Analysis of Flood Discharge at Catchment Area of West Jurang Mangu Reservoir using HEC-HMS

Ngakan Putu Purnaditya[1*], Dahlia Raudothul Jannah[1], Subekti[1], Bambang Adhi Priyambodho[1], Restu Wigati[1]
[1]Department of Civil Engineering, Sultan Ageng Tirtayasa University, Indonesia

Article Info

Article history:

Received, March 6, 2025
Accepted, April 22, 2025
Published, April 30, 2024

Keywords:

Watershed, Flood, QGIS, HEC HMS

ABSTRACT

High rainfall in Indonesia is one of the causes of flooding, especially in vulnerable areas such as watersheds. In addition to high rainfall, an increase in population and land use that is not in accordance with its function can worsen watershed conditions and cause an increase in flood risk. South Tangerang City is one of the areas prone to flooding, so flood control efforts are carried out such as widening rivers, raising embankments, and building retention ponds. Around the catchment area of the West Jurang Mangu Reservoir, flooding with a height of 50 60 cm still occurs, so further research was carried out at that location. In this study, the research method used QGIS to determine the catchment area, followed by hydrological analysis of the planned flood discharge using the HSS Synder method and modeling with HEC-HMS software. The results showed that the planned flood discharge using HSS Synder at return periods of 2, 5, 10, 25, and 50 years was 2.55 m^3/s; 3.599 m^3/s; 4.261 m^3/s; 5.033 m^3/s; and5.718 m^3/s.

Available online at http://dx.doi.org/10.62870/fondasi

Corresponding Author:

Ngakan Putu Purnaditya,
Department of Civil Engineering,
Sultan Ageng Tirtayasa University,
Jl. Jendral Soedirman Km 3, Banten, 42435, Indonesia.
Email: * purnaditya@untirta.ac.id

1. INTRODUCTION

Flooding is a natural phenomenon where floodplains and water catchment areas have been occupied and used for land conversion by humans [1]. In addition to high rainfall, high population growth and activities that are not in accordance with the function in land use can cause an increase in flood risk in various regions [2]. Increased flood risk can occur due to the inability of rivers to accommodate the volume of surface water or the presence of obstacles to surface flow that block the entry of water into natural channels, such as rivers [3]. One of the areas with vulnerability to flooding is the watershed [4]. Watershed (DAS) is a place that serves to accommodate, store, and drain water naturally to the lake or to the sea [5]. Watershed is one of the areas that can experience flooding events due to high rainfall and poor land use [6]. According to the South Tangerang SDABMBK Office, South Tangerang City is one of the cities that has a vulnerability to flooding events, so flood control is carried out in several places in the form of river widening, raising river banks, and making retention ponds [7]. In the area around the catchment area of the West Jurang Mangu Reservoir, Therefore, the problem of inundation and flooding is not only overcome in flooding still occurs with a height of around 50-60 cm, so a flood plan study was conducted at the study location [8].

2. RESEARCH METHODS

This research was conducted at the West Jurang Mangu Reservoir located in South Tangerang (Figure 1).

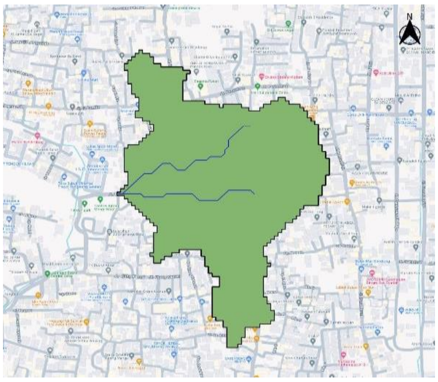

Figure 1. Research Location

The method used to obtain the value of river flow discharge plans with hydrological analysis. Furthermore, watershed delineation is carried out using the help of QGIS software and the HSS Synder method with HEC-HMS software so as to obtain the value of the planned river flood discharge of the West Jurang Mangu Reservoir watershed.

2.1 Hydrological Analysis

The hydrological analysis used in this research includes processing rainfall data, rainfall intensity, conveyance coefficient, and catchment area data. This research uses maximum rainfall with a 15 year period at the South Tangerang Rainfall Post Station. In its stages, a consistency test, frequency analysis and continued with the selection of the distribution which then entered the probability distribution test stage. Rain data consistency test can be done in several ways, one of which is the Rescaled Adjusted Partial Sums (RAPS) method [9].

$$S_k^{**} = \frac{S_k}{D_Y} \quad (1)$$

In determining the type of probability distribution used, there are statistical parameters to determine which data is suitable for each type of distribution. [10]. The calculation of these statistical parameters includes the average value ($\bar{X}$), standard deviation (S), coefficient of variation (Cv), coefficient of skewness (Cs), and coefficient of kurtosis (Ck).

Standard Deviation

$$S = \sqrt{\frac{\sum_{i=1}^{i} (X_i - \bar{X})^2}{n-1}} \quad (2)$$

Coefficient of Skewness (Cs)

$$Cs = \frac{n \sum_{i=1}^{i} (X_i - \bar{X})^3}{(n-1)(n-2)(S)^3} \quad (3)$$

Coefficient of kurtosis (Ck)

$$Ck = \frac{n^2 \sum_{i=1}^{i} (X_i - \bar{X})^4}{(n-1)(n-2)(n-3)(S)^4} \quad (4)$$

Coefficient of variation (Cv)

$$Cv = \frac{S}{\bar{X}} \quad (5)$$

Table 1. Calculation of Frequency Distribution Statistical Parameters

No.	Distribution	Requirements
1.	Gumbel	Cs ≤ 1,14 Ck ≤ 5,4
2.	Normal	Cs ≈ 0 Ck ≈ 3
3.	Log Normal	$Cs = Cv^3 + 3Cv$ $Ck = Cv^8 + 6Cv^6 + 15\,Cv^4 + 16Cv^2 + 3$
4.	Log Pearson III	Cs ≠ 0 Apart from the above values

The four frequency distribution methods use the basic rainfall plan formula as follows.

$$X_T = \bar{X} + S \times K_T \quad (6)$$

Testing the probability distribution equation to determine the suitability of the selected data sample in representing the static distribution of the data sample being analyzed [10] with two distribution test methods, which are as follows.

Chi-Square Test

$$X^2 = \sum_{i=1}^{n} \frac{(O_f - E_f)^2}{E_f} \quad (7)$$

Smirnov Kolmogorov

$$P(X) = \frac{m - b}{n + 1 - 2b} \quad (8)$$

After testing and calculating the frequency distribution of the planned rainfall, the intensity of the planned rainfall is analyzed using the Mononobe method. In planning the estimated flood discharge using short-term rainfall data of daily rainfall, the regression equation of the IDF curve can be derived using the mononobe method [15].

$$I = \frac{X_{24}}{24} \times \frac{24}{Tc}^{2/3} \quad (9)$$

The design flood analysis process requires hourly rainfall data (hyetograph) so it is necessary to establish an hourly rainfall distribution pattern through observations of major rainfall events. If the available rainfall data is in the form of daily rainfall data, it is necessary to calculate the rainfall distribution model, including the uniform, triangular, or Alternating Block Method (ABM) rainfall distribution model [11]. In the process of making ABM graphs, the first step is to calculate the intensity of rainfall in 6 hours. Then the calculation of the depth of rainfall is carried out, then the value of the depth of rainfall is sorted to form an ABM graph [12].

2.2 Catchment Area Value with QGIS

The use of QGIS in this research is used to obtain the catchment area value and curve number based on land use in the West Jurang Mangu Reservoir catchment area.

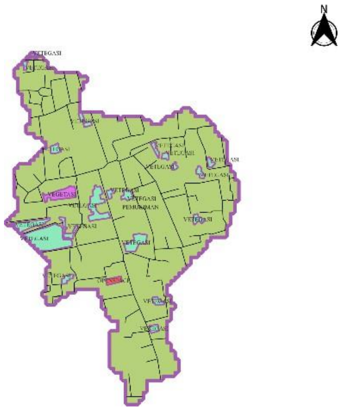

Figure 2. Land Use in the West Jurang Mangu Reservoir Catchment Area

2.3 Plan Flood Discharge with HEC-HMS

HEC-HMS software is software designed as a rain-runoff mechanism of the flow system so that it can represent the hydrological processes that occur. HEC-HMS is used to obtain plan flood hydrograph data in the river basin for West Jurang Mangu Reservoir [13]. The flood hydrograph data generated by HEC-HMS is obtained from the data owned for the plan flood hydrograph analysis process. In analyzing flood plans using HEC-HMS, there are several data that need to be inputted such as catchment area data, the loss method used, and the flood discharge method used [14]. The following is a description of the required data.

Table 2. HEC-HMS Plan Flood Modeling Data

Nilai Basin Model	
Komponen	Basin Model
Area (km^2)	0,178333
Loss Method	SCS *Curve Number*
Transform Method	Synder Unit Hydrograph
Nilai pada *Loss Method*	
Initial Abstraction (mm)	12,81
Curve Number	79,86
Impervious (%)	93
Nilai pada *Transform*	
Standard Lag (HR)	0,56
Peaking Coefficient (Cp)	0,60

3. RESULTS AND DISCUSSION

3.1 Frequency Distribution Annalysis of BMKG Rain Data

The distribution of rainfall frequency distribution using four methods, namely Gumbel, Normal, Log Normal, and Log Pearson Type III using return periods of 2, 5, 10, 25, and 50 years resulted in the Gumbel method that fulfills the distribution suitability test requirements and becomes the value that will be used as input data to generate the plan flood discharge.

Table 3. Annual Maximum Daily Rainfall Data

No	Year	X_{max} (mm)	X_i (mm)
1	2009	114	208,9
2	2010	108,9	123,8
3	2011	61,9	119,5
4	2012	79,8	118,9
5	2013	96	117
6	2014	119,5	114
7	2015	117	108,9
8	2016	97	105
9	2017	80,2	97
10	2018	86,3	96
11	2019	77,4	86,3
12	2020	208,9	80,2
13	2021	118,9	79,8
14	2022	123,8	77,4
15	2023	105	61,9
Total		$\sum$	1594,6
A lot of Data		n	15
Average		$\bar{X}$	106,3067

The consistency test for annual maximum daily rainfall data with one rainfall station uses the Rescaled Adjusted Partial Sums (RAPS) method.

Table 4. RAPS Method Calculation

For 90% Consistency Limit				
$Q/(n^{1/2})$ or $R/(n^{1/2})$	**Calculations**		**Table**	**Conclusion**
$Q/(n^{1/2})$	1,03	<	1,08	Consistent data
$R/(n^{1/2})$	1,12	<	1,28	Consistent data
For 95% Consistency Limit				
$Q/(n^{1/2})$ or $R/(n^{1/2})$	**Calculations**		**Tabel**	**Conclusion**
$Q/(n^{1/2})$	1,03	<	1,18	Consistent data
$R/(n^{1/2})$	1,12	<	1,36	Consistent data
For 99% Consistency Limit				
$Q/(n^{1/2})$ or $R/(n^{1/2})$	**Calculations**		**Tabel**	**Conclusion**
$Q/(n^{1/2})$	1,03	<	1,33	Consistent data
$R/(n^{1/2})$	1,12	<	1,49	Consistent data

From the calculation of the consistency test carried out above, the value of the 15-year rainfall data used proved to be consistent. So the calculation of the frequency distribution of rainfall using four methods, namely the normal method, the gumbel method, the log normal method, and the log pearson type III method using return periods of 2, 5, 10, 25, and 50 years.

Table 5. Frequency Distribution of Rainfall Plan Analysis

Plan Rain Frequency Distribution				
Tr (Plan Year)	**Normal (mm)**	**Gumbel (mm)**	**Log Normal (mm)**	**Log Pearson Tipe III (mm)**
2	175,89	218,98	182,18	202,65
5	164,29	193,17	165,44	178,56
10	149,76	164,07	146,61	148,87
25	134,82	139,12	129,50	127,55
50	106,31	99,45	102,18	99,09

Based on the results of testing the distribution suitability of the rainfall frequency distribution with BMKG rainfall data using the normal, gumbel, log normal, and log pearson type III distributions and return times of 2, 5, 10, 25, and 50 years, it is known that the rainfall used in the next calculation uses the frequency distribution of the gumbel method.

Table 6. Frequency Distribution Conformity Test

Distribution Fit Test				
Chi-Square Test				
Tr (Year)	**Normal**	**Gumbel**	**Log Normal**	**Log Pearson Tipe III**
X^2_{hitung}	3,33	4,67	15,33	14
X^2_{kritis}	5,99	5,99	5,99	5,99
Conclusion	Qualify	Qualify	Not Qualify	Not Qualify
Smirnov-Kolmogorov Test				
α_{hitung}	0,20	0,20	0,14	1,91
α_{kritis}	0,34	0,34	0,34	0,34
Conclusion	Qualify	Qualify	Qualify	Not Qualify

3.2 Rainfall Intensity

The following is the value of the planned rainfall intensity using the time of concentration.

Length of river flow, L = 401.6076 m

Flow slope value, S = 0.0139733

Concentration time, $Tc = 0,195 \times \frac{401,6067^{(0,77)}}{S^{(0,385)}} = 10,2099$ min = 0,1702 hours

Rainfall intensity, $I = \frac{99,4480}{24} \times \left(\frac{24}{0,1702}\right)^{2/3} = 112,2739$ mm/hor

Furthermore, calculations are carried out using the ABM method to obtain rainfall values that will be used as rainfall data values in the calculation of planned flood discharge.

Rainfall intensity, $I = \frac{XTR}{6} \times \left(\frac{6}{Td\ (hour)}\right)^{2/3}$

Rainfall, $P = Td \times I = 1 \times 54,728 = 54,728$ mm

$\Delta P = P_n - P_{(n-1)} = 54,728 - 51,501 = 3,227$ mm

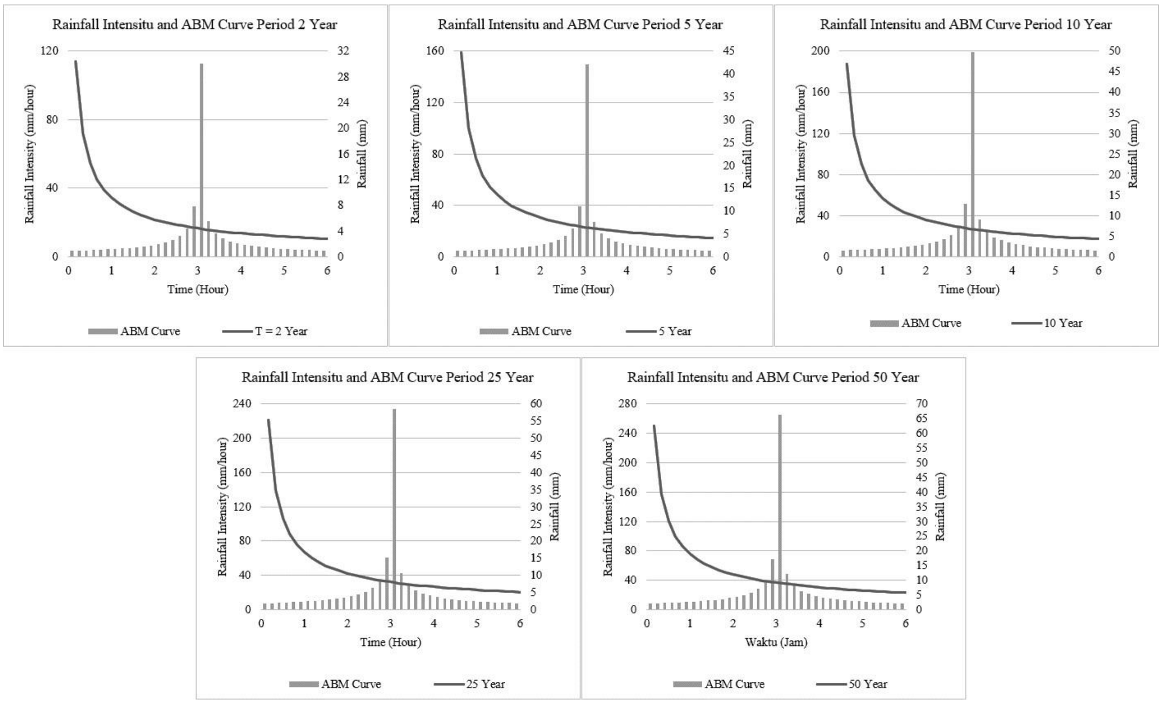

Figure 3. Rainfall Intensity

3.3 Synder Method Plan Flood Discharge

Flood discharge plan with HSS Synder method is calculated with the help of HEC-HMS. This analysis is carried out by entering data in the form of rainfall, catchment area, the value of the curve number method so that the value of the planned discharge using the Synder method is produced.

Figure 4. ***Catchment Area*** **in HEC-HMS**

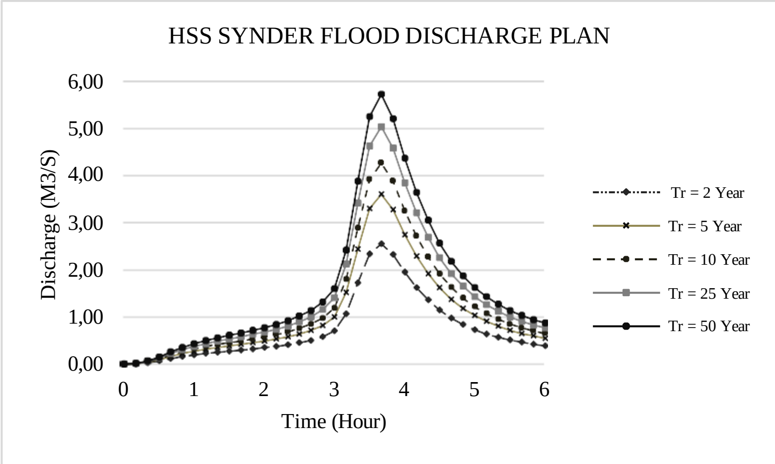

Figure 5: Graph of Flood Discharge Plan in HEC-HMS

The results of the modeling carried out in the form of planned flood discharge and inflow discharge will be a reference in the analysis of water level elevation in the retention pond. Based on the results of HEC-HMS modeling, the maximum peak flood discharge for return periods 2, 5, 10, 25, and 50 is obtained at the peak time of 220 minutes (3.67 hours) of 2.55 m^3/s; 3.60 m^3/s; 4.26 m^3/s; 5.03 m^3/s; 5.72 m^3/s. This planned flood discharge is used as the pool inflow value resulting from the river flood routing process modeled using the Muskingum method.

4. CONCLUSION

The plan flood discharge in the West Jurang Mangu Reservoir watershed for the 2-year return period is 2.55 m^3/s; 5-year return period is 3.599 m^3/s; 10-year return period is 4.261 m^3/s; 25-year return period is 5.033 m^3/s; and 50-year return period is 5.718 m^3/s.

REFERENCES

[1] R. Y. Tallar, *Dasar-Dasar Hidrologi Terapan*, Pertama. Gorontalo: Ideas Publishing, 2023.

[2] TDMRC, *Studi Kelayakan Penanganan Banjir Trumon Aceh Selatan Kerjasama dengan Perguruan Tinggi (Swakelola)*. Aceh: Universitas Syiah Kuala, 2019.

[3] W. Al'amin and Y. Muliati, 'Perencanaan Kolam Retensi Untuk Penanganan Banjir Di Kecamatan Cicendo Kota Bandung', *Rekayasa Sipil*, vol. 17, no. 2, pp. 1978–5658, 2023.

[4] T. Latue and P. C. Latue, 'Pemodelan Spasial Daerah Rawan Banjir di DAS Batu Merah Kota Ambon', *Buana Jurnal Geografi, Ekologi dan Kebencanaan*, vol. 1, no. 1, pp. 1–13, Aug. 2023, doi: 10.56211/buana.v1i1.341.

[5] F. Ramadhan, Y. Amelia, R. Herdianto, & Elvi, and R. Syofyan, 'Analisis Pengendalian Puncak Banjir Menggunakan Kolam Retensi di DAS Batang Air Dingin Kota Padang Analysis of Peak Discharge Control with Retention Ponds At Batang Air Dingin Watershed Padang City', *Jurnal Ilmiah Poli Rekayasa*, vol. 16, no. 1, 2020.

[6] E. Prawati, E. Rolia, and F. Ashiddiqy, 'Analisa Sistem Drainase Terhadap Penanggulangan Banjir Dan Genangan Di Kecamatan Metro Timur – Kota Metro - Lampung', *TAPAK*, vol. 12, no. 1, pp. 2089–2098, 2022, [Online]. Available: http://u.lipi.go.id/1320332466

[7] Dinas SDABMBK, 'Upaya Pemkot Tangsel Mengurangi Titik Banjir Membuahkan Hasil', dsdabmbk.tangerangselatankota.go.id.

[8] M. Amelia R, 'Banjir di Jurangmangu Tangsel Mulai Surut', detikNews.

[9] B. Triatmodjo, *Hidrologi Terapan*, Pertama. Yogyakarta: Beta Offset Yogyakarta, 2008.
[10] I. M. Kamiana, *Teknik Perhitungan Debit Rencana Bangunan Air*, Pertama. Yogyakarta: Graha Ilmu, 2011.
[11] I. Mahdi, 'Intensitas Hujan Tinggi, Pemkot Mitigasi Titik Banjir', tangselpos.id.
[12] M. G. Ishak and R. Herman, *Rekayasa Sungai*, Pertama. Sulawesi Tengah: UNTAD Press, 2020.
[13] A. Salsabila and I. L. Nugraheni, *Penghantar Hidrologi*. Bandar Lampung: AURA CV. Anugrah Utama Raharja, 2020.
[14] L. D. Darmawan, 'Analisis Debit Banjir untuk Pengendalian banjir Kolam Retensi Kemang manis, Kec. Ilir Barat II. palembang', *TEKNO*, vol. 16, 2019.
[15] Indarto, *Hidrologi : Metode Analisis dan Tool untuk Interpretasi Hidograf Aliran Sungai*. Jember: Bumi Aksara, 2016.
[16] V. Te Chow, D. R. Maidment, and L. W. Mays, *Applied Hydrology International Edition 1988*. 1988.
[17] A. Nidya Sari, R. Pranoto, V. Suryan, P. Negeri Sriwijaya, and oliteknik Penerbangan Palembang, 'Perhitungan Hidrograf Banjir dengan Metode Hidrograf Satuan Sintesis SCS (Soil Conservation Service) di Kota Palembang', *Journal of Airport Engineering Technology (JAET)*, vol. 1, no. 1, pp. 1–7, 2020, [Online]. Available: https://e-journal.poltekbangplg.ac.id/index.php/jaet