). Filling Meteorologic Model, containing rain data and evapotranspiration data, h).Charging Control Specification, containing start and end time of calculation process, i) Filling Time-series Data, containing rain data, j) Checking Watershed Data, k). Doing Simulation, l). Conducting Calibration. m). Analysis of relative errors and correlations.

3. RESULT AND DISCUSSION

In the calculation of the average rainfall area using the daily rainfall data from 3 rain stations, namely Station DAM Klatakan, DAM Tugusari and DAM Karanganom. Daily rainfall data is 25 years from 1990 until 2015. Analysis of the average rainfall area used polygon thiessen method, the choice of this method is done because the number of rain stations only 3 (three) with the position spread evenly on the Bedadung River Basin. After the calculation of the extent of the influence of each station obtained coefficient value thiessen each station as presented in table 1.

The value of curve number (CN) can be started by determining the type of soil group. SCS developed a soil classification system based on soil properties, detailed soil maps, or soil infiltration rates. CN value is influenced by soil classification in Watershed, because in this research is not done research on soil classification. The soil classification in Bedadung River Basin is determined based on geological map of Jember Regency.

Table 1. Thiessen Coefficient Bedadung river area

o	Name of rain station	Area (Km^2)	Thiessen Coefficient
	DAM Klatakan	70.342	0.6536
	DAM Tugusari	5.89	0.0547
	DAM Karanganom	31.396	0.2917
	Amount	107.628	1.0000

Based on the above geological map in get that Bedadung River Basin consists of two types of land are:

1. Qvab (Breksi Argopuro) : Breccia volcano is arranged andesit, inserted lava.
2. Qaf (Argupuro Fume Deposition) : Rebellion of argopuro volcano rock.

Table 2. Classification of soil groups

Ground Class	**Soil Characteristics**	**Infiltration Rate (cm/h)**
A	Deep sand, deep loess, aggregated dust	0.78-1.14
B	Loess shallow, sandy loam	0.38-0.78
C	Diamond clay, shallow sandy clay, low grade soil organic matter and high clay soil	0.13-0.38
D	Substantially expanding soils, if heavy clay, and certain saline soils	< 0.13

Source : HEC-HMS TechRef ManualMar2000

Table 3. Calculation of Curve Number (CN)

No	Land Use	Area (Km^2)	CN
1	Rice Fields Rain	6.482	65
2	Irrigated Rice Fields	7.709	63

3	Shrubs	7.586	68
4	Plantations and Forests	74.227	25
5	Settlement	6.295	51
6	Moor	5.236	65
7	Land	0.091	68

$$CN = \frac{(A1\ x\ CN1) + (A2\ x\ CN2) + \ldots\ldots..(An\ X\ CNn)}{A}$$

$$= \frac{(6.482\ x\ 65) + (7.709\ x\ 63) + (7.586\ x\ 68) + (74.227\ x\ 25) + (6.295\ x\ 51) + (5.236\ x\ 65) + (0.091\ x\ 68)}{(6.482 + 7.709 + 7.586 + 74.227 + 6.295 + 5.236 + 0.091)}$$

$$= \frac{3946.093}{107.626} = 36.7$$

$$S = \frac{1000 - 10CN}{CN}$$

$$= \frac{1000 - 10\ x\ 36.7}{36.7}$$

= 17.3

Ia = 0.2 x S
= 0.2 x 17.3
= 3.45 mm

In this research will be used SCS unit hydrograph method. The SCS hydrograph unit model is a single-peaked hydrograph model and a dimensionless hydrograph. SCS hydrograph can be used easily, the main parameter required is the time lag between the effective rain point and the hydrograph weight. These parameters are based on data from some catchment areas. Calculation of Time lag (tlag) is as follows :

Tc = 0.57 x $A^{0,41}$
= 0.57 x $107.628^{0.41}$
= 3.88 hour (232.871 minutes)

t_{lag} = 0.6 x Tc
= 0.6 x 3.88
= 2.33 hour (139.723 minutes)

- Modeling by Using HEC-HMS

In this model, there are several kinds of hydrograph methods of synthetic units. While to complete this hydrological analysis is used synthetic hydrograph unit of SCS (soil conservation service) by analyzing several parameters, then this hydrograph can be adapted to the conditions in Bedadur River Basin. As a comparison, the data is recorded from the automatic discharge AWLR (Automatic water level recorder) located in Rowotamtu, Rambipuji Sub-district, Jember District. Physical representation of watershed and river areas is present and arranged on the model basin. The hydrological elements are related in the tissues that simulate a direct runoff process. The elements used to simulate runoff are subbasins and junctions. The model elements of Bedadung River Basin are presented in Figure 1. Sub-basin Loss Rate Method (Water loss process), is a way to calculate water loss that occurs through infiltration process. SCS developed empirical parameter curve

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number which assumes various factors of soil layer, land use, and porosity to calculate total rainfall runoff. SCS Curve Number consists of several parameters that must be input is initial loss or initial infiltration value, SCS Curve Number, and imperviousness. For initial infiltration value and SCS Curve Number can be seen in figure 3.

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Baseflow can be interpreted as a baseline flow, this model is used to describe the base flow that occurs during runoff so it can be calculated the height of the hydrograph peak that occurs. In the modeling method used recession (recession) with the assumption that the base flow is always there and has a hydrograph peak in one unit of time and has a relationship with rainfall (precipitation). The parameters used in this recession model are initial flow, recession ratio and treshold flow. Initial flow is a calculated baseline flow value or from observational data, the recession ratio constant is the value of the ratio between the current and yesterday flow constantly has a value of 0 to 1. While the treshold flow is the threshold value of the runoff flow and the baseline flow. To calculate this value can be used exponential way or assumed with a large value ratio from peak to peak.

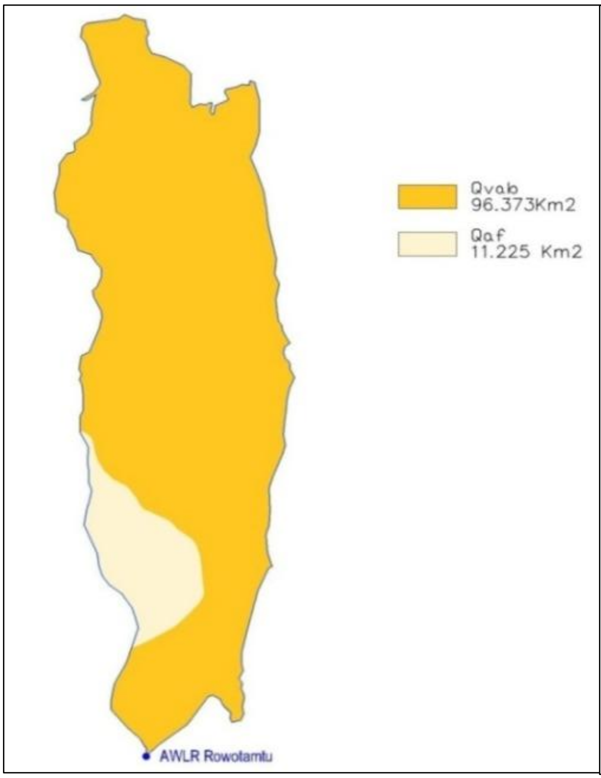

Figure 1. Geological map in the study area.

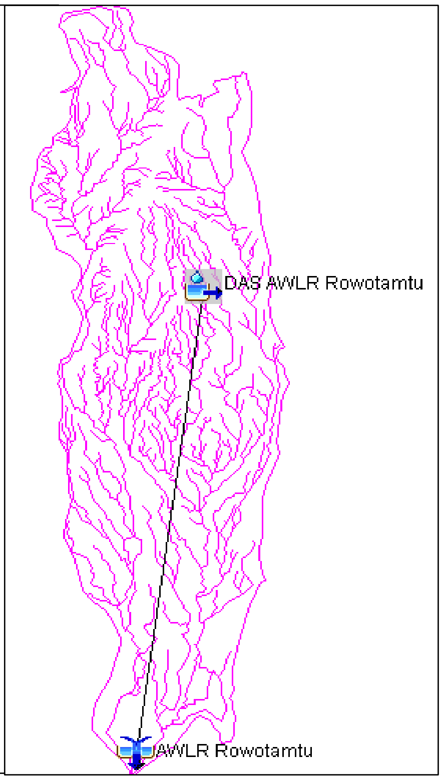

Figure 2. Subbasins and granting elements

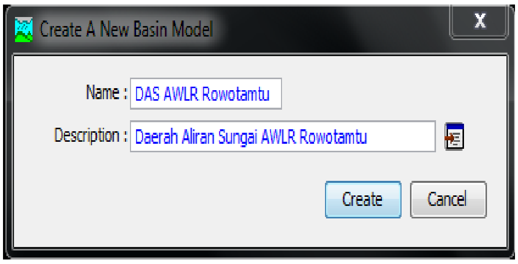

Figure 3. The creation of sub-river basin names

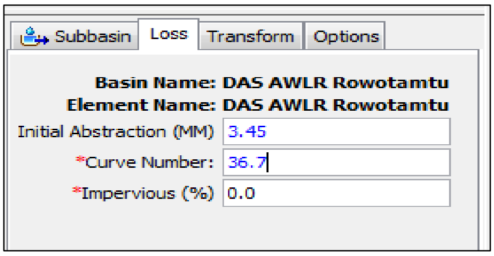

Figure 4. Sub-basin values Loss Rate Method (process of water loss)

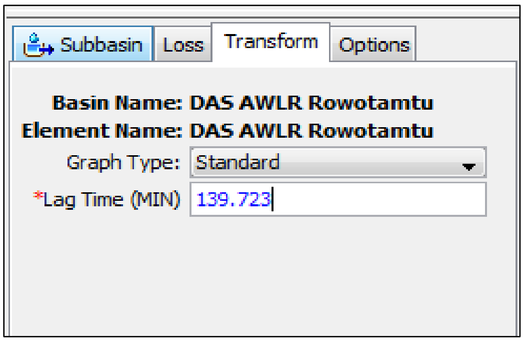

Figure 5. Value of Sub-basin Transform (Basic flow process)

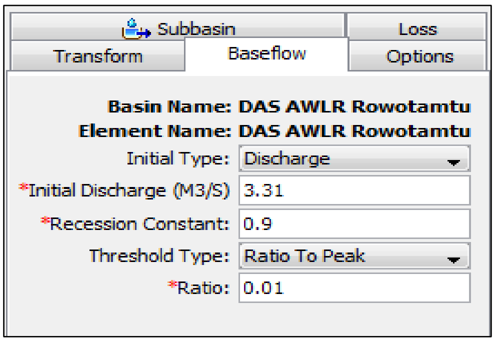

Figure 6. Value of Sub-Basin Baseflow method

- Metereologic Model (Rain Data Model)

The selection of rain stations to be used in the analysis is done by clicking on the rainfall data pilot that has been done before in watershed, next select the rain station to use.

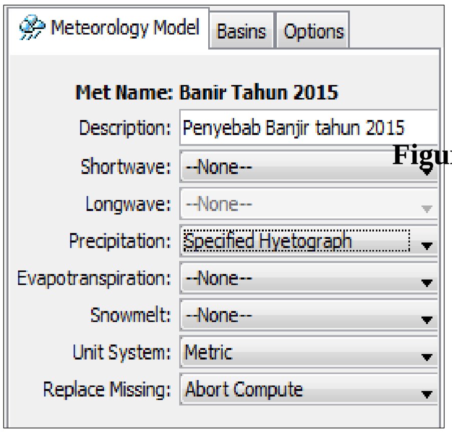

Figure 7. Options metereologic Model Filling

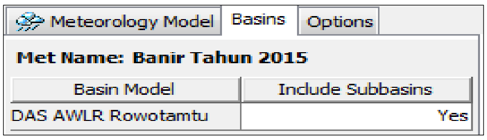

Figure 8. Selection of rain stations On the watershed

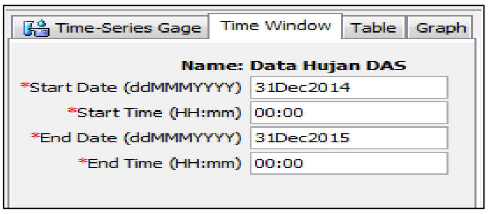

Figure 9. Preparation time rainfall data (rain data model)

The hydrograph design should be based on real rainfall events. Precipitation data input or effective rainfall during floods, can be 5 minutes, hour-time or daily. It should be noted that the rainfall area obtained from the average rainfall thiessen method with respect to the influence of rainfall stations in the area.

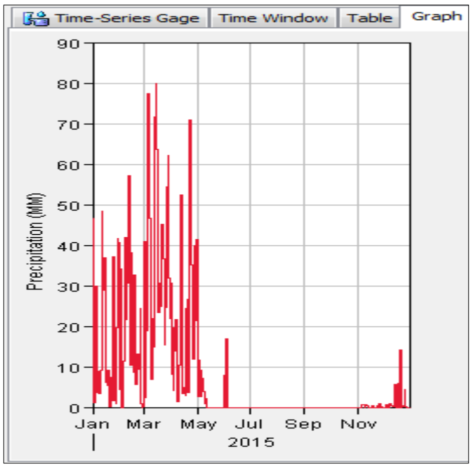

Figure 10. Time Series Data Value (Rain Data Charging)

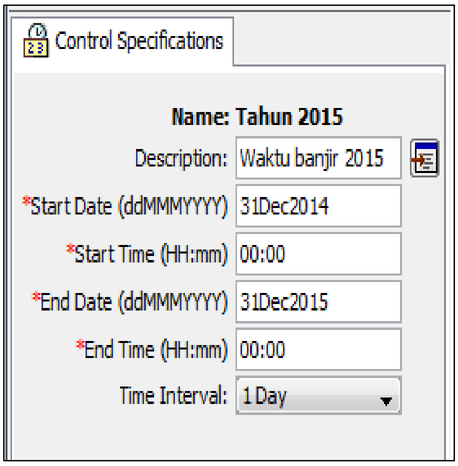

Figure 11. Value of Control Specifications (Running time**)**

Control Specifications contains the input time of the start and end of the program running and the desired time interval (15 minutes, 1 hour, 1 day). The procedure used is the same as basin model or meteorological model. Once all of the above input variables are entered, to execute modeling in order to run then the model and model meteorologic models should be unified. The execution result of this method can be seen in the graph and the output value below. The output below is the flood discharge plan for the 1st anniversary period. The results of the HEC-HMS model simulation for 2015 as shown in Figure 12 above. Obtained top discharge simulation model of 89.1 m^3/sec and total outflow volume of 2687.43 mm with peak discharge time occurred on March 15, 2015. For the initial stages of testing, model calibration based on rain data and measured discharge data in 2015. The calibration Done based on the parameters contained in the basin model is the value of initial, curve umber, and time lag.

From the parameters of the first selected initial parameters are used as an initial condition, then the parameters are made independent variable is determined its value by way of retest until the obtained values that meet. While for other parameters made dependent variable, it aims to facilitate in optimizing. The criterion that meets the value is if from the values obtained graphs that are similar between the measured discharge graph with the calculated discharge. In this study for independent variables in the set is the value of curve number and initial abstraction while the dependent variable is the time lag. The calibration data can be observed for model work by observing differences in observational discharge and theoretical discharge. Based on the result of HEC-HMS method analysis got the peak discharge simulation model of 89.1 m^3/sec and the total outflow volume of 2687.43 mm with peak discharge time occurred on March 15, 2015. While for the observation debit of Bedadung River Basin readout result is peak discharge of 335.9 m^3/sec and total outflow volume of 7105.97 mm with peak discharge time on March 6, 2015.

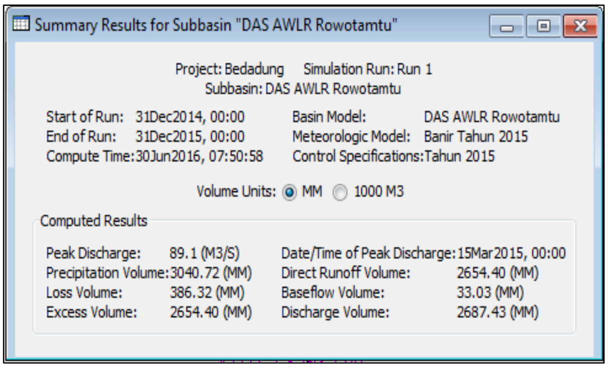

Figure 11. Results of the peak time simulation process and peak discharge

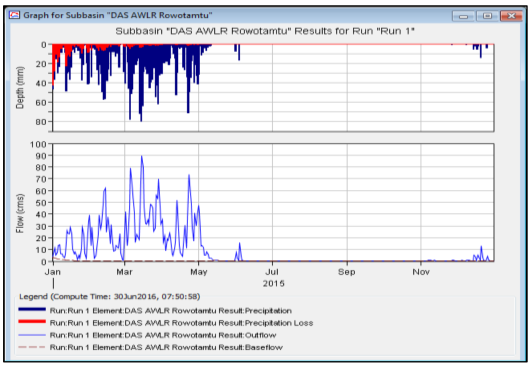

Figure 12. Bedadung simulation process Watershed Hydrograph

- Recapitulation of Calibration Results

By simulating simultaneously, at various variations of CN values, the values of correlation coefficients and relative errors vary, the results are shown in Table 5. After a comparison of some of the alternatives presented in tables and graphs can be concluded on the 13th alternatives that have the highest correlation coefficient (0.7249) and the relative error is the smallest (0.7216). The difference between the correlation coefficient and the relative error on alternate-13 is 0.0033.

Table 5. Comparison of correlation coefficient coefficient values and Relative error at various CN & Initial abstraction

No	CN	Ia	correlation coefficient	Relative error	Difference
1	36.665	3.455	0.670	0.735	0.065
2	40.000	3.000	0.677	0.731	0.055
3	45.000	2.444	0.684	0.729	0.045
4	50.000	2.000	0.691	0.727	0.036
5	55.000	1.636	0.696	0.725	0.029
6	60.000	1.333	0.702	0.724	0.022
7	65.000	1.077	0.706	0.723	0.017
8	70.000	0.857	0.710	0.723	0.013
9	75.000	0.667	0.714	0.722	0.008
10	80.000	0.500	0.717	0.722	0.005
11	85.000	0.353	0.721	0.722	0.001
12	90.000	0.222	0.723	0.722	0.001
13	95.000	0.105	0.725	0.722	0.003

4. CONCLUSIONS

The analysis, Response Assessment Watershed Hydrological Program Bedadung with HEC-HMS with secondary data processing and automatic discharge data at the point AWLR Rowotamtu located in the district of Jember Rambipuji can be summarized as follows: By determining the value of surface runoff coefficient (curve number) and initial abstraction as independent variable, while the duration of concentration (lag time) as dependent variable. Showed that there is a relationship (correlation coefficient) which tightly between flood discharge calculation methods HEC-HMS with discharge on the observation of the field recording Rowotamtu AWLR tool. With correlation coefficient values for various curve number and initial abstraction values ranging from 0.6697 to 0.7249.

Based on the analysis method of HEC-HMS obtained peak discharge model simulation results of 83.5 m^3/sec and total volume of outflow amounting to 3027.30 mm with a peak discharge occurred on March 15, 2015. While the observation of the discharge readings obtained AWLR rowotamtu peak discharge of 335.9 m^3/s and total outflow volume of 7105.97 mm with peak discharge time on March 6, 2015. For the purposes of the calculation of flood discharge using HEC-HMS at Rowotamtu AWLR basin located in the district of Jember Rambipuji drawn from the data that has a value that is the highest correlation coefficient. The recommended parameters are as follows: Curve Number 95, Initial Abstraction: 0.11 mm, Lag Time 139.72 minutes

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