Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Utilization of GIS And HEC-HMS Hydrological Model to Forecasting of Peak Discharge of the Air Bengkulu Sub-Catchments

Gusta Gunawan[1]*, Rena Misliniyati[2], Bambang Sulistyo[3], Iqbal Kurniawan Trisaputra[4], Iqbal Patrianusa[5]
[1,2]Civil Engineering Department, Faculty of Engineering, Bengkulu Univerisity, Bengkulu, 38122, Indonesia
[3]Department of Soil Science, Faculty of Agricultural, Bengkulu University, Bengkulu, 38122, Indonesia
[4]Department of Environment, Seluma Regency, Bengkulu Province, Indonesia
[5]Department of Public Works, Bengkulu City, Bengkulu Province, Indonesia
*Correspondence: g.gunawan@unib.ac.id

ARTICLE INFO

Received: 22 Dec 2024

Revised: 17 Feb 2025

Accepted: 27 Feb 2025

ABSTRACT

Introduction: The increasing frequency and intensity of floods in Bengkulu's watersheds are driven by land-use changes and climate variability, prompting the need for accurate flood discharge estimation, especially in ungauged basins.

Objectives: This study aims to estimate peak discharge using the integration of the HEC-HMS hydrological model and the SCS-CN method, supported by GIS-based spatial data analysis, in the Bengkulu Hilir sub-watershed.

Methods: The research employs a quantitative modeling approach with five stages: data collection and preprocessing, rainfall distribution analysis (via PSA 007 and Log Pearson Type III), watershed parameterization using ArcMap, model calibration with NSE and RMSE metrics, and simulation using return periods (2-100 years). Synthetic Unit Hydrograph (SUH) models were evaluated to support hydrograph development under limited streamflow data conditions.

Results: This study integrates the HEC-HMS hydrological model with the Soil Conservation Service Curve Number (SCS-CN) method and GIS-based spatial analysis to forecast peak discharge in the Bengkulu Hilir sub-watershed. Sixteen years of rainfall data (2007–2022) were analyzed using frequency distribution techniques, selecting Log Pearson Type III as the optimal model. The calibrated HEC-HMS model demonstrated superior performance, achieving Nash-Sutcliffe Efficiency (NSE) values up to 0.98 and low Root Mean Squared Error (RMSE). Simulations revealed a substantial increase in peak discharge, from 29.27 m^3/s for the 2-year return period to 118.87 m^3/s for the 100-year event, with peak discharge consistently occurring at the 13th hour. GIS spatial analysis delineated over 1,800 hectares of flood-prone areas in urban and lowland zones of Bengkulu, emphasizing the urgency for targeted flood mitigation and adaptive planning.

Conclusions: This study demonstrates that integrating HEC-HMS, the SCS-CN method, and GIS spatial analysis provides a reliable approach for estimating peak discharge in the Bengkulu Hilir sub-watershed. The model showed strong performance (NSE up to 0.98), with peak discharges rising from 29.27 m^3/s (2-year) to 118.87 m^3/s (100-year). The identification of over 1,800 hectares of flood-prone areas highlights the urgency for focused flood risk management. This framework offers a robust and adaptable tool for flood forecasting in data-limited tropical catchments.

Keywords: *HEC-HMS, SCS-CN, GIS, flood modeling, peak discharge, synthetic unit hydrograph*

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Introduction

Flooding remains one of the most frequent and devastating hydrological hazards globally, causing significant damage to infrastructure, disrupting socio-economic systems, and threatening human lives (Guduru & Mohammed, 2024; Kundzewicz et al., 2014). Flood events typically occur when river discharge exceeds channel capacity, leading to overflow and inundation of adjacent floodplains (Hughes, 1980; Di Baldassarre et al., 2010). This highlights the pivotal roles of hydrological and geomorphological factors in governing flood dynamics and assessing flood risk. Watershed susceptibility to flooding is influenced by climate variability, topographic characteristics, and anthropogenic land-use changes (Asadi et al., 2024; Kundzewicz & Matczak, 2012). Climate variability alters precipitation regimes and flood frequencies (Peters et al., 2014; Trenberth, 2011), whereas topography modulates runoff generation and flow paths (Smith & Ward, 2019). Furthermore, human activities such as deforestation and urbanization have significantly increased flood risks through alterations in watershed hydrology (Bradshaw et al., 2017; Foley et al., 2005). A watershed functions as a hydrological unit that collects precipitation, channels runoff, and discharges it into a common outlet such as a river, lake, or ocean. However, rapid urbanization and deforestation resulting in the conversion of forests, wetlands, and recharge zones into impervious surfaces have significantly altered natural hydrological processes (Mokhtari et al., 2024; Li et al., 2024). These changes accelerate surface runoff, reduce infiltration, and increase peak discharge, thereby exacerbating flood risks (Zhang et al., 2023).

Watersheds act as hydrological units that collect precipitation and convey runoff into rivers, lakes, or oceans (Kundzewicz et al.,2012). However, accelerated urbanization and deforestation have considerably altered these natural processes, mainly through the conversion of permeable surfaces into impervious ones. This transformation enhances surface runoff, diminishes infiltration, and increases peak discharge rates, thereby exacerbating flood risks (Mokhtari et al., 2024; Zhang et al., 2023; Guo, Li, & Zhang, 2020). These land-use changes, combined with the increasing frequency and intensity of extreme precipitation events driven by climate change, have made flooding a more frequent and severe hazard globally (Wang et al., 2023; He, Zhang, & He, 2021).

Hydrological modeling is crucial for understanding watershed responses to rainfall and for developing flood risk mitigation strategies. In data-rich regions, models calibrated with observed discharge data can produce reliable flood forecasts (Bentahar & Yebdri, 2024; Kontogiannis, 2024). However, in many ungauged or data-limited basins, synthetic unit hydrograph (SUH) methods offer practical alternatives for simulating runoff and estimating peak discharge (Natakusumah et al., 2011; Tunas et al., 2024; Dai, Zhang, & Lu, 2020). Yet, conventional SUH models often neglect critical factors such as changes in land-use, soil infiltration capacity, and watershed morphology, which can limit their accuracy (Jaberzadeh et al., 2024; Syed, Sattar, & Rehman, 2018).

To overcome these limitations, the Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) has been extensively utilized worldwide. HEC-HMS is a modular and adaptable tool designed to simulate precipitation-runoff processes by incorporating rainfall loss estimation, runoff generation, and flow routing (Halwatura & Najim, 2013; Zhang et al., 2023; He et al., 2021). Integration with the Soil Conservation Service Curve Number (SCS-CN) method enhances runoff estimation by considering soil types, land use, and antecedent moisture conditions (Ibrahim & Klari, 2021; Li et al., 2024; Asadi et al., 2024).

In the flood-prone region of Bengkulu, Indonesia, limited hydrological monitoring and rapid land-use change have exacerbated vulnerability to flash floods. Current flood prediction frameworks often lack spatial precision and sufficient data for reliable forecasting, leaving communities exposed to severe impacts (Khaleghi et al., 2021; Ramos, Costa, & Silva, 2020; Zhang & Shi, 2020). This study addresses this gap by developing synthetic flood hydrographs for Bengkulu's sub-watersheds using HEC-HMS and SCS-CN models, estimating peak discharges under various return periods to support improved watershed management and disaster risk reduction

Methods

This study employs a quantitative research approach utilizing hydrological modeling to simulate the hydrological response of a watershed to rainfall events and estimate peak flood discharge. The methodology is structured into five key stages: hydrological modeling approach, data acquisition and preprocessing, model simulation and calibration, model performance evaluation, and result interpretation and application.

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

1. Hydrological Modeling Approach

Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS)

The HEC-HMS model is employed to simulate the precipitation-runoff process, quantify watershed hydrological response, and estimate peak discharge under varying hydrometeorological conditions. This model provides a comprehensive framework for surface runoff computation, infiltration loss estimation, and streamflow routing within the river network (Feldman, 2000).

The governing equation for water balance in HEC-HMS follows:

$P = Ia + F + Q$

where:

- P = total precipitation (mm)
- Ia = initial abstraction, including interception and depression storage (mm),
- F = infiltration during the storm event (mm),
- Q = surface runoff (mm).

Soil Conservation Service Curve Number (SCS-CN) Method

The SCS-CN method is utilized to estimate precipitation losses due to infiltration and evapotranspiration, thereby determining surface runoff volume. The Curve Number (CN) is derived from key watershed parameters, including land use characteristics, soil classification, and antecedent moisture conditions, ensuring accurate runoff estimation (Mishra & Singh, 2003). The direct runoff Q is computed as:

$$Q = (P - Ia)^2 / (P - Ia + S), \text{ for } P > Ia$$

where:

S = potential maximum retention (mm), given by:

$S = (25400/CN) - 254$

2. Data Acquisition and Preprocessing

To ensure the reliability and accuracy of hydrological simulations, the study integrates multiple datasets, including rainfall and streamflow records. Historical rainfall data spanning 16 years (2007–2022) were collected from eight strategically positioned rain gauge stations managed by Balai Wilayah Sungai Sumatera Region VII and BMKG Bengkulu Province. The streamflow data, though limited, were supplemented with synthetic hydrograph models when direct measurements were unavailable.

Quality Assurance

To validate the integrity of the rainfall dataset, a consistency check was conducted using the Rescaled Adjusted Partial Sums (RAPS) method. This test confirmed that the rainfall series from all stations adhered to acceptable statistical thresholds for both the 1% and 5% significance levels. Erroneous or incomplete entries were excluded, and missing values were addressed through linear interpolation using neighboring stations with similar topographic and climatic profiles.

Spatial Resolution

Rainfall distribution was spatially refined using the Thiessen Polygon method, applied through ArcMap GIS software. This ensured that each station's influence was accurately weighted according to its surrounding area, enhancing spatial representativeness across the Bengkulu watershed.

Temporal Coverage

The dataset covers daily rainfall records over a 16-year period, providing a robust temporal window for evaluating precipitation trends and flood recurrence intervals. The return period simulations (2, 5, 10, 25, 50, and 100 years) were based on the maximum daily rainfall values observed during this time frame, adjusted through hydrological frequency analysis using the Gumbel and Log Pearson Type III distributions.

Rainfall and Streamflow Data

Historical rainfall and streamflow records are obtained from official hydrometeorological agencies and validated for consistency. In the absence of observed streamflow data, Synthetic Unit Hydrograph (SUH) methods are employed to generate flood hydrographs.

Selection of SUH Models

Several SUH models, including GAMA-1. GAMA-2, ITB-1, ITB-2, Limantara, Nakayasu, SCS, and Snyder, are evaluated based on their applicability to the watershed under study. The unit hydrograph peak discharge is determined as:

$$Q_p = (CA * A) / T_p$$

3. Model Simulation, Calibration, and Validation

Hydrological Model Calibration

The HEC-HMS model is calibrated using observed rainfall-runoff data where available. Calibration involves adjusting model parameters to minimize discrepancies between simulated and observed hydrographs.

Return Period Simulations

The model is applied to simulate peak discharge and flood-prone areas under different return periods (e.g., 2-, 5-, 10-, 25-, 50-, and 100-year events), using the Gumbel Extreme Value Distribution:

$$Y_T = \bar{y} + K_t \times S$$

4. Model Performance Evaluation

The accuracy and reliability of the model are assessed using multiple statistical metrics:
• *Nash-Sutcliffe Efficiency* (*NSE*) (Nash & Sutcliffe, 1970):

$$NSE = 1 - \frac{\sum_{i=1}^{n}(P_i - Q_i)^2}{\sum_{i=1}^{n}(P_i - \bar{P}_i)^2}$$

• Coefficient of Determination (R^2):

$$NSE = \frac{\sum(Q_o - X_o)}{sqrt(\sum(Q_o - X_o)^2 \sum(Q_s - X_s)^2}$$

1. *Root Mean Squared Error (RMSE)*

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - Q_i)^2}{n}}$$

where:

P_i = Observation data

Q_i = Estimated data

n = Amount of data

2. *Nash-Sutchliffe Efficiency (NSE)*

$$RMSE \quad = 1 - \frac{\sum_{i=1}^{n}(P_i - Q_i)^2}{\sum_{i=1}^{n}(P_i - \bar{P}_i)^2}$$

Research Location

The location of the research is in the Bengkulu Water Basin, which is included in the scope of the Sumatera River Regional Center (BWSS) VII. River water from the Bengkulu Water Watershed flows through several villages and sub-districts located in Central Bengkulu Regency and Bengkulu City. The condition of the river has waters whose water flows continuously which empties into the sea. The characteristics of the watershed are that the upstream of the area has a more undulating topography to mountains. The Bengkenang watershed covers an area of 499.39 km2 with 3 sub-watershed parts, namely the Rindu Hati, Susup and Bengkulu Hilir sub-watersheds.

The focus of this research is on the Bengkulu Hilir Sub Watershed. This is based on the fact that in these areas there is often a sudden increase in water discharge due to rain events. The location of the study can be seen in Figure 1.

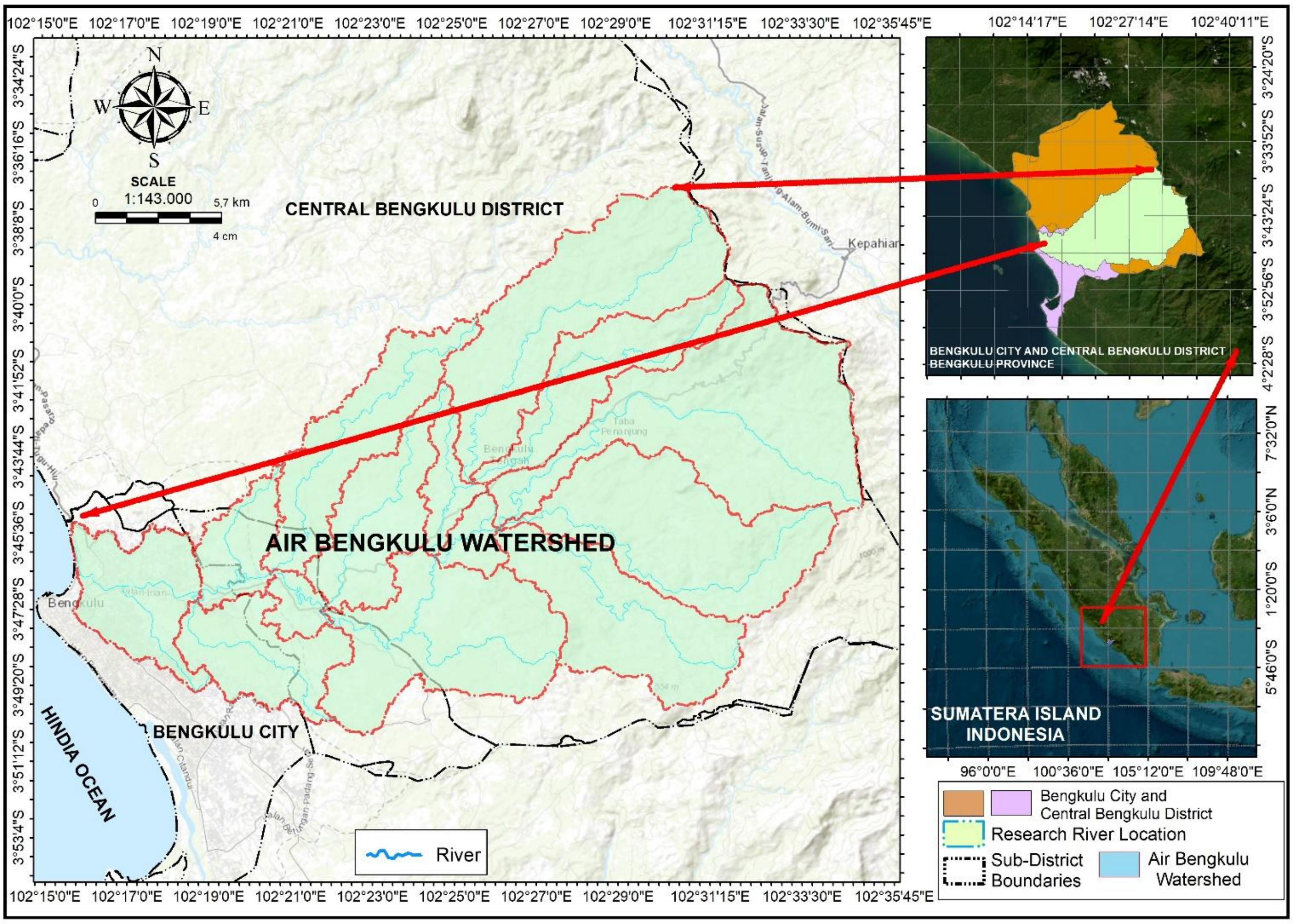


Figure 1 Research Location

Hydrology

Rainfall Consistency Test of RAPS Method

The data consistency test was carried out using the Rescaled Adjusted Partial Sums (RAPS) method. Consistency test means testing the correctness of field data that is not affected by errors at the time of transmission or measurement, the data must describe hydrological phenomena in the field (Sari et al., 2020)

The RAPS method is one of the methods to test the consistency of rainfall data by calculating the cumulative value of its deviation against the average value. This method assumes that the data amounts to only one station. The data can be said to be consistent if the values of Qcal and Rcal are smaller than the values of Qtabel and Rtabel (Suryaningtyas et al., 2020).

Rainfall in the Thiessen Polygon Method Area

The rainfall recorded from each rain station is only the amount of rainfall at each observation point in the area. If there are several rain gauges in an area, then to get the price of rainfall in the area is to take the average value.

Rainfall data obtained from rain gauges is rain that occurs only in one place or point (point rainfall). Considering that rain varies greatly depending on the place (space), for a large area, one rain gauge cannot describe the rain in the area. In this case, regional rain needs to be obtained from the average rainfall value of several rain measuring stations in or around the area (Ningsih, 2017).

According to (Triatmodjo, 2008) this method calculates the weight of each station which represents the surrounding area. In an area of a watershed, it is considered that the rain is the same as that of a nearby station, so the rain recorded at a station represents that area. The Thiessen polygon is a method of calculating regional rainfall based on the interpolation of rainfall values between one station and another (Ajr & Dwirani, 2019). The Thiessen method uses the following equation:

$$d = \frac{(A_1 \times d_1) + \cdots .. + (A_n \times d_n)}{A_1 + A_n}$$

where:

d = Average area rainfall height (mm)

A1,A2,...An = Area representing stations 1,2,3,..,n (km2)

d1,d2,...dn = Rainfall height at stations 1,2,3,..,n (mm)

Parameters Statistics

According to Soewarno (1995), the measurement of dispersion is the calculation of the mean value, standard deviation, slope coefficient, curtosis coefficient and variation coefficient. To obtain the dispersion measurement value, the following formula is used:

1. $\underline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$
2. $Sd = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \underline{X})^2}{n-1}}$
3. $Cs = \frac{n\sum_{i=1}^{n} \{(X_i) - \underline{X}\}^3}{(n-1)(n-2)Sd^3}$
4. $Ck = \frac{\frac{1}{n}\sum_{i=1}^{n} \{(X_i) - \underline{X}\}^4}{Sd^4}$
5. $Cv = \frac{Sd}{\underline{X}}$

Parameter Logaritmik

1. $\underline{X} = \frac{\sum_{i=1}^{n} Log Xi}{n}$
2. $Sd = \sqrt{\frac{\sum_{i=1}^{n} \times \{loglog\ (Xi) - Log\ (X)\ \}^2}{n-1}}$
3. $Cs = \frac{\sum_{i=1}^{n} \times \{loglog\ (Xi) - Log\ (X)\ \}^3}{(n-1)(n-2) \times S^3}$
4. $Ck = \frac{\frac{1}{n}\sum_{i=1}^{n} \{(X_i) - \underline{X}\}^4}{Sd^4}$

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

5. $Ck = \frac{\frac{1}{n}\sum_{i=1}^{n} \{(X_i) - \underline{X}\}^4}{Sd^4}$

where:

Sd = Standard deviation

Cs = Skewness coefficient

Ck = Curtosis coefficient

Cv = Coefficient of variation

Xi = Value of the variant to i

$\underline{X}$ = Average value of variants

N = Amount of data

Rainfall Distribution Plan

According to (Limantara, 2018) in analyzing the frequency of hydrological data, both rain data and river discharge data, it is proven that there are very few data that are in accordance with the distribution of Normal, Gamma with parameter II, Log Gumbel, and Hazen. In contrast, most of the hydrological data corresponds to the other 3 distributions, namely Gumbel, Normal Log, and Pearson III Log. The recommended hydrological frequency analysis in Indonesia uses the Pearson III Log because according to the experience the distribution is more flexible. But each distribution has its own distinctive and specific properties. Planned rainfall is needed to determine the amount of planned flood discharge if flood discharge data with a long enough observation interval is not available. To determine the amount of rainfall in this plan, data on the maximum daily rainfall in the region is needed. The amount of planned rainfall is calculated by analyzing the probability of rainfall frequency. Several available methods that will be adjusted to the distribution of the data include:

1. Distribution of Type I Gumbel

$$X_t = \bar{x} + \frac{(Y_T - Y_n)}{S_n} \times \sigma_n$$

where:

X_t = Planned rainfall value with measured data T year (mm)

$\bar{x}$ = Average rainfall value (mm)

Y_T = The reduced variation value of the variable that is expected to occur at the T year anniversary,

which is expected to occur on the T anniversary of the year, is a function of the probability of.

$$Y_T = -ln \times \left[ln\left(\frac{Tr}{Tr - 1}\right)\right]$$

where :

Yn = The average value of the reduced variate mean depends on the amount of data (n), the average YT in appendix 11

Sn = The standard deviation of the reduce variate standard deviation depends on the amount of data (n)

σ_n = Standard deviation (standard deviation),

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

2. Pearson Type III Log Distribution

$$Y_T = \bar{y} + K_t \times S$$

where:

Y_T = Logarithmic value of X or log X with a repeat period T
$\bar{y}$ = Calculated mean (preferably geometric average) value y_T

S = Deviation of the value standard y_T

K_t = Characteristics of opportunity distribution (koefieisen awkwardness Cs) Log Pearson Type III

$$X_t = Y_T{}^{10}$$

where:

X_t = Planned rainfall value with measured data T year (mm)

3. Normal Log Distribution

$$X_t = \underline{X} + Kt \times Sn$$

where:

X_t = The amount of precipitation that may occur with the X-year anniversary period (mm)

$\underline{X}$ = Average rainfall (mm)

Sn = Deviation of the annual maximum rainfall data standard

Kt = Variable standard for the T year anniversary period

Spread Fit Test

According to Limantara (2018), the hydrological data used to estimate the design flood or mainstay discharge using frequency analysis is not necessarily in accordance with the selected distribution. Therefore, it is necessary to carry out a test of goodness of fit. The frequency distribution of the data sample to the opportunity distribution function that is expected to describe/represent the frequency distribution requires parameter testing. There are two types of compatibility tests, namely the Chi-Square Compatibility test (Chi-Square) and the Smirnov-Kolmogrov Compatibility test (Soewarno, 1995).

1. Chi-Square Fit Test

According to (Soewarno, 1995) the test with this method is based on the expected number of observations in the class division, and is determined by the number of observation data read in the class, or by comparing the Chi-Square value (X2Hiku) with the critical Chi-Square value (X2Hiku).

$$P = \frac{m}{n+1} \times 100\%$$

dimana:

P = Probability (%)

m = Data sequence number

n = Amount of data

The value of "Δ" max compared to "Δ" critical, the distribution will be appropriate if (Δ max) < (Δ critical).

1. Smirnov-Kolmogrov Goodness-of-Fit Test

The test is carried out by comparing the chances of each data, between empirical data and theoretical distribution, which is expressed by Δ. The largest value (Δ max) is compared to Δ critical (from the Smirnov Kolmogorof table) with a certain level of confidence (α). The distribution is considered appropriate if: Δ max < Δ critical (Limantara, 2010).

$$x^2 = \sum_{t=1}^{n} \frac{(Oi - Ei)^2}{Ei}$$

where:

x^2 = Chi-Square pricing is calculated

Ei = The number of theoretical values in sub-group i

Oi = The number of observation values in the i subgroup

n = Amount of data

Rainfall Intensity PSA 007 (Genta Model)

The distribution of hourly rain (rain distribution) is determined by direct observation of hourly rain recording data at the station that has the most influence on the watershed, if there is none, it can imitate the behavior of hourly rain similar to the local area at the same latitude. The distribution is obtained by grouping the rainfall height into a range with a certain height. From the data that has been compiled in the rain height range, the design rain height distribution is selected based on the analysis of the frequency and the highest frequency of occurrence in the rain distribution at certain times. Furthermore, the percentage of rain per hour to the total rainfall height in the rainfall distribution is determined.

The selection of Critical Storm Duration, in principle, depends on the area of DPS and other influences such as the area of reservoir inundation and the configuration of overflow buildings, so that for each dam even though it has the same DPS area, it is not certain that the duration of critical rain is the same.

The selection of the duration of rain with its distribution pattern greatly affects the results of the design flood that is taken into account. The same rainfall distributed with long rainfall will produce a lower peak flood than one distributed with a short duration.

If flood hydrograph data from automatic water guessing posts and hourly rain distribution data from automatic rain stations are not available, rain distribution patterns can be established by referring to PSA-007

Flood Discharge Plan

In general, the planned flood discharge (design flood) in Indonesia is determined based on recorded rainfall data, because flood discharge data can rarely be applied due to the limitation of the observation period, the method used for the planned flood discharge is the SCS CN synthetic unit hydrograph method (HSS) using HEC-HMS software.

SCS (Soil Conservation Services) Non-Dimensional Hydrograph is a synthetic unit hydrograph where the discharge is expressed as the ratio of the discharge q to the peak discharge qp and the time in the ratio of time t to the rise time of the unit hydrograph Tp. If the peak discharge and delay time of an effective rain duration (Lag Time) are known, then the unit hydrograph can be estimated from the SCS synthetic hydrograph unit, where:

1. $Lag\ Time = \frac{L^{0,8}(2540-22,86 \times CN)^{0,7}}{14,104\ X\ s^{0,5}}$
2. Waktu Naik $= \frac{tr}{2} + t_p$

3. Time Base $= 5 \times t_p$

4. $q_p = \frac{CA}{Tp}$

With CN is the Curve Number that can take into account the total rainfall for various characteristics of watersheds with different soil types and land use (Supit, 2013).

HEC HMS (Hydrological Modeling System)

HEC-HMS (Hydrological Modeling System) program which is a computer program to calculate the variety of rainfall and the routing process in a watershed system. The software was developed by the Hydrologic Engineering Centre (HEC) of the US Army Corps of Engineers. In the HEC-HMS software, there are calibration and simulation facilities for distribution models, continuous models and the ability to read GIS data. In HEC-HMS there are several separate models where each selected model has different inputs. Several models are used to calculate the volume of runoff, direct runoff, baseflow and channel flow. Calibration can only be done if the required hydrological data is available, otherwise it is enough to verify based on the cross-sectional capacity condition.

HSS CN (Curve Number)

1. Method Loss

Loss is a method that functions to take into account the part of rainfall lost due to infiltration, interception, evaporation, and runoff and find effective rainfall. Effective rain or excess precipitation is rain that causes runoff. The Loss method used is the SCS CN Method, with the required parameters, namely Initial Abtraction/InitLoss (initial abstraction), Curve Number/CN (number of curves), and Percent Impervious/PctImp. The selection of the SCS Method is based on land use in the Bengkenang watershed which will affect runoff or the lost part of rainfall. The SCS (Soil Conservation Servise) method is a soil conservation method developed by the US Soil Conservation Service. The basic concept of this method is to calculate the average rainwater loss that occurs during the rain through the process of infiltration/permeability and land cover so that it affects the discharge that flows into the river. This method consists of four parameters. i.e. initial abstraction (Ia), flow curve number (CN) and impervious layer (Usda, 1986), (Heimhuber, 2013).

2. Curve Number

The determination of the number of CN curves in the HEC-HMS model is by overlay analysis between the land use map and the soil hydrological group map. The result of the overlay is used into the CNLookUp Table. Where, this method is stated as a hydrological influence based on soil hydrological groups, land use, and previous groundwater content (Abushandi & Merkel, 2013) soil hydrological group maps using maps from the map from Global Hydrologic Soil Groups (HYSOGs250m) with descriptions can be seen in Table 1 and Table 2.

Table 1. Pixel value HSG

Pixel values	Description
1	HSG-A: low runoff potential (>90% sand and <10% clay)
2	HSG-B: moderately low runoff potential (50-90% sand and 10-20% clay)
3	HSG-C: moderately high runoff potential (<50% sand and 20-40% clay)
4	HSG-D: high runoff potential (<50% sand and >40% clay)
11	HSG-A/D: high runoff potential unless drained (>90% sand and <10% clay)

Pixel values	Description
12	HSG-B/D: high runoff potential unless drained (50-90% sand and 10-20% clay)
13	HSG-C/D: high runoff potential unless drained (<50% sand and 20-40% clay)
14	HSG-D/D: high runoff potential unless drained (<50% sand and >40% clay)

Source : (Ross et al., 2018)

Table 2. Soil Texture Class

HSG	Soil texture class	Runoff potential	soilGrids250m texture class value
A	Sand	Low	12
B	Sandy loam, Loamy sand	Moderately low	9, 11
C	Clay loam, Silty clay loam, Sandy clay loam, Loam, Silty loam, Silt	Moderately high	4, 5, 6, 7, 8, 10
D	Clay, Silty clay, Sandy clay	High	1, 2, 3
A/D	Sand	High	12
B/D	Sandy loam, Loamy sand	High	9, 11
C/D	Clay loam, Silty clay loam, Sandy clay loam, Loam, Silty loam, Silt	High	4, 5, 6, 7, 8, 10
D/D	Clay, Silty clay, Sandy clay	High	1, 2, 3

Source : (Ross et al., 2018)

Soil hydrology is adjusted to the condition of land cover in a watershed, with the provision that can be seen in Table 3.

Table 3. Hydrologic Soil Group

NO	Land Cover	Hydrologic Soil Group			
		A	B	C	D
1	Fresh water	98	98	98	98
2	Forest	57	73	82	86
3	Kebun	57	73	82	86
4	Grassland / Vacant Land	72	82	87	89
5	Settlements	61	75	83	87
6	Rawa	98	98	98	98
7	Irrigation paddy fields	62	71	78	81
8	Rainfed Rice Fields	72	81	88	91
9	Bushes	48	67	77	83
10	Farmland	66	77	85	89

Source : (Noor Annisa Ramadan et al., 2018)

- Persen Impervious (PetIMP)

Impervious Percent (PctImp), A parameter that affects the volume of runoff in a watershed is the area of impervious area (impervious to water).

Table 4. Persen Impervious

Land Use	Persen Impervious
Tree	0
Rumput	5
Minority Settlement	20
Residential Areas	30
Komersial	85
Air	100

Source : (USACE, 2013)

2. Method Transform

The Transform method is a unit hydrograph method that will be used to calculate the amount of runoff. The transform method used is the SCS Unit Hydrograph method. This method requires parameters such as time lag, which is the grace period between the effective rain weight point and the hydrograph weight point (peak discharge). The calculation on the Empirical Equation of the SCS Method for lag estimation, namely HSS SCS CN of a watershed is explicitly determined by the lag time parameter, which depends on the length, slope, cross-section of channels and rivers and their roughness coefficients. The HSS SCS grace time can be estimated through calibration, for those who have observation data at the water suspected post. In cases where there is no data, SCS suggests that the grace period is estimated from the time of tc concentration through the formula.

$$T_{lag} = 0.6 \text{ tc}$$

Results

4.1 Rainfall Analysis and Consistency

Rainfall data uses rainfall data for the last 16 years, namely 2007-2022 obtained from BWSS region 7 and BMKG Bengkulu Province with a total of 8 rain posts which can be seen in Table 5.

Table 5. Maximum Rainfall

No	Year	Rhmax (mm) Pos Hujan							
		Taba Penanjung Post (mm)	Plow Post (mm)	Published by Mutung (mm)	Unib (mm)	Tanjung Agung (mm)	Muara Bangka Hulu (mm)	Padang Harapan (mm)	Mateo Bengkulu (mm)
1	2007	154	109	114	-	-	-	-	-
2	2008	125	154	78	77	128	95	180	224
3	2009	112	95	164	219	162	101	180	125
4	2010	151	95	98	159	142	125	128	120
5	2011	180	100	91	168	155	106	140	137
6	2012	178	54	71	112	88	102	118	152
7	2013	116	28	104	163	126	162	177	147

2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

8	2014	110	120	88	156	119	90	147	123
9	2015	116	200	162	135	120	76	124	145
10	2016	180	240	130	198	153	71	147	171
11	2017	150	100	127	130	190	50	177	258
12	2018	130	124	61	202	182	35	157	147
13	2019	245	177	131	150	195	185	162	148
14	2020	102	123	66	186	176	135	179	150
15	2021	98	186	106	184	139	130	122	137
16	2022	-	-	-	260	147	226	235	257
Average		143	127	106	167	148	113	158	163

The results of the analysis of rainfall data consistency showed consistent rainfall data where from the results of the calculation of the values of Q/n 0.5 Count and R/n 0.5 Count varied from 8 rain posts with values smaller than Q/n 0.5 and R/n 0.5 values with a degree of confidence of 1% and 5%. From the results of this consistency test, it has met the requirements so that further analysis can be continued.

Table 6. Data Consistency Test

Condition		
A	Q/n 0.5	R/n 0,6
1%	1,368	1,512
5%	1,188	1,37

Rain Post	Q/n 0.5 Calculate	R/n 0.5 Calculate	Information	
			1%	5%
Taba Penanjung Post	0,499	0,989	Data Consistency	Data Consistency
Plow Post	0,499	0,989	Data Consistency	Data Consistency
Published by Mutung	0,629	1,037	Data Consistency	Data Consistency
Unib	0,671	1,117	Data Consistency	Data Consistency
Tanjung Agung	0,768	0,983	Data Consistency	Data Consistency
Muara Bangka Hulu	0,553	1,037	Data Consistency	Data Consistency
Padang Harapan	0,770	1,110	Data Consistency	Data Consistency
Mateo Bengkulu	0,656	1,110	Data Consistency	Data Consistency

The river is located within the Air Bengkulu Watershed (DAS) and is monitored by eight rain gauge stations closest to the study site. Therefore, an analysis of regional rainfall was conducted using the Thiessen Polygon method. The Thiessen Polygon rainfall analysis was carried out using the Arc-MAP application to determine the areal influence of each rainfall station. Regional rainfall was calculated using Equation (1), and the sorted results of the Thiessen Polygon rainfall analysis can be seen in Table 7, while the Thiessen Polygon itself is illustrated in Figure 2.

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Figure 2 Poligon Thiessen

Figure 2 illustrates the Thiessen Polygon map constructed for the Air Bengkulu watershed. This method spatially delineates the area of influence for each of the eight rain gauge stations used in the study. By drawing perpendicular bisectors between adjacent stations, the watershed is divided into polygons, each representing the region closest to a specific station. The area-weighted rainfall for the entire watershed is then computed by multiplying the rainfall recorded at each station by the corresponding polygon area. This spatial interpolation technique enhances the accuracy of regional rainfall estimation by accounting for the geographical distribution of rainfall data. The use of ArcMap GIS software allowed precise digitization and area calculations of each polygon, thereby ensuring the reliability of the average rainfall values used in subsequent hydrological modeling. This step is essential for data-scarce basins where uniform rainfall distribution cannot be assumed, and accurate regional rainfall input is critical for reliable flood forecasting and hydrological simulation.

Table 7. Rainfall that has been sorted

No	Years	$R_{Thiessen}$ (mm)
1	2022	39,38
2	2007	97,68
3	2012	99,73
4	2013	99,90
5	2014	106,54
6	2020	108,54
7	2018	112,35
8	2008	115,16
9	2010	119,44
10	2021	126,70
11	2011	126,91
12	2009	137,26

13	2017	138,23
14	2015	148,42
15	2016	167,08
16	2019	178,94

Table 8 presents the annual regional rainfall data for the Air Bengkulu watershed, sorted from the lowest to the highest values based on Thiessen Polygon analysis. This ranking facilitates identification of rainfall variability across 16 years (2007–2022), highlighting years with extreme precipitation that could significantly influence flood risk modeling. The sorted data supports the selection of rainfall values for frequency analysis and helps determine return periods for planned flood discharge estimation. By organizing rainfall in ascending order, this table provides a clear overview of temporal rainfall trends, serving as a foundational input for hydrological modeling using the HEC-HMS system.

4.2 Statistical and Distribution Analysis

Dispersion measurement, namely the calculation of the mean value, standard deviation, slope coefficient, curtosis coefficient and coefficient of variation according to the distribution distribution that will be used for planned rainfall, the following are the results of the calculation of statistical and logarithmic parameters can be seen in Table 8.

Table 8. Statistical and Logarithmic Parameters

Gumbel	
Average = average Xi	120,14
Standard Deviation (SD)	32,07
Lots of Data (n)	16,00
Cs	-0,51
Ck	5,39
Cv	0,27
In	0,52
Sn	1,03
Log Pearson Tipe III	
Rata-rata log c	2,06
Standard Deviation (Sd Log Xi)	0,15
Lots of Data (n)	16
Cs	-2,12
Ck	9,97
Cv	0,07
Log Normal	
Ln Xi rate-rate	4,74
Standard Deviation (Sd Ln Xi)	0,34
Lots of Data (n)	16

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Cs	-2,12
Ck	12,51
Cv	0,07

The purpose of this analysis is to obtain planned rainfall that meets the parameters as a condition for matching the distribution distribution. The analysis of distribution types will use 3 distribution type methods, namely Gumbel Type I, Normal Log and Log Person Type III. The rainfall data obtained will be compared with the conditions of each type of distribution, the data that meets will be used for the analysis of rainfall intensity. The analysis of the distribution types of the three methods is explained as follows:

1) Gumbel

Table 9. Rainfall Plan Gumbel Method

No	Period	$\bar{x}$	Sd	Yn	Sn	Yt	Xt
1	2	120,14	32,07	0,52	1,03	0,37	115,50
2	5	120,14	32,07	0,52	1,03	1,50	150,74
3	10	120,14	32,07	0,52	1,03	2,25	174,07
4	25	120,14	32,07	0,52	1,03	3,20	203,55
5	50	120,14	32,07	0,52	1,03	3,90	225,42
6	100	120.14	32.07	0.52	1.03	4.60	247.12

Table 9 displays the estimated planned rainfall values calculated using the Gumbel Type I distribution method for various return periods (2, 5, 10, 25, 50, and 100 years). This distribution is commonly used in hydrological studies to model extreme events such as maximum rainfall. The table includes key statistical parameters such as the mean, standard deviation, and reduced variate values (Yn, Sn, Yt) used to calculate the planned rainfall (Xt). The results help determine expected rainfall magnitudes for different recurrence intervals, which are critical for designing flood mitigation infrastructure and understanding potential flood scenarios in the study area.

2) Log Pearson Tipe III

Table 10. Rainfall Plan Pearson Log Method Type 3

No	Period	Log X	Sd Log X	Cs	k	Y	Xt
1	2	2,06	0,15	-2,12	0,32	2,11	128,07
2	5	2,06	0,15	-2,12	0,76	2,17	148,69
3	10	2,06	0,15	-2,12	0,87	2,19	153,95
4	25	2,06	0,15	-2,12	0,92	2,20	156,70
5	50	2,06	0,15	-2,12	0,93	2,20	157,53
6	100	2,06	0,15	-2,12	0,94	2,20	157,91

Table 10 presents the planned rainfall values derived from the Log Pearson Type III distribution for several return periods. This method is preferred when rainfall data exhibit skewness, as it can accommodate asymmetrical distributions. The table includes the mean logarithmic values, standard deviation, skewness coefficient (Cs), and calculated frequency factor (k), which are used to estimate the planned rainfall (Xt). This distribution was selected for use in further modeling due to its suitability based on goodness-of-fit and parameter conformity, providing more accurate and context-appropriate rainfall inputs for hydrological simulations in the Air Bengkulu watershed.

3) Log Normal

Table 11. Rainfall Normal Log Method Plan

No	Period	k	Sd.k	Ln RRancangan	Xt
1	0,00	0,00	4,74	114,93	0,00
2	0.84	0,28	5,03	152,63	0,84
3	1,28	0,43	5,18	177,09	1,28
4	1,75	0,59	5,34	207,55	1,75
5	2,05	0,69	5,44	229,68	2,05
6	2,330	0,79	5,53	252,46	2,33

Table 11 shows planned rainfall values calculated using the Log Normal distribution method, which assumes that the logarithm of rainfall data follows a normal distribution. The table includes the mean of the natural logarithm of rainfall (Ln RRancangan), standard deviation, and standard normal variable (k) for each return period. This method is often applied in hydrological studies for datasets with moderate skewness. The results offer an alternative perspective on expected rainfall magnitudes, complementing the outputs from the Gumbel and Log Pearson III distributions, and contributing to a comprehensive analysis for selecting the most reliable rainfall model for flood forecasting.

The distribution suitability test analyzed is the Chi Square and Smirnov Kolmogorov tests on the distributions used, namely the Gumbel Distribution, Log Pearson Type III, and Log Normal, by comparing the calculation results of each suitability test with each requirement, namely the Chi Square Test (X2Calculate <X2Critical) and the Smirnov Kolmogorov Test (Δ max <Δ Critical) with the X2Critical and Δ Critical values obtained from the test table used, namely a confidence level of 1% and 5%. So if the suitability test is accepted/not accepted, it will be a consideration in selecting the type of planned rainfall distribution. The results of the rainfall distribution suitability test can be seen in Table 12.

Table 12. Distribution Compatibility Test and Selection of Planned Rainfall Distribution Type

No.	Repeat Time	Distribution		
		Type I Gumbel	Log Normal	Log Pearson III
1	2	115,502	114,932	128,065
2	5	150,739	152,633	148,689
3	10	174,065	177,087	153,948
4	25	203,548	207,551	156,696
5	50	225,416	229,682	157,533
6	100	247,123	252,462	157,911
UJI SMIRNOV KOLMOGOROF				
ΔKritis α (1%)		0,39	0,39	0,39
ΔKritis α (5%)		0,33	0.33	0,33

No.	Repeat Time	Distribution		
		Type I Gumbel	**Log Normal**	**Log Pearson III**
Lots of Data (n)		16,00	16,00	16,00
ΔCalculate		0,17	0,12	0,28
Description (1%)		Accepted	Accepted	Accepted
Description (5%)		Accepted	Accepted	Accepted
Difference (1%)		0,22	0,27	0,11
Difference (5%)		0,16	0,21	0,05
TEST CHI SQUARE				
X2Kritis α (1%)		9,21	9,21	9,21
X2Kritis α (5%)		5,99	5,99	5,99
Degree of Freedom (Dk)		2,00	2,00	2,00
X2Calculate		3,38	4.00	19,63
Description (1%)		Accepted	Accepted	Rejected
Description (5%)		Accepted	Accepted	Rejected
Difference (1%)		5,84	5,21	-10,42
Difference (5%)		2,62	1,99	-13,63

The results of the distribution match test of the three distribution methods have a value smaller than the value of the critical value requirement for the degree of confidence of 1% and 5% so that the three types of distribution can be considered in the selection of the type of planned rainfall distribution.

In addition to the compatibility test, the requirements for each rainfall distribution test are also considered, and the selection and distribution match test can be seen in Table 13.

Table 13. Test Requirements

No	Distribution Type	Condition			Calculation Results			Information
1	Gumbel Method Type I	Ck	≈	5.4	Ck	=	5,39	Accepted
		Cs	≈	1.14	Cs	=	-0,51	
2	Method Log Normal	Cs	=	Cv3+3Cv	Cs	=	-2,12	Rejected
			=	1.1198				
		Ck	=	Cv8+6Cv6+15Cv4+16Cv2+3	Ck	=	12,51	Rejected
			=	5.31				
3	Pearson Log Method Type III	Cs	<	0	Cs	=	-2,12	Rejected
		Ck	≈	0.3	Ck	=	9,97	

The results of the match test and the requirement test of each rainfall distribution showed that the rainfall distribution of the Pearson Log Type III plan could be accepted and met the requirements so that the rainfall of the Pearson Log Type III plan to be used in the analysis of rainfall intensity PSA 007.

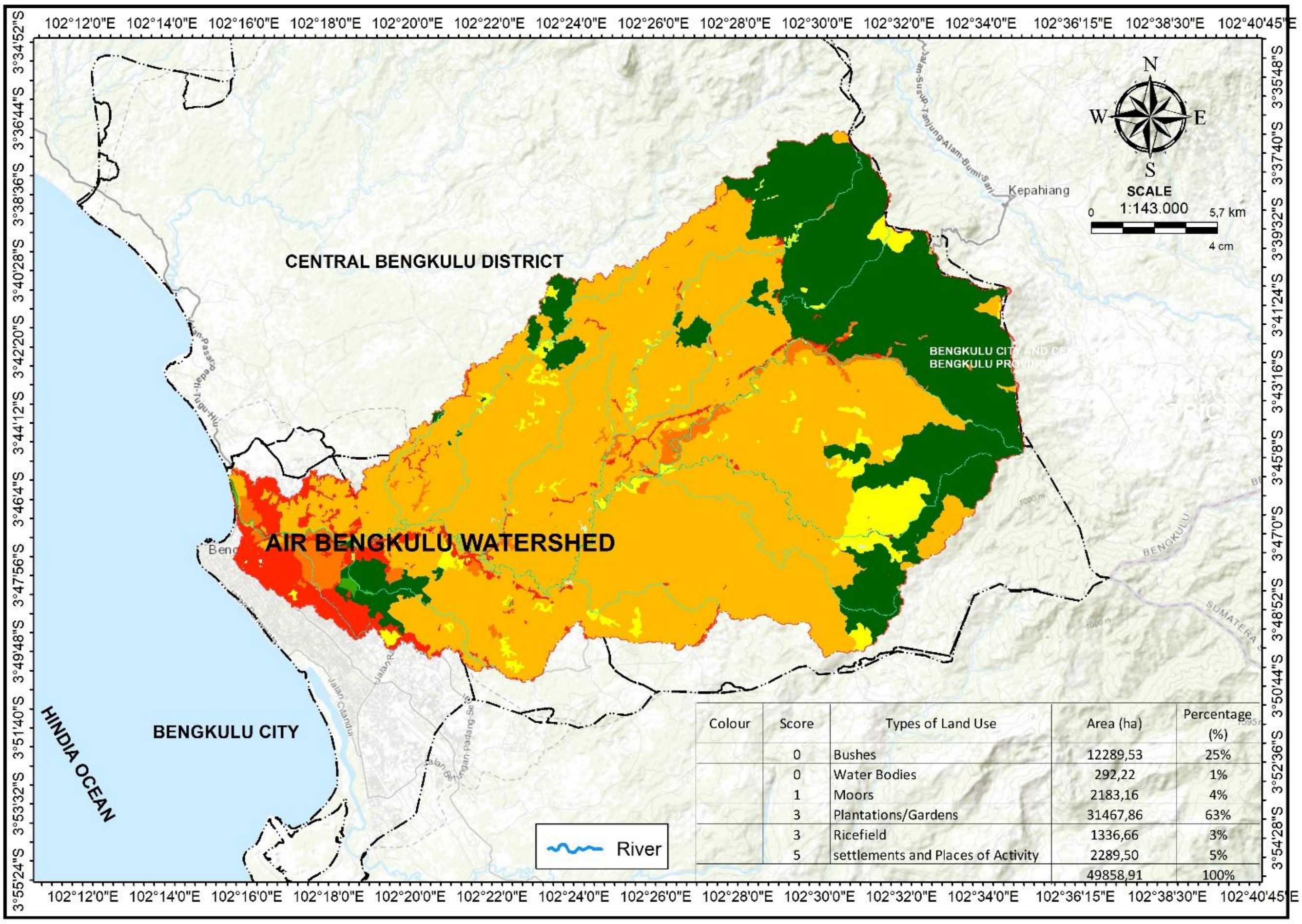
Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

4.3 Rainfall Intensity and Hydrograph Construction

The planned rainfall value obtained from frequency analysis needs to be transformed into the form of hourly rainfall. The transformation is carried out using a rain distribution pattern, which can be taken from the recording of rain stations. If the rain recording data at the rain station is not available, then the rain distribution pattern can follow the pattern that has been developed in other regions (Christian et al., 2017). The purpose of the hourly rainfall distribution analysis is to estimate the percentage of total rainfall that falls in each hour. The rain of the hours is processed and averaged. The method that can be used is the PSA 007 method (DGWRD, 1985).

The rainfall data used in this study consist of design rainfall series that satisfy the distribution requirements, specifically derived using the Log-Pearson Type III method. Subsequently, the net rainfall was calculated by incorporating the runoff coefficient of the Air Bengkulu watershed. This runoff coefficient is determined based on the land cover within the Air Bengkulu watershed, as illustrated in Figure 3.



Colour	Score	Types of Land Use	Area (ha)	Percentage (%)
	0	Bushes	12289,53	25%
	0	Water Bodies	292,22	1%
	1	Moors	2183,16	4%
	3	Plantations/Gardens	31467,86	63%
	3	Ricefield	1336,66	3%
	5	settlements and Places of Activity	2289,50	5%
			49858,91	100%

Figure 3 Land Cover Source : (VII, 2023)

Figure 3 presents the land cover map of the Air Bengkulu watershed, which is a critical input for hydrological modeling using the HEC-HMS and SCS-CN methods. Land cover classification influences surface runoff characteristics by determining infiltration rates and imperviousness across different areas. The map differentiates various land use categories such as forest, settlement, agricultural land, and water bodies, each assigned a specific Curve Number (CN) value reflecting its runoff potential. This spatial data was processed using ArcMap GIS and overlaid with soil hydrological group information to derive composite CN values for each sub-basin. Accurate land cover mapping ensures that runoff generation and rainfall transformation into discharge are realistically represented, thereby enhancing the precision of flood simulations and peak discharge estimation.

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

The flow coefficient was calculated on average with Arc-Map 10.8 software which then obtained an average value of the flow coefficient (Cp) of 0.47. The following is the rainfall data that can be seen in Table 14.

Table 14. Netto Rainfall

Repeat Time	Rainfall Plan (mm)	Curah Hujan Netto (Rn) (mm)
2 years	111,29	27,82
5 years	150,15	37,54
10 years	169,80	42,45
25 years	190,16	47,54
50 years	202,93	50,73
100 years	241,96	60,49

The percentage of rainfall distribution in the Bengkulu Water Basin is 6 hours by converting to 24 hours with the provisions of PSA 007. So that the percentage of rain distribution is 6 hours. PSA 007 The Department of Public Works (1985) suggested the magnitude of the rain intensity based on the PSA 007 requirements table, made the rain intensity calculated the rain distribution. Critical rain and rain distribution are arranged in the form of a bell shape. Where the highest rain is placed in the middle. The second highest rain is on the left, the third highest is on the right, the fourth highest is on the left, and so on. Then analyze the distribution of net rain based on net rain data (Rn) with a percentage of 6 hours of rain (bell shape) so that the distribution of net rain of the hours can be seen in Table 15.

Table 15 Rainfall Distribution PSA 007

The Hour	Conversion Hours	Repeat Time					
		2	5	10	25	50	100
1	4	2,20	2,88	3,32	3,88	4,30	4,71
2	8	6,06	8,63	11,62	14,56	18,27	21,21
3	12	39,11	50,32	56,44	65,03	69,87	75,42
4	16	3,30	4,31	4,98	5,82	6,45	7,07
5	20	2,20	2,88	3,32	3,88	4,30	4,71
6	24	2,20	2,88	3,32	3,88	4,30	4,71
Quantity (mm)		55,08	71,88	83,01	97,07	107,49	117,84
Rainfall Draft (mm)		115,50	150,74	174,07	203,55	225,42	247,12
Flow-in Coefficient		0,25	0,25	0,25	0,25	0,25	0,25
Effective Rain		55,08	71,88	83,01	97,07	107,49	117,84

Table 15 presents the hourly distribution of net rainfall across six time intervals for different return periods (2, 5, 10, 25, 50, and 100 years) using the PSA 007 method. This method applies a bell-shaped rainfall pattern commonly used in hydrological design in Indonesia. The table shows how rainfall is concentrated around the middle hours (especially hour 3), which represents the peak rainfall intensity. Each return period displays progressively higher values, reflecting increasing rainfall magnitude. The distribution is essential for constructing hydrographs in flood modeling, as it provides a realistic temporal structure of rainfall input used in the HEC-HMS simulation.

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

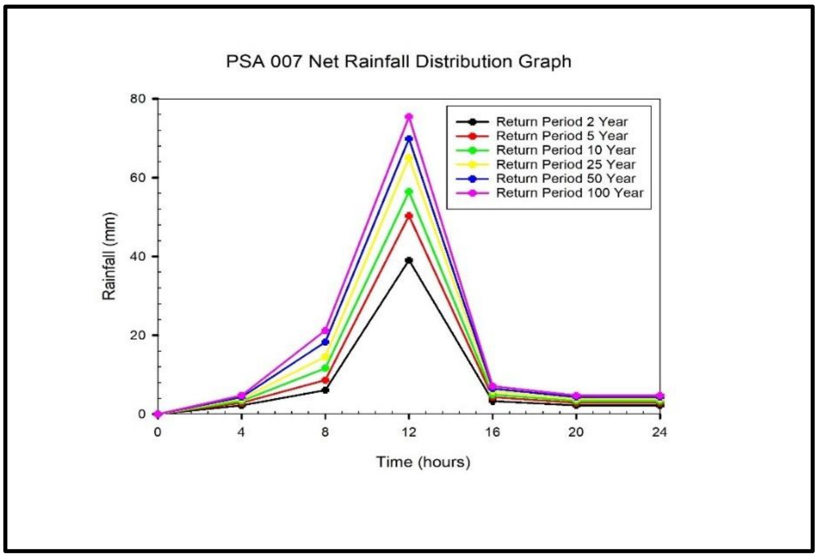


Figure 4 PSA 007 Rainfall Distribution Graph

Figure 4 graphically illustrates the PSA 007 rainfall distribution pattern over six hourly intervals. The bell-shaped curve shows that the most intense rainfall typically occurs in the third hour, tapering off symmetrically before and after this peak. This pattern is used to simulate critical storm events in hydrological models, ensuring that peak discharge estimations reflect realistic storm dynamics. The graphical representation enhances understanding of temporal rainfall variation and is crucial for visualizing how rainfall intensity changes over time during a design storm event used in the HEC-HMS flood forecasting process.

4.4 Peak Discharge Estimation

4.4.1 HEC HMS (Hydrology Model)

Elevation Model which represents the shape of the earth or elevation in the Bengkenang watershed. The condition of the watershed division is adjusted to the oulet of the sub-watershed to be studied, in this study using outlets located downstream of the river. The results of the Bengkenang watershed delimitation can be seen in Figure 5.

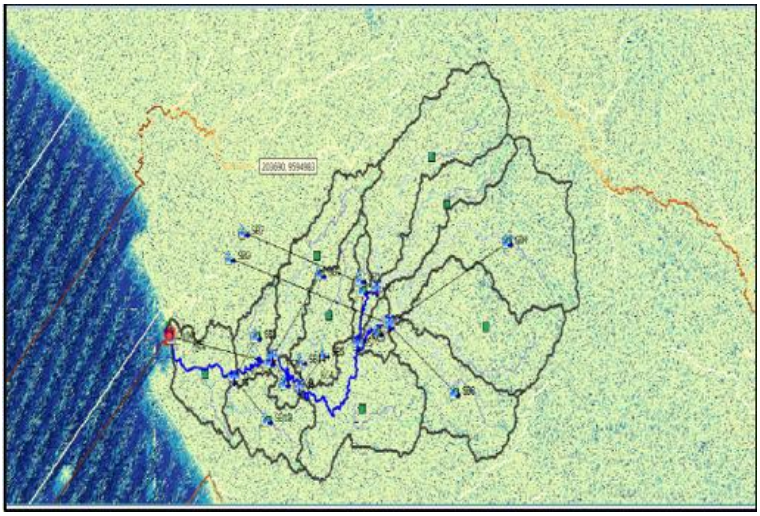


Figure 5 Watershed Definition

Figure 5 illustrates the delineation of the Bengkulu watershed and its sub-basins based on topographical and hydrological characteristics using a Digital Elevation Model (DEM). The watershed boundary defines the area contributing surface runoff to a common outlet, which is essential for accurate hydrological modeling. This

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

delineation was performed using GIS tools to identify flow direction, stream networks, and catchment areas. The defined watershed ensures that rainfall-runoff processes are spatially consistent with natural drainage patterns. Accurate watershed mapping supports effective simulation of hydrological responses in the HEC-HMS model, facilitating peak discharge estimation, sub-basin parameter assignment, and flood risk analysis.

4.4.2 HEC HMS Parameters for SCS CN (Curve Number)

Runoff rain modeling, using the Synthetic Unit Hydrograph (HSS) of SCS CN. The basin components of the model have 4 main parameters which are also methods in the HEC-HMS Model. The methods used for the HEC HMS Model are the Loss Method (SCS CN Method) and the Transform Method (SCS Unit Hydograph Method), these two parameters are the parameter menus in the HEC-HMS Model, as follows:

- Loss Method

The number of surface flow curves (curve number) was calculated in a composite manner determined through overlay analysis between the Soil Hydrological Group Map (KHT), Land Use Map. The map is matched with the CN number attribute into the CN LookUp Table according to the previous groundwater condition data (Antecedent Moisture Condition / AMC).

- Initial Abtraction (InitLoss)

InitLoss value (Initial Abstraction/ Ia) from land use, treatment and hydrological conditions, and previous groundwater content.

- Curve Number (CN)

Soil hydrology determination uses maps from Global Hydrologic Soil Groups (HYSOGs250m) for Curve Number-Based Runoff Modeling where in the Bengkenang watershed there are 4 types of pixel values, namely 2, 4, 13 and 14 with categories C, D, C/D and D/D. Overlay is carried out between the soil hydrological map and the land cover map which is then adjusted to the CN value based on the influence of each map, The following are the categories of soil hydrological maps with land cover maps can be seen in Figure 6.

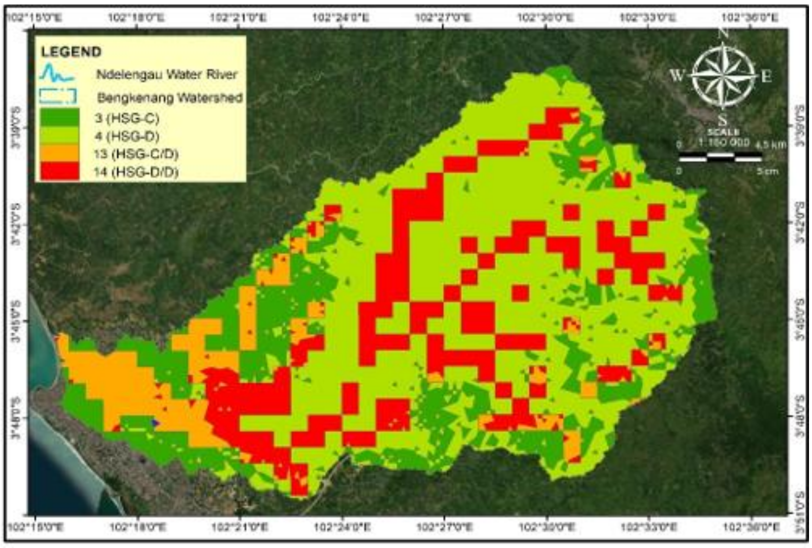


Figure 6 Soil Type

The CN value is analyzed in each Sub Basin using ARC-MAP Software, so that the Average CN value from each Sub Basin is obtained

- Persen Impervious (PetIMP)

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

The Impervious Percent Value (PctImp) is adjusted to the land cover of the Bengkulu watershed which is then analyzed for the average value in each Sub Basin using ARC MAP software

1. Method Transform

This method depends on the length, slope, cross-section of channels and rivers and their roughness coefficients. The HSS SCS grace time can be estimated through calibration, for those who have observation data at the water suspected post. The research area has no data, SCS suggests that the grace time is estimated from the time of tc concentration through the equation formula 23.

4.4.3 HMS HEC Parameters for Synthetic Hydrographs

The parameters that will be used as inputs to the HEC-HMS software can be seen in Table 18. These parameters were obtained from the results of the analysis for the CSS CN HSS and the results of the delineation of the Bengkulu Water Watershed.

Table 16. Parameter HEC HMS SCS CN

Sub Basin	Broad (km2)	CN	Longest Flowpart Length (km)	Basin Slope (m/m)	Longest Flowpath (m)	Basin Slope (%)	Tc (hours)	Tc (minutes)	Time Lag	S	Initial Abstraction (ia)	Persen Impervious (%)
SB-1	66,18	84,36	26,24	0,28	26240,68	27,82	8,47	508,15	304,89	47,08	9,42	5,20
SB-2	60,61	84,97	23,89	0,26	23886,53	26,45	7,84	470,21	282,13	44,93	8,99	5,63
SB-3	15,15	82,60	11,29	0,13	11286,13	12,70	4,32	259,26	155,56	53,51	10,70	9,58
SB-4	83,83	83,25	29,08	0,30	29075,10	30,02	9,23	553,97	332,38	51,11	10,22	5,89
SB-5	30,32	84,75	17,27	0,18	17272,07	18,11	6,04	362,33	217,40	45,72	9,14	5,27
SB-6	28,20	81,87	12,48	0,07	12483,96	6,60	4,68	281,08	168,65	56,24	11,25	23,29
SB-7	30,47	84,39	23,00	0,27	23002,76	27,50	7,62	457,27	274,36	46,99	9,40	5,25
SB-8	43,97	84,19	21,78	0,25	21779,90	24,84	7,30	437,76	262,65	47,71	9,54	5,02
SB-9	35,76	83,09	23,88	0,18	23881,04	18,40	7,87	472,23	283,34	51,70	10,34	5,17
SB-10	26,58	82,91	13,15	0,07	13148,89	6,79	4,87	292,02	175,21	52,36	10,47	10,44
SB-11	9,12	85,83	9,65	0,17	9647,53	17,01	3,77	226,45	135,87	41,94	8,39	6,68
SB-12	0,00	84,10	0,11	0,07	109,47	7,06	0,11	6,31	3,79	48,02	9,60	5,00
SB 13	6,91	86,29	6,56	0,17	6558,13	16,64	2,77	165,99	99,59	40,34	8,07	8,70
SB-14	55,60	85,24	19,04	0,18	19043,77	18,21	6,52	391,10	234,66	43,98	8,80	6,02
SB-15	6,38	86,15	6,90	0,10	6904,39	9,95	2,88	172,69	103,61	40,82	8,16	11,43

4.4.5 Hydrograph Flood Plan HEC HMS SCS Curve Number Method

The hydrograph of the planned flood results from the Running HEC HMS is presented in the form of a graph that represents the planned flood discharge based on the reperiod, the height of the discharge is greatly influenced by the parameters in the watershed. The planned flood discharge graph can be seen in Figure 7.

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

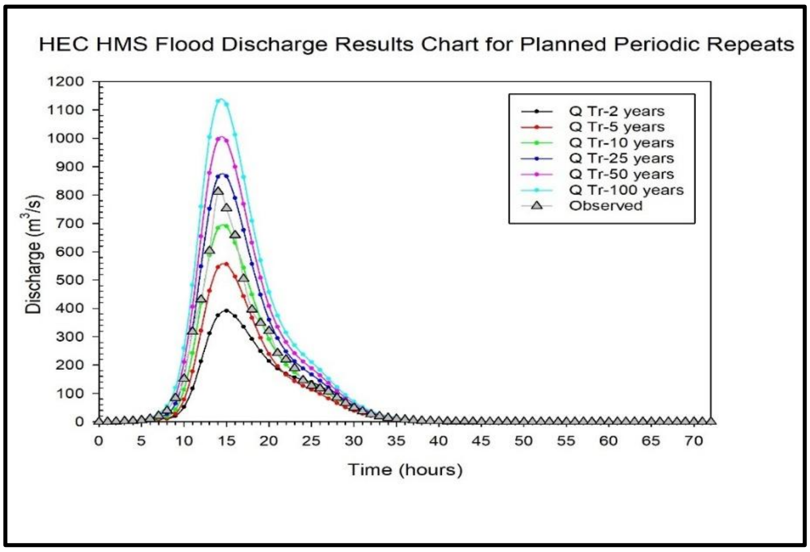


Figure 7 Planned Flood Discharge Chart

The results of the analysis showed that the planned flood discharge from the results of running the HEC HMS software using the selected planned rainfall with several influences of the HEC HMS parameters of the SCS Curve Number method, the results of the analysis were that the peak time occurred at the 13th hour with the planned flood discharge for the 2-year re-period of 29.265 m3/s, 5 years of 52.665 m3/s, 10 years is 66,133 m3/s, 25 years is 80,835 m3/s, 50 years is 105,120 m3/s, 100 years is 118,870 m3/s. From the results of this study, further analysis can be carried out, namely hydraulic analysis in the form of flood inundation that occurs.

4.5 Model Validation

Validation was carried out using observation data. Validation is carried out by calculating the NSE (Nash-Sutchliffe Efficiency) and RMSE (Root Mean Squared Error) values. A data is said to be good if it has the largest NSE value (close to 1) and the smallest RMSE value. If a data has results as in these provisions, then the data is closer to the results of measurements in the field. Validation can be seen in Table 17.

Table 17. Validation of Hydrograph Data Results of HEC HMS Model

Repeat Time	RSME	NSE	Information
2-Year Anniversary	115,91	0,70	Meet
5-Year Anniversary	95,75	0,80	Good
10-Year Anniversary	27,57	0,98	Good
25th Anniversary	54,27	0,93	Good
50th Anniversary	98,05	0,79	Good
100th Anniversary	114,36	0,54	Meet

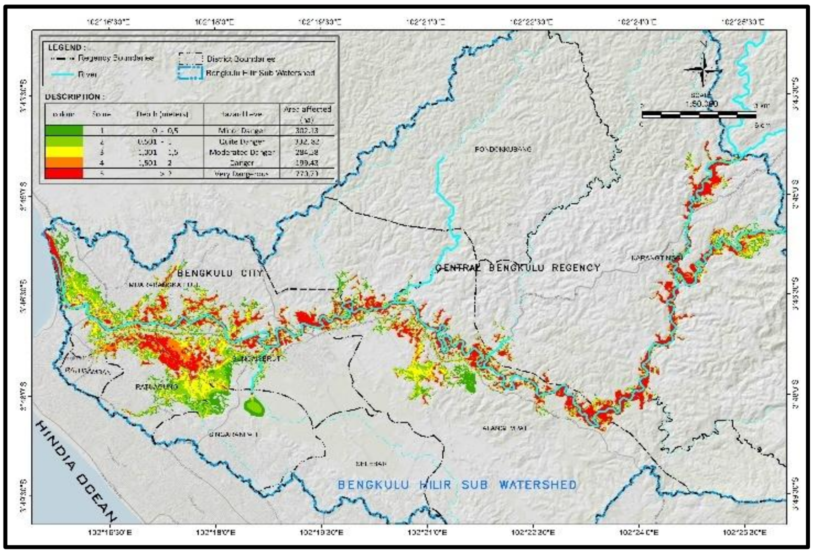
The validation results showed that the flood hydrophoblast from the HEC HMS model results at 5 retime, 10 year retime, 25 year retime, and 50 year reage had the best results.

4.5.1 Geographic Information System (GIS)

1. Simulation 1 (Without the influence of seawater and without the influence of lake water height)

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article



Administrative Village/Village	Simulation Area 1 (Ha)	Simulation Area 2 (Ha)	Simulation Area 3 (Ha)
Bengkulu City			
Belakang Pondok	0,22	0,22	2,18
Bentiring	98,06	88,56	123,64
Bentiring Permai	57,66	55,42	122,85
Beringin Raya	25,34	15,15	84,79
Dusun Besar	69,47	40,62	237,44
Jembatan Kecil	-	-	8,31
Kampung Kelawi	7,47	7,28	16,38
Kandang Limun	-	-	30,34
Kebun Tebeng	16,18	14,23	39,61
Padang Jati	0,12	-	1,25
Panorama	72,32	71,42	85,68
Pasar Bengkulu	12,89	12,05	21,74
Pematang Gubernur	8,32	8,07	28,17
Rawa Makmur	108,30	106,01	180,70
Rawa Makmur Permai	38,66	37,64	109,69
Sawah Lebar	13,57	11,02	39,92
Sawah Lebar Baru	52,54	51,72	71,66
Semarang	168,03	160,54	203,99
Sidomulyo	-	-	85,87
Sukamerindu	18,51	18,09	29,52

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Surabaya	130,71	104,24	166,18
Tanah Patah	5,10	3,61	25,59
Tanjung Agung	31,87	31,37	44,71
Tanjung Jaya	49,32	48,61	60,90
Timur Indah	-	-	0,63
Total Area	984,67	885,86	1821,10
Central Bengkulu			
Gajah Mati	18,67	18,67	18,26
Jayakarta	8,72	8,72	8,10
Kancing	61,93	61,93	61,81
Karang Tinggi	57,90	57,90	57,83
Kembang Seri	76,81	76,76	63,73
Nakau	35,64	31,03	30,54
Pagar Jati	15,65	15,45	15,02
Penanding	118,90	118,90	118,58
Pulau Panggung	126,30	126,33	124,04
Taba Jambu	14,98	3,66	3,29
Taba Mutung	16,71	16,71	16,70
Taba Pasmah	92,17	88,45	56,90
Taba Terunjam	62,72	62,70	58,00
Talang Empat	6,98	6,65	2,15
Tengah Padang	154,60	153,36	71,70
Ujung Karang	36,66	36,69	36,54
Total Area	905,34	883,90	743,18

CONCLUSION

This study successfully applied the integration of Geographic Information Systems (GIS) and the HEC-HMS hydrological model using the SCS-CN method to estimate peak discharge in the Air Bengkulu sub-catchments. The analysis of 16 years of rainfall data (2007–2022), validated through consistency tests and interpolated using the Thiessen Polygon method, provided a solid foundation for constructing accurate synthetic unit hydrographs. Frequency analysis using Gumbel Type I, Log Normal, and Log Pearson Type III distributions revealed that Log Pearson Type III was the most suitable for planned rainfall modeling.

Rainfall intensity was further refined using PSA 007 guidelines, and effective rainfall was calculated based on a runoff coefficient derived from land use and soil characteristics. The HEC-HMS simulation demonstrated peak discharges for various return periods, with values ranging from 29.27 m^3/s (2-year) to 118.87 m^3/s (100-year), and a consistent peak time at the 13th hour.

Model validation using NSE and RMSE confirmed high reliability and accuracy. These results provide critical input for flood mitigation planning, infrastructure development, and early warning systems. This research offers valuable guidance for practitioners, policymakers, and local communities in enhancing regional flood risk management and supports future integration of hydrological and hydraulic models for more detailed inundation mapping.

Acknowledgment

Thank you to the Government of the Republic of Indonesia and the University of Bengkulu Research Institute for funding the research. Thank you to the Faculty of Engineering, University of Bengkulu for providing a laboratory to conduct this research.

Authors' Note

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

RefErences

[1] Asadi, S., Karimi, P., & Ahmadi, H. (2024). Impact of land-use change on watershed flood vulnerability: A case study. *Journal of Hydrology*, 612, 128141. [https://doi.org/10.1016/j.jhydrol.2023.128141]
[2] Bentahar, M., & Yebdri, F. (2024). Application of hydraulic models in flood risk mapping. *Hydrology and Earth System Sciences, 28*, 911–925. [https://doi.org/10.5194/hess-28-911-2024]
[3] Bradshaw, C. J. A., Brown, K., & Lee, M. (2017). Human land-use changes and their impacts on watershed hydrology and flooding. *Hydrological Processes, 31*(3), 463–476. https://doi.org/10.1002/hyp.11034
[4] Dai, Y., Zhang, L., & Lu, X. (2020). Comparison of synthetic unit hydrograph methods for flood estimation in semi-arid regions. *Hydrological Processes, 34*(15), 3170–3184. [https://doi.org/10.1002/hyp.13856]
[5] Di Baldassarre, G., Montanari, A., & Brath, A. (2010). Floodplain mapping using hydrogeomorphic and hydraulic approaches. *Water Resources Research*, 46(6), W06506. [https://doi.org/10.1029/2009WR008666]
[6] Foley, J. A., DeFries, R., Asner, G. P., et al. (2005). Global consequences of land use. *Science*, 309(5734), 570–574. [https://doi.org/10.1126/science.1111772]
[7] Guo, Q., Li, S., & Zhang, Y. (2020). The influence of land-use change on flood risks in coastal watersheds. *Hydrological Sciences Journal, 65*(4), 507–523. [https://doi.org/10.1080/02626667.2020.1799783]
[8] Guduru, J.U., & Mohammed, A.S. (2024). Hydrological modeling using HEC-HMS model: Case of Tikur Wuha River Basin, Rift Valley River Basin, Ethiopia. *Environmental Challenges*. https://www.sciencedirect.com/science/article/pii/S2667010024001835
[9] Halwatura, D., & Najim, M. (2013). Application of the HEC-HMS model to simulate flood events in an ungauged watershed. *Environmental Earth Sciences, 69*(5), 1593–1607. [https://doi.org/10.1007/s12665-012-1832-3]
[10] Ibrahim, M. H., & Klari, S. A. (2021). Efficiency of the SCS-CN method in estimating runoff in urbanized watersheds. *Water, 13*(6), 789. [https://doi.org/10.3390/w13060789]
[11] Jaberzadeh, S., Moghaddam, M., & Jafari, A. (2024). Evaluation of hydrological models for flood forecasting in an arid region. *Environmental Modeling & Assessment, 29*(3), 271–284. [https://doi.org/10.1007/s10666-024-09755-7]
[12] Mohammed, A. A. (2024). Evaluation of flood risk models using synthetic unit hydrographs. *Hydrological Research, 49*(2), 235–248. [https://doi.org/10.1002/hrs.412]
[13] Hughes, D.A. (1980). Floodplain inundation: Processes and relationships with channel discharge. *Earth Surface Processes*. https://doi.org/10.1002/esp.3760050308
[14] He, Q., Zhang, L., & He, Y. (2021). Application of HEC-HMS in flood forecasting for urban areas under climate change scenarios. *Journal of Environmental Management, 279*, 111481. [https://doi.org/10.1016/j.jenvman.2020.111481]
[15] Khaleghi, S., Kalantari, Z., & Naseripour, M. (2021). Risk assessment of urban flooding and mitigation strategies: A review of case studies. *Urban Water Journal, 18*(5), 345–358. [https://doi.org/10.1080/1573062X.2020.1800819]
[16] Kontogiannis, E. (2024). Data-driven hydrological modeling for flood prediction: Advances and challenges. *Hydrology and Earth System Sciences*, 28(3), 1571–1585. [https://doi.org/10.5194/hess-28-1571-2024]
[17] Kundzewicz, Z. W., & Matczak, P. (2012). Climate change impacts on floods and droughts in Europe. *Hydrological Sciences Journal*, 57(2), 281–290. [https://doi.org/10.1080/02626667.2012.657460]

Journal of Information Systems Engineering and Management
2025, 10(48s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

[18] Kundzewicz, Z. W., et al. (2014). Flood risk and climate change: Global and regional perspectives. *Hydrological Sciences Journal*, 59(1), 1–28. [https://doi.org/10.1080/02626667.2013.857411]
[19] Li, X., Asadi, S., & Li, Y. (2024). Land-use change and its effects on hydrological processes in tropical watersheds. Journal of Hydrology, 610, 127891. [https://doi.org/10.1016/j.jhydrol.2023.127891]
[20] Mokhtari, M., et al. (2024). Effects of impervious surface expansion on urban flood hazards. *Science of The Total Environment*, 856, 158837. [https://doi.org/10.1016/j.scitotenv.2022.158837]
[21] Natakusumah, E., Tunas, S., & Santoso, S. (2011). Synthetic unit hydrograph approach for flood estimation in ungauged basins. *Hydrological Processes*, 25(5), 762–771. [https://doi.org/10.1002/hyp.7859]
[22] Peters, D., Smith, J., & Johnson, L. (2014). Climate variability and flood risk: understanding the role of landscape and climate change. *Journal of Hydrology*, 519, 3205□3217. [https://doi.org/10.1016/j.jhydrol.2014.10.045]
[23] Peters, D., Smith, J., & Johnson, L. (2014). Climate variability and flood risk: Understanding the role of landscape and climate change. *Journal of Hydrology, 519*, 3205–3217. https://doi.org/10.1016/j.jhydrol.2014.10.045
[24] Ramos, M., Costa, S., & Silva, D. (2020). Advancements in flood prediction techniques for coastal areas. *Coastal Engineering, 161*, 103704. [https://doi.org/10.1016/j.coastaleng.2020.103704]
[25] Syed, M. R., Sattar, A., & Rehman, F. (2018). Assessment of urbanization effects on flood risks in river basins: A case study of Karachi, Pakistan. *Urban Water Journal, 15*(9), 747–759. [https://doi.org/10.1080/1573062X.2018.1510429]
[26] Smith, L., & Ward, R. (2019). Topographic influences on flood susceptibility in mountainous watersheds. *Water Resources Research, 55*(7), 6059–6075. https://doi.org/10.1029/2018WR023934
[27] Syed, K. H., Sattar, A., & Rehman, S. (2018). Synthetic unit hydrograph models for ungauged basins: Limitations and improvements. *Hydrological Sciences Journal*, 63(7), 1073–1087. [https://doi.org/10.1080/02626667.2018.1444458]
[28] Trenberth, K. E. (2011). Changes in precipitation with climate change. *Climate Research*, 47(1-2), 123–138. [https://doi.org/10.3354/cr00953]
[29] Tunas, S., Yim, K., & Farid, M. (2024). Simulation of flood hydrographs using synthetic unit hydrographs for ungauged basins. *Hydrology and Earth System Sciences, 28*(5), 1829–1847. [https://doi.org/10.5194/hess-28-1829-2024]
[30] Wang, C., Wang, L., & Yang, Q. (2023). Impacts of extreme rainfall events on river flooding in urban areas: A case study of Shanghai. *Journal of Hydrology, 589*, 125181. [https://doi.org/10.1016/j.jhydrol.2020.125181]
[31] Zhang, Q., & Shi, W. (2020). A review of flood prediction models in urbanized watersheds. *Natural Hazards, 103*(1), 143–163. https://doi.org/10.1007/s11069-020-04192-0
[32] Zhang, X., He, Q., & Wang, J. (2023). Hydrological impacts of land use change and urbanization on flood peaks. Journal of Hydrology, 615, 128524. [https://doi.org/10.1016/j.jhydrol.2023.128524]