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Flood Hydrograph Modeling Based on Rainfall Data in The Dayeuhkolot Watershed Using Hec-Hms

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Abstract. Dayeuhkolot, located 9 km from the center of Bandung City or about 18 km from Soreang, is a Citarum sub-watershed that experiences flooding every year. The causes of flooding are natural factors such as high rainfall and human factors such as blocked or damaged drainage channels, inappropriate land use, deforestation in the upstream areas, etc. Floods cause loss of life and property damage. Population growth results in more urbanization, airtight areas, less infiltration, and more significant flood peaks and runoffs. The flood hydrograph projection uses this study's GSMAP rainfall data and land cover data. The flood hydrograph method used is the SCS curve number method, which obtained 12 river discharge events of more than 300 m^3/second from 2018 to 2022. Then calibration and validation were carried out using the trial-and-error method using the HEC – HMS software to obtain parameter values hydrology and ArcGIS to obtain the value of the land cover curve for the next stage of calibrating the values obtained from the HEC - HMS modeling by classifying land cover for 2018 - 2022. The predictions and calibration results of hydrological parameters are input for future flood hydrograph projections.

Keywords: *land cover; GSMaP; flood hydrograph; HEC – HMS; ArcGIS.*

1 Introduction

Many cities and urban areas are on floodplains because the land is fertile and flat, suitable for agriculture and urban development. Rivers provide water for domestic, industrial, and irrigation purposes; they also provide convenient means of navigation, transportation, and communication. Cities have many impermeable areas that effectively prevent rainwater from seeping into the ground. This resulted in significant flooding and flood damage caused by large runoff and high-water inundation [1][2]. Soil, topography, and land cover are the most critical factors controlling precipitation-runoff processes at the level of individual watershed flood events. Because changes in soil and topography are negligible in the short term, changes in land cover are considered the critical factor that alters the precipitation-runoff process [3]. The change in land cover is because the rainwater retention capacity of the basin decreases, leading to faster runoff and more significant peak runoff [4].

Given these issues, a hydrological analysis study is needed to use a precipitation-runoff conversion model to predict runoff in the Dayeuhkolot watershed. Storm runoff modeling is the unit used to approximate hydrological parameters encountered in the field [5]. In this study, the HEC-HMS model was used. The HEC-HMS model is designed to simulate or simulate the process of stormwater conversion into runoff in a watershed. Hydrological Engineering Center (HEC) – The Hydrological Modeling System (HMS) is a software developed by the Hydrological Engineering Center (HEC) of the U.S. Army Corps of Engineers. This software was developed to predict the performance of the system. HEC - HMS models require calibration. The hydrological parameters of the model were calibrated by assessing the similarity between the simulated results and the observed data [6]. Therefore, this study aims to predict the flood level of the Dayeuhkolot watershed.

2 Area Study

The location of this research is in the Dayeuhkolot Watershed, Dayeuhkolot Watershed, which is the Citarum Sub-watershed which has an area of ± 1433.6 km^2, and the length of the river is 58.548 km^2. At the expense of the Dayeuhkolot Watershed is located in the city of Bandung, West Java. The research location can be seen in Figure 1.

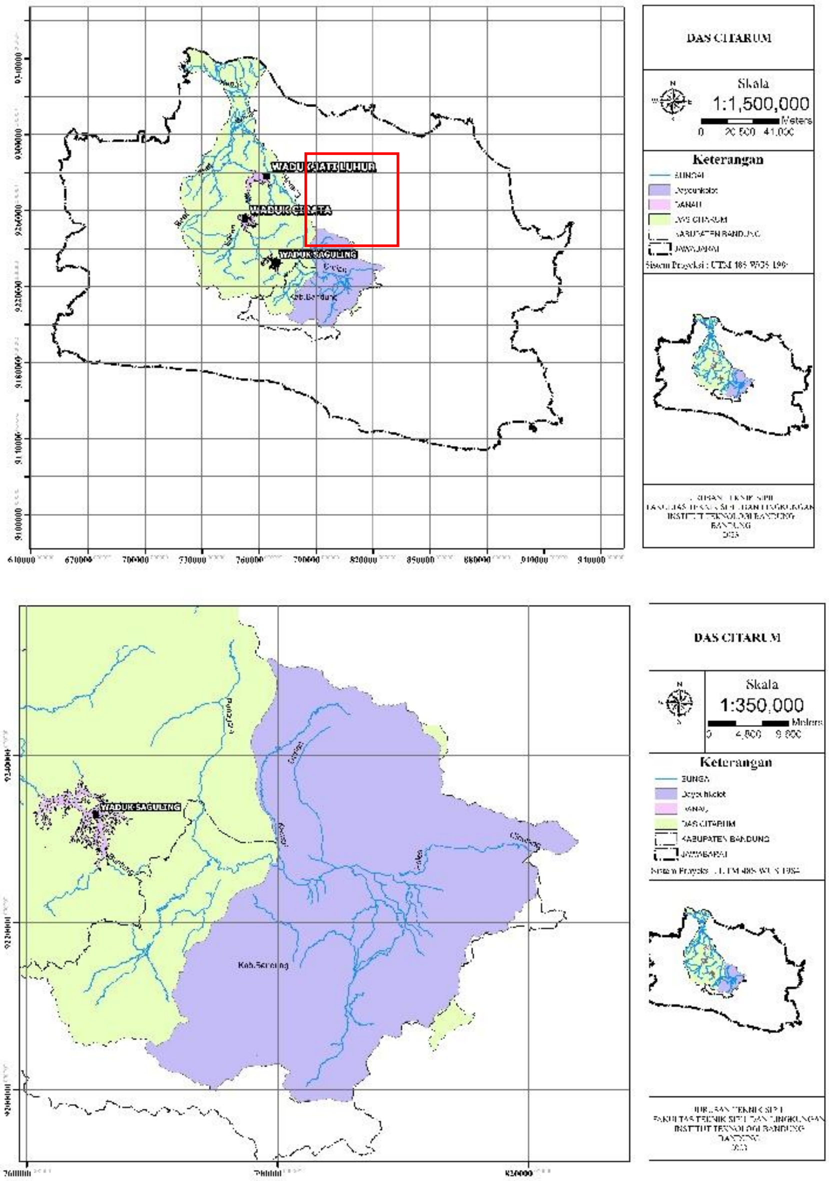

Figure 1. the location of the Dayeuhkolot watershed.

3 Methodology

Research on flood hydrograph projections based on rainfall, discharge data, and land cover data is a descriptive analysis study. The flowchart can be seen in Figure 2

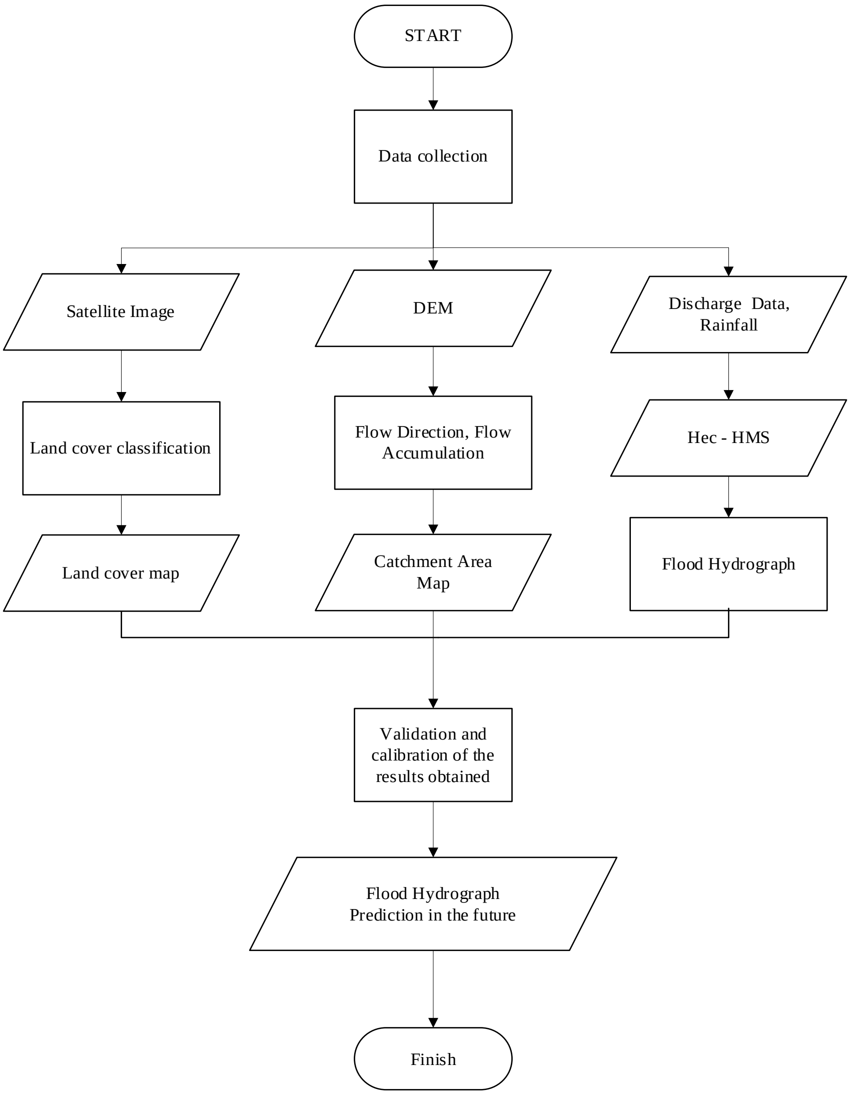

Figure 2. Methodology flowchart

3.1 Data Collection

This study uses rainfall, air level, and flow data at flow measurement points to predict flood hydrographs. The satellite data used is GSMAP. Water level and discharge data use data from PJT2 (Perum Tirta Jasa 2). Materials and tools used in this study are as follows:

1. Rainfall data obtained from GSMaP.
2. Digital Elevation Model (DEM) obtained from https://earthexplorer.usgs.gov/.
3. Satellite imagery used for land cover obtained from https://earthexplorer.usgs.gov/.
4. Observation discharge data obtained from the ALWR monitoring post in Dayeuhkolot.

Tool:

1. Software ArcGIS 10.8
2. HEC – HMS 4.9

3.1.1 Hourly Rainfall

GSMaP data accessed using FileZilla was downloaded from 2018 to 2022. Then the rainfall data was processed using R Studio. The results can be seen in figure 3.

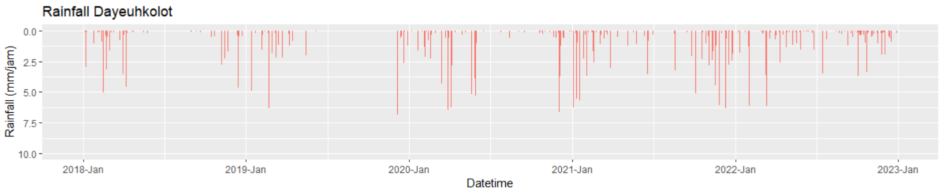

Figure 3. GSMaP Dayeuhkolot rainfall from 2018 until 2022

Then use RStudio to correct the data using the quantile mapping method to get the corrected rainfall results. The calibrated GSMaP rainfall data has the same characteristics as field data [7]. The quantile map uses rainfall observations from Dayeuhkolot to adjust for regional rainfall. Rainfall observations were processed using the Polygon Thiessen method to get the amount of precipitation for the Dayeuhkolot area. The corrected rainfall results are smaller than the uncorrected GSMaP rainfall. The data used in this study is the corrected rainfall shown in Figure 4.

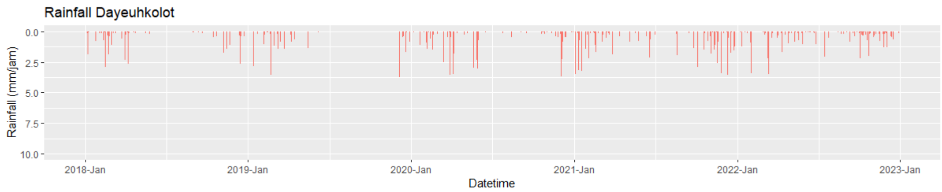

Figure 4. GSMaP Dayeuhkolot corrected rainfall from 2018 until 2022

Even during peak rainfall periods, there are significant differences in measurement calibration between field and satellite data. For this reason, the model uses HEC-HMS with rainfall data input as GSMaP data and flow data calculated from field discharge data [8].

3.1.2 Discharge

The Dayeuhkolot discharge data for 2018-2022 was downloaded from the Perum Jasa Tirta 2 website. The downloaded data contains hourly water level data in meters and hourly discharge data in cubic meters per second. Then Data in Repair data by deleting data with significant spikes in less than an hour. Before and after the corrected data are shown in Figures 5 and 6

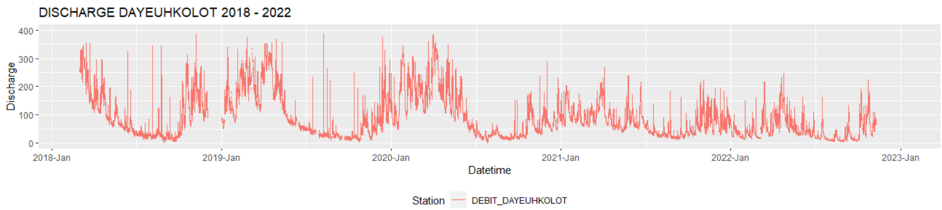

Figure 5. Dayeuhkolot discharge from 2018 until 2022

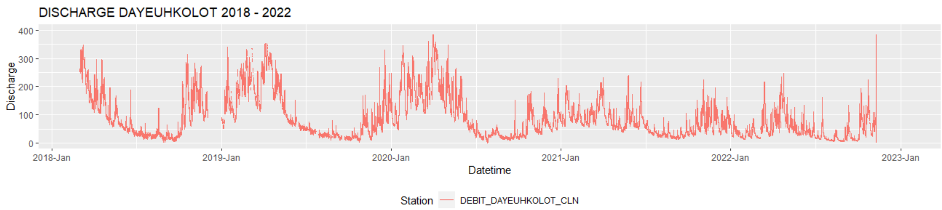

Figure 6. Dayeuhkolot discharge corrected from 2018 until 2022.

3.2 Data Analysis

The data collected is in the form of rainfall and discharge plotted using RStudio. The results of the R studio plot selected discharge that exceeds the capacity of the river, which is more than 300 cubic meters per second. Furthermore, after analyzing the discharge obtained from PJT2, 12 flood events were received. From the 12 flood events, flood modeling was then made using the HEC-HMS.

3.2.1 Rainfall Analysis

The stages of rainfall analysis include collecting rainfall data and processing rainfall data. The rainfall data obtained will become regional rainfall. The average impact area for each rainfall station is based on the formed polygons. Based on Equation 1 [9], regional rainfall is formulated using the Thiessen polygon method.

$$d = \frac{d_1A_1 + d_2A_2 \ldots + d_nA_n}{A} \quad (1)$$

Where

A = area (km^2)

d = average rainfall height

$d_1, d_2, \ldots, d_n$ = amount of rainfall per station (mm)

$A_1, A_2, \ldots, A_n$ = area of influence of headings 1, 2, …. N

3.2.2 Discharge Rain Modeling Simulation

The parameters included in the model are watershed area, loss, lag time, and baseflow. The hydrological model simply represents a complex hydrological system [10]—a hydrological model to model the condition of a watershed in the form of a flow network. A catchment area is an area that provides a river and reservoir system [11].

The HSS Soil Conservation Service (SCS) method is used to perform hydrographic analysis. The SCS method synthesis unit hydrograph is a dimensionless hydrograph developed from the research of synthesis unit hydrographs in various watersheds with multiple sizes and locations. which is in

Figure7.

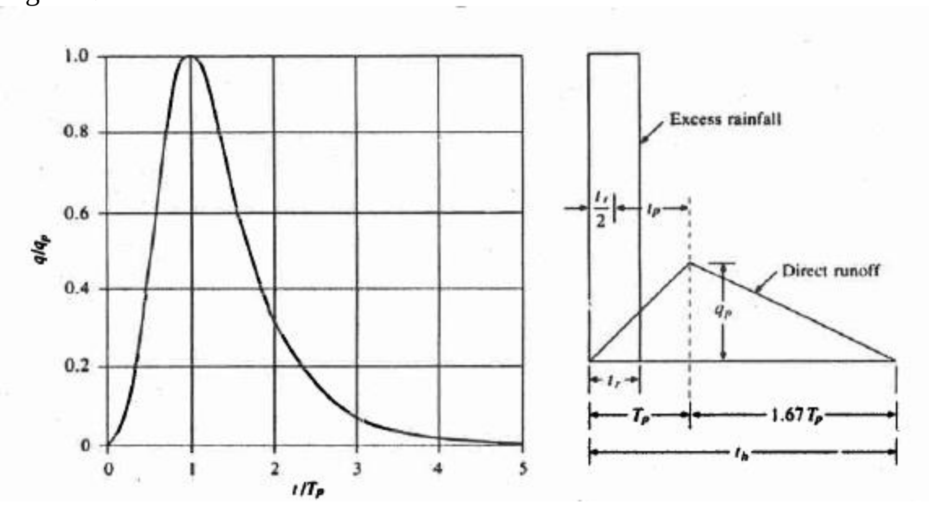

Figure 7. Hydrograph of the Soil Conservation Service (SCS) Unit
Source: (Chow, 1988).

3.2.3 HEC – HMS

The HEC-HMS model was developed by the US Army Corps of Engineers [12] and is used in many hydrological simulations. The HEC-HMS model can be applied to urban flood analysis, flood frequency, flood warning system planning, reservoir overflow capacity, flow recovery, etc. [13]. The proliferation of personal computers and the development of the US Army Corps of Engineers HEC-1 model in 1998 into a user-friendly GUI (Graphical User Interface)-based HECHMS model, available in the public domain, became another helpful tool for Field Hydrologists.

3.2.4 Model Calibration

Model calibration was carried out to determine the success of the model in representing river flow using the efficiency coefficient [14] and root mean square error (RMSE) [14] from the Nash-Sutcliffe (NSE) model [15] using equations 2 and 3.

$$NSE = 1 - \frac{\sum_{t=1}^{N}(Q_S(t) - Q_o(t))^2}{\sum_{t=1}^{N}(Q_S(t) - \overline{Q_o})^2} \quad (2)$$

Where:

$Q_S(t)$ = simulated discharge
$Q_o(t)$ = observation discharge
$\overline{Q_o}$ = average observation discharge

N = Amount of data

Table 1 NSE Criteria Value

NSE Value	Interpretation
NSE > 0,75	Good
0,36 < NSE < 0,75	Qualified
NSE < 0,36	Not Qualified

Source : (Motovilov et al., 1999)

Calibration was carried out until the model obtained a Nash – Sutcliffe (NSE) greater than 0.36 [16].

Root means square error (RMSE)

$$RMSE = \sqrt{\frac{\sum_{t=1}^{N}(X_i - Y_i)}{N}} \quad (3)$$

Where:

X_i = actual data values

Y_i = estimated/forecasting value

N = Amount of data

3.2.5 Model Validation

After calibration of the hydrological parameters obtained, the next step is verification. Verification is verifying or testing the truth of something. In this study, validation was carried out by finding the curve number value obtained from the hydrological parameters, which were then calibrated to be compared with land cover data. For the basic equation [17][12], use equations 4 and 5, then change them to equation 6.

$$t_c = \frac{100L^{0.8}[\left(\frac{1000}{CN}\right) - 9]^{0.7}}{1900S^{0.5}} \quad (4)$$

$$t_c = 1.67\ x\ t_{lag} \quad (5)$$

$$CN = \frac{991}{\left(\frac{\left(1.67t_{lag}\right)x1900S^{0.5}}{100L^{0.8}}\right)^{\frac{1}{0.7}} + 9} \quad (6)$$

Where:

t_c = concentration time (minute)

t_{lag} = Grace period (minute)

CN = *Curve Number*

L = River length (*ft)*

S = *Slope (%)*

4 Results

From the data collected, namely rainfall data and discharge data, data analysis was carried out. After analysis, it was found that there were 12 flood events with debits exceeding 300 m3/second. Can be seen in Figure 8

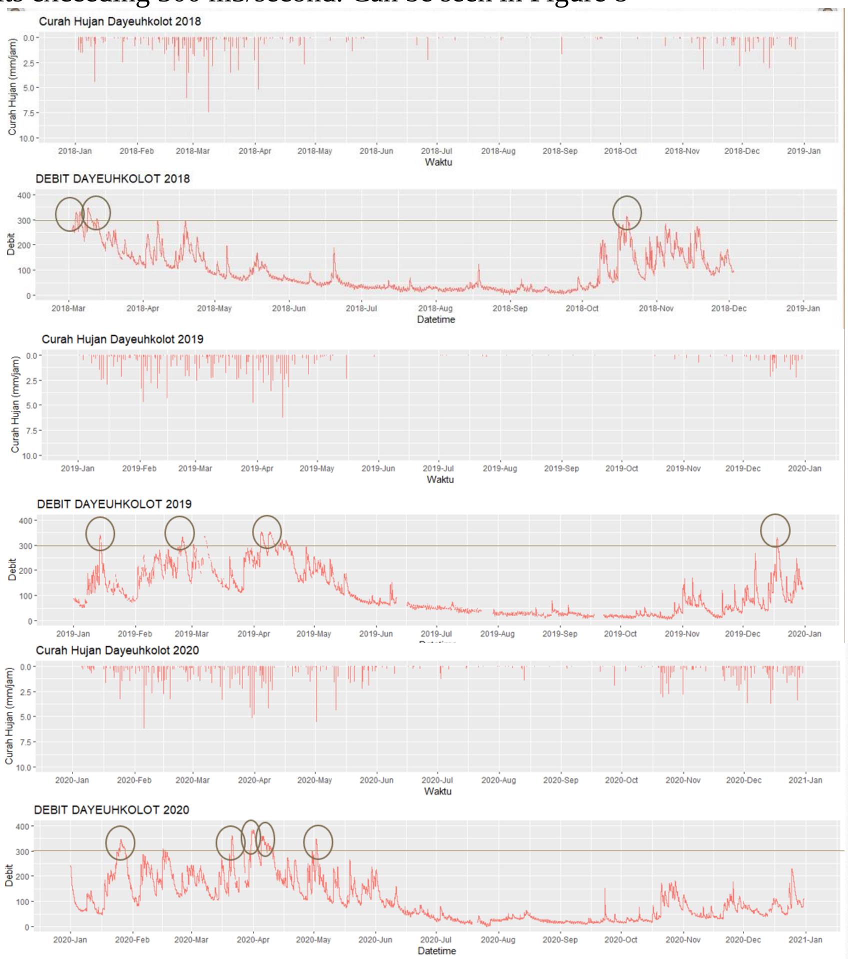

Figure 8. flood events.

The next step in this research is modeling the flood hydrograph using HEC – HMS, after which model calibration and model validation is carried out by classifying the Dayeuhkolot watershed land cover, then comparing the results of the Curve Number obtained from HEC – HMS and the results of land cover classification from satellite imagery. After that, the land cover prediction was carried out using Malaccha [18]. After obtaining land cover predictions, a prediction model for the Dayeuhkolot watershed flood hydrograph was made. The input of this prediction model uses the results of hydrological parameters obtained from 12 previous flood event models. Furthermore, a comparison of the flood hydrographs between 2018 and 2022 was carried out with the prediction models that had been made previously. This aims to determine whether there is an effect of changes in land cover from year to year in line with changes in the recorded flood hydrograph.

5 Conclusion & Recommendation

5.1 Conclusion

The flood event is taken from the discharge data obtained from PJT2. There were 12 flood events from 2018 - 2022; in 2018, there were three flood events; in 2019, there were four flood events. And in 2020, there were five flood events, while in 2021 and 2022, there was no discharge exceeding 300 m^3/second.

5.2 Recommendation

This research requires further studies to predict future flood hydrographs by considering the effects of climate change so that the results obtained are more perfect than current research. This study can reference flood management measures in the Dayeuhkolot area.

References

[1] Morris D, Hargreaves B, Pazzaglia F, Weisman R and Williamson C. Assessing the interactive effects of landscape, climate, and UV radiation on river ecosystems: modeling transparency to UVR and the response of biota, Workshop progress report,(Grant# R829642), Lehigh University Bethlehem, PA, USA; 2004.

[2] Pauleit S, Duhme F. Assessing the environmental performance of land cover types for urban planning. In: Landscape andurban planning. 52: 1-20, 2000.

[3] Miller, S. N., Kepner, W. G., Mehaffey, M. H., Hernandez, M., Miller, R. C., Goodrich, D. C., Devonald, K. K., Heggem, D. T., & Miller, W. P. (2002). Integrating landscape assessment and hydrologic modeling for land cover change analysis. Journal of the American Water Resources Association, 38(4). https://doi.org/10.1111/j.1752-1688.2002.tb05534.x

[4] Rohmat, F. I. W., Sa'adi, Z., Stamataki, I., Adi Kuntoro, A., Farid, M., & Suwarman, R. (2022). Flood modeling and baseline study in urban and

high population environment: A case study of Majalaya, Indonesia. Elsevier. https://doi.org/10.1016/j.uclim.2022.101332

[5] Affandy, N. A., & Anwar, N. (2011). Pemodelan Hujan-Debit Menggunakan Model HEC-HMS di Das Sampean Baru. *Seminar Nasional Penanganan Kegagalan Pembangunan Dan Pemeliharaan Infrastruktur*, *5*.

[6] Tunas, G. (2005). Kalibrasi parameter model hec-hms untuk menghitung aliran banjir das bengkulu. *Majalah Ilmiah MEKTEK*, *1*.

[7] Burnama NS, Rohmat, Farid M, Wijayasari W. Utilization of quantile mapping method using cumulative distribution function (CDF) to calibrated satellite rainfall GSMaP in Majalaya watershed. IOP Conf Ser Earth Environ Sci. 2023;

[8] Burnama NS, Rohmat F, Farid M, Kuntoro AA, Kardhana H, Solehudin. Rainfall-runoff Analysis Using Satellite Data in The Majalaya Watershed. Proc 2nd ITB Grad Sch Conf. 2022;321–31.

[9] Dewi Handayani Untari Ningsih. (2012). Metode Thiessen Polygon untuk Ramalan Sebaran Curah Hujan Periode Tertentu pada Wilayah yang Tidak Memiliki Data Curah Hujan. *Jurnal Teknologi Informasi DINAMIK*, *Volume 17*(No 2).

[10] Harsoyo, B. (2010). REVIEW MODELING HIDROLOGI DAS DI INDONESIA. *Jurnal Sains & Teknologi Modifikasi Cuaca*, *11*(1). https://doi.org/10.29122/jstmc.v11i1.2179

[11] Adya Ariska, G., Lilis Handayani, Y., & Sujatmoko, B. (2020). Analisis Hidrologi Model Soil Moisture Accounting Menggunakan Program HEC-HMS (Studi https://doi.org/10.25299/saintis.2020.vol20(01).4753

[12] Feldman, A. D. (2000). Hydrologic Modeling System Technical Reference Manual. *Hydrologic Modeling System HEC-HMS Technical Reference Manual*, *March*.

[13] U.S. Army Corps of Engineers, 2008. Hydrologic Modeling System (HEC-HMS) Applications Guide: Version 3.1.0. Institute for Water Resources, Hydrologic Engineering Center, Davis, CA.

[14] Cheng, C., Cheng, S., Wen, J., & Lee, J. (2013). Time and Flow Characteristics of Component Hydrographs Related to Rainfall–Streamflow Observations. *Journal of Hydrologic Engineering*, *18*(6). https://doi.org/10.1061/(asce)he.1943-5584.0000675

[15] Chai, T., & Draxler, R. R. (2014). Root mean square error (RMSE) or mean absolute error (MAE)? -Arguments against avoiding RMSE in the literature. *Geoscientific Model Development*, *7*(3). https://doi.org/10.5194/gmd-7-1247-2014

[16] Motovilov, Y. G., Gottschalk, L., Engeland, K., & Rodhe, A. (1999). Validation of a distributed hydrological model against spatial

observations. *Agricultural and Forest Meteorology*, *98–99*. https://doi.org/10.1016/S0168-1923(99)00102-1

[17] Chow, V. Te, Maidment, D. R., & Mays, L. W. (1988). Applied hydrology (letters). In *Applied Hydrology*.

[18] Wijayasari, W., & Immaddudin Wira Rohmat,Faizal Viridi, S. (2022). *Malaccha: An R-based end-to-end Markov transition matrix extraction for land cover datasets*. https://www.sciencedirect.com/science/article/pii/S2352711023000110