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Assessing the Performance of PNP Reservoir Based on Short-Term Rainfall Data in the Upper Kuranji Watershed, Padang, Indonesia

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ABSTRACT

This study was conducted to assess the performance of the PNP Reservoir in managing water resources as well as reducing flood risk in the Batu Busuk Sub-watershed, which is located in the upstream part of the Kuranji watershed, Padang City. The uniqueness of this study lies in the comprehensive approach that combines IDF analysis with three methods (Talbot, Sherman, and Ishiguro), flood discharge estimation through the Rational and Nakayasu SUH methods, and modeling of reservoir inflows and outflows using the Muskingum flood routing method. Based on the results of the IDF analysis, the highest rain intensity during the two-hour duration was recorded at 27.22 mm/hour (Talbot), 24.67 mm/hour (Sherman), and 23.49 mm/hour (Ishiguro). Before the reservoir was constructed, the peak flood discharge reached 0.33 m³/sec at 0.35 hours. The simulation results showed that the reservoir was able to reduce the peak discharge by 0.57% and caused a delay in the peak flow of 0.6 minutes. This finding shows that the PNP reservoir contributes positively to flood control, although the efficiency of the reduction is still limited. Overall, the results of this study can serve as an important reference in the design of adaptive reservoirs in areas characterized by steep topography and high rainfall, and emphasize the role of reservoirs as part of sustainable flood mitigation infrastructure in tropical urban areas.

1. Introduction

Reservoir is a structure in the form of a basin designed to store rainwater or surface runoff, and is generally utilized for irrigation, clean water supply, recreational activities, and flood control. As a water resource conservation structure, reservoirs play a role in storing surface runoff and other water sources. A small-scale reservoir is a form of water conservation in the form of a pond or basin that stores runoff water and additional water sources to meet various water needs, with a storage capacity ranging from 500 m³ to 3,000 m³ and a maximum depth from the base to the top of the reservoir of 3 meters [1].

Reservoirs play a strategic role in regulating water flow, reducing flood risk, and increasing water availability in drought-prone areas. In addition, reservoirs also function as rainwater and surface runoff reservoirs, flood control facilities, and important elements in water resource conservation areas [2][3]. This research is focused on the PNP Reservoir located in the Batu Busuk Sub-watershed, upstream of the Kuranji watershed, Padang City, as shown in Figure 1.

Figure 1. PNP Reservoir Batu Busuk Sub-watershed Upper Kuranji Watershed Padang City

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The utilization of retention basins as a means of collecting rainwater has been regulated in Presidential Instruction No. 1/2018 and Circular Letter of the Minister of PUPR No. 07/SE/M/2018 dated May 30, 2018 regarding Guidelines for the Construction of Small Retention Basins and Other Water Retention Buildings in Villages, which are intended to support agricultural activities [1].

Watershed is defined as an area that channels rainwater into the main river and its tributaries [4]. Watersheds include various factors that affect water flow, such as land use, water resource management, and impacts on the environment. Optimal watershed management plays an important role in flood control efforts, preservation of water resources, and ecosystem protection. This research focuses on the utilization of reservoirs as a means of flood control in the Batu Busuk Sub-watershed, which is located in the upstream part of the Kuranji Watershed, Padang City, as shown in Figure 2.

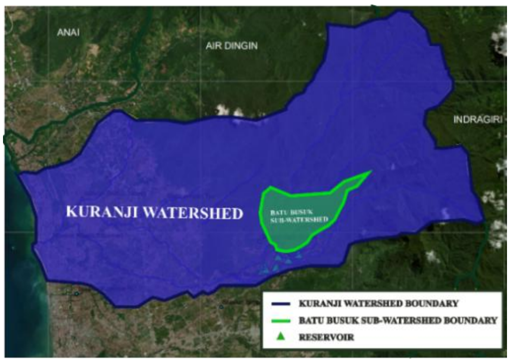

Figure 2. Map of Batu Busuk Sub Das Upper Kuranji Sub Das

Watersheds are understood as areas that have a close relationship between human activities in meeting the needs of life and efforts to preserve the ecosystem. However, this condition often raises environmental problems, where human activities in meeting needs often cause damage to ecosystems. This damage makes watersheds a source of serious environmental problems, which can trigger natural disasters such as landslides, erosion, and floods [5].

PNP Reservoir, located in Batu Busuk Sub-watershed, Upper Kuranji Watershed, Padang City, West Sumatra Province, is located in an area with high rainfall and mountainous topography. In addition, regional geological conditions in some locations show the presence of many faults. This situation affects the geohydraulics dynamics of the rivers in the province and causes considerable water damage potential [6]. Rivers with these natural characteristics are prone to natural disasters such as cliff avalanches, flash floods, and inundation due to flooding, which can threaten the safety of communities around the riverbanks.

As part of an important water resources infrastructure, Reservoir PNP in the Batu Busuk Sub-watershed of the Upper Kuranji Watershed has a catchment area that functions to collect rainwater before it is channeled into the reservoir. This catchment area includes a variety of land cover, including forests, agricultural land, as well as the surrounding urban areas. The existence of the reservoir in this strategic location is supported by detailed mapping of the catchment area characteristics, as shown in Figure 3, which makes it a key factor for the survival of the communities in the area.

Figure 3. Catchment Area Map and PNP Reservoir Location

2. Research Methods

Following the overall analytical workflow, which included reservoir storage capacity analysis, rainfall IDF analysis, and flood hydrograph estimation, the final step involved flood routing simulation. This phase aimed to assess the effectiveness of the PNP Reservoir in reducing peak flood discharge and delaying the peak flow time at the outlet before the runoff continues toward the river mouth. The Muskingum method was employed to model the relationship between inflow and outflow within the Batu Busuk Sub-watershed segment of the Upper Kuranji watershed. The flood routing scheme of the reservoir network in the area can be seen in Figure 4.

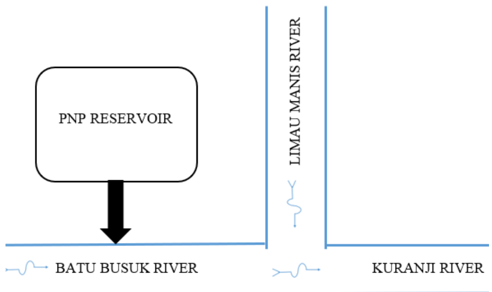

Figure 4. Flood Routing Scheme of PNP Reservoir

2.1 Research Stages

In accordance with the flood routing framework, a comprehensive and systematic series of analytical steps was implemented to evaluate the performance of the PNP Reservoir in mitigating flood risks. This evaluation employed an integrated hydrological and hydraulic approach, beginning with the acquisition of critical field data. The data collection phase involved precise rainfall measurements using calibrated rain gauges, dimensional surveying of the reservoir structure with a theodolite, and spatial mapping of the catchment area through satellite-based tools such as Google Earth. These foundational datasets were crucial for establishing an accurate representation of the physical and environmental characteristics of the study site.

Subsequently, the reservoir's water storage capacity was assessed through the contour method, which allowed for detailed volumetric analysis by calculating the surface area of each reservoir section and the elevation intervals between them. This technique yielded an estimate of the reservoir's maximum holding volume prior to the onset of surface runoff, serving as a baseline for assessing its capacity under extreme rainfall scenarios.

Parallel to this, a multi-method rainfall intensity analysis was conducted using empirical models—Talbot, Sherman, and Ishiguro—to gain a nuanced understanding of short-duration rainfall behavior in the region. The resulting intensity data were integrated with land-use parameters including surface cover types, soil characteristics, and slope gradients to estimate peak discharge values. Two established hydrological approaches were utilized for this purpose: the Rational Method, suitable for urbanized and impervious surfaces, and the Synthetic Unit Hydrograph (SUH) of Nakayasu, which models the catchment's temporal response to rainfall events.

In the final analytical phase, the Muskingum method was applied to simulate flood routing processes, focusing on the temporal and quantitative relationship between inflow and outflow within the reservoir system. This hydrologic routing model facilitated an evaluation of the reservoir's effectiveness in attenuating peak discharges and delaying peak flow timing. Such metrics are pivotal in determining the structure's functionality as a flood mitigation measure. The entire analytical workflow is encapsulated in a process flow diagram, as illustrated in Figure 5.

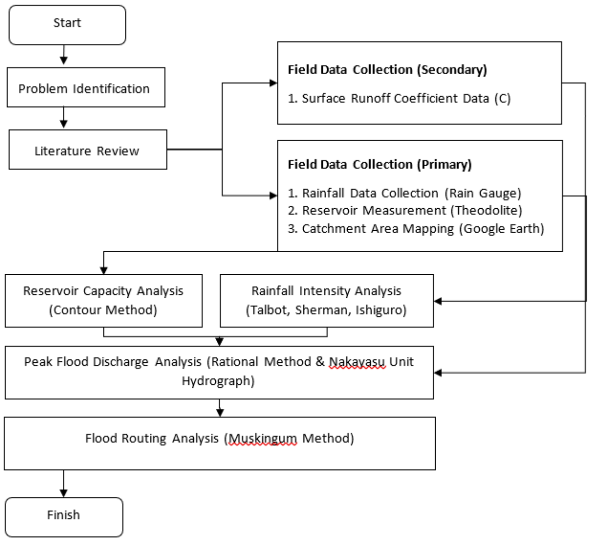

Figure 5. Flowchart of PNP Reservoir Flood Routing Process

2.2 Data Collection Process

As a first step in supporting the flood routing analysis of the reservoir system, a comprehensive data collection activity was conducted. The data collected included detailed information on the geographical location of the reservoir, including coordinates and surrounding topographical conditions, which was useful for understanding the hydrological characteristics of the catchment area. In addition, rainfall data was also collected as an important component in the calculation of inflow discharge to the reservoir. This rainfall data is obtained through direct observation in the field using a rain gauge, and determines the accuracy of the peak flood discharge estimation that will be used in the flood routing modeling simulation.

The location of the PNP Reservoir in the Batu Busuk Sub-watershed of the Upper Kuranji Watershed, Padang City, was determined so that it could be identified on Google Earth. In addition, understanding the location of the reservoir to be studied is important for understanding the surrounding environmental conditions and planning appropriate steps in dealing with potential flooding. The coordinates of the reservoir locations are presented in Table 1.

The rainfall data used in this analysis was obtained through measurements using a rain gauge installed at the PNP Reservoir location. Observations were made on Tuesday, January 21, 2025, with a rain duration of 2 hours, from 09:30 to 11:30. The rainfall data can be seen in Table 2.

Table 1. PNP Reservoir location coordinates

Infrastructure	Coordinates	
	E	S
PNP Reservoir	100°28'5.93 "E	0°54'48.58 "S

Table 2: Rainfall data

Time (minutes)	Rainfall intensity (mm/minutes)	Cumulative Rainfall (mm)
0	0.00	0.00
5	2.00	2.00
10	3.00	5.00
15	3.00	8.00
20	2.00	10.00
25	2.00	12.00
30	3.00	15.00
35	3.00	18.00
40	4.00	22.00
45	3.00	25.00
50	3.00	28.00
55	3.00	31.00
60	4.00	38.00
65	3.00	39.00
70	2.00	40.00
75	1.00	41.00
80	1.00	42.00
85	1.00	43.00
90	1.00	44.00
95	1.00	45.00
100	1.00	46.00
105	1.00	47.00
110	1.00	48.00
115	2.00	50.00
120	2.00	52.00

2.3 Reservoir Capacity

The estimation of storage capacity of the reservoirs is currently done using the topographic method, which allows the calculation of storage volume (in cubic meters) based on spatial data and available parameters. Measuring the depth of the reservoir was done directly using a theodolite, as the depth was within the reach of the tool. This method differs from some similar studies that used bathymetric surveys to measure the depth of the reservoir. The data obtained was then processed using the contour method so that the storage volume of the reservoir could be calculated using Equation 1.

$$V = \Delta H \, (n-1) \frac{\sum_{i=1}^{n} Li}{n} \tag{1}$$

Where V is the volume of reservoir (m³/sec), ΔH is the contour interval (m), n is the number of contour lines, and L_i is inundation area at the i-th contour line (m²).

2.4 Short-term Rainfall Intensity

Short-term rainfall data with durations of 5 minutes, 10 minutes, 30 minutes, 60 minutes, and hours are used to construct intensity-duration-frequency (IDF) curves [7][8][9][10][11][12][13][14]. This type of data can only be obtained from rain gauge station. Based on the short-term rainfall data, the IDF curve is analyzed using one of this following empirical approach, namely Talbot, Sherman, and Ishiguro.

The Talbot method is an empirical approach often used to calculate short-term rainfall intensity, as it is able to practically describe the relationship between rainfall intensity and duration. Talbot (1881) developed this method which is popular for its ease of application, with a and b being obtained from measured values [8][11][15]. The Talbot method calculation is performed using Equation 2 to Equation 4.

$$I = \frac{a}{t+b} \tag{2}$$

$$a = \frac{[\Sigma(I.t)]\,[\Sigma(I^2)] - [\Sigma(I^2.t)][\Sigma(I)]}{N[\Sigma(I^2)] - [\Sigma(I)][\Sigma(I)]} \tag{3}$$

$$b = \frac{[\Sigma(I)]\,[\Sigma(I.t)] - N\,[\Sigma(I^2.t)]}{N[\Sigma(I^2)] - [\Sigma(I)][\Sigma(I)]} \tag{4}$$

Where I is the rainfall intensity (mm/h), t is the rain duration (hour), a and b is the constant, and N is the number of data.

The Sherman method is an empirical method developed by Sherman (1905) to calculate rainfall intensity, which is considered appropriate for rainfall periods with a minimum duration of 2 hours [8][11][15]. The Sherman method calculation is performed using Equation 5 to Equation 7.

$$I = \frac{a}{t^n} \tag{5}$$

$$\log a = \frac{[\Sigma(\log I)]\,[\Sigma((\log t)^2)] - [\Sigma\,(\log t\,.\,\log I)][\Sigma(\log t)]}{N[\Sigma((\log t)^2)] - [\Sigma(\log t)][\Sigma(\log t)]} \tag{6}$$

$$n = \frac{[\Sigma(\log I)]\,[\Sigma(\log t)] - N\,[\Sigma(\log t\,.\,\log I)]}{N[\Sigma((\log t)^2)] - [\Sigma(\log t)][\Sigma(\log t)]} \tag{7}$$

Where I is the rainfall intensity (mm/h), t is the rain duration (hour), a, b, and n is the constant, and N is the number of data.

The Ishiguro method, developed by Ishiguro (1953), includes empirical methods for calculating rainfall intensity and is considered appropriate for short-duration rainfall [8][11][15]. The calculation of the Ishiguro method is done using Equation 8 to Equation 10.

$$I = \frac{a}{\sqrt{t}+b} \quad (8)$$

$$a = \frac{[\Sigma(I.\sqrt{t})][\Sigma(I^2)] - [\Sigma(I^2.\sqrt{t})][\Sigma(I)]}{N[\Sigma(I^2)] - [\Sigma(I)][\Sigma(I)]} \quad (9)$$

$$b = \frac{[\Sigma(I)][\Sigma(I.\sqrt{t})] - N[\Sigma(I^2.\sqrt{t})]}{N[\Sigma(I^2)] - [\Sigma(I)][\Sigma(I)]} \quad (10)$$

Where I is the rainfall intensity (mm/h), t is the rain duration (hour), a, b, and n is the constant, and N is the number of data.

2.5 Flood Discharge

After rainfall intensity data is obtained from various methods, the next step is to calculate the peak flood discharge arising from the rainfall. This calculation is important to determine the amount of flow into the reservoir which will then be used in the flood routing process.

In this study, rainfall–runoff transformation is conducted using the rational and unit hydrograph method. The rational method is a simple approach to estimate peak surface runoff discharge by considering rainfall intensity, runoff coefficient, and catchment area. The calculation of surface flow discharge can be done through the rational method [16][17]. Equation 11 is used to calculate runoff using rational method.

$$Qp = 0.278.C.I.A \quad (11)$$

Where Q_p as the peak flood discharge (m³/sec), C as the runoff coefficient, I as the rainfall intensity during the concentration time (mm/hour), and A as the catchment area (km²)

The unit hydrograph describes the outflow from a catchment area in response to evenly distributed rainfall over a certain period, influenced by catchment characteristics, rainfall intensity, and the shape of the canal or stream network. In this study, the method used is the Nakayasu SUH, which is commonly used to estimate flood discharge in a watershed. Watershed width and design rainfall are the main factors in calculating the design flood rate according to the Nakayasu SUH method [18][19][20][21][22]. The calculation of Nakayasu uses Equation 12.

$$Qp = \frac{A.R_0}{3{,}6\,(0{,}3\,T_p + T_{0{,}3})} \quad (12)$$

Where Q_p as the peak flood discharge (m³/sec), R as the rainfall unit, T_p as the rainfall intensity during the concentration time (mm/hour), $T_{0.3}$ as the time required for the discharge to decrease 0.3 of peak.

2.6 Flood Routing

The Muskingum method is one of the flood routing techniques used to estimate outflow based on inflow and outflow at a previous time [23]. Developed by McCarthy in 1938, this method is widely used in hydrological studies to model water flow in open channels, such as rivers and canals. In this research, the Muskingum method is applied to calculate flood routing in reservoirs. The calculation uses Equation 13 to Equation 16.

$$C_0 = \frac{-KX+0.5\Delta t}{K-KX+0.5\Delta t} \quad (13)$$

$$C_1 = \frac{KX+0.5\Delta t}{K-KX+0.5\Delta t} \quad (14)$$

$$C_2 = \frac{K-0.5\Delta t}{K-KX+0.5\Delta t} \quad (15)$$

$$Q_{out,t+1} = C_0 I_{t+1} + C_1 I_t + C_2 O_t \quad (16)$$

Where Q_p represent the peak flood discharge (m³/sec), $Q_{out,t+1}$ as the discharge outflow at time $t+1$, I_t as the inflow discharge at time t, I_{t+1} as the inflow discharge at time $t+1$, O_t as the discharge outflow at time t, Δt as the time interval between two observations, K as the storage constant, X as the flow weighting factor, C_0, C_1, C_2 as the routing coefficient.

In order to make the calculation using the Muskingum method more accurate, a flow coefficient (C) value is required that reflects the surface runoff characteristics of the land type being analyzed. This coefficient is an important element in determining the amount of runoff discharge entering the system, and is obtained based on the land use classification as shown in Figure 6.

2.7 Flood routing of PNP reservoirs

The flood routing process involving the Reservoir aims to measure the ability of the Reservoir to reduce the magnitude of the peak flood discharge while delaying the time of the peak discharge at the outlet point, before the water flows to the river mouth in the Reservoir system in the Batu Busuk Sub-watershed PNP area, Upper Kuranji Watershed, Padang City.

Land cover	C	Land cover	C
Business		**Lawns, sandy soil**	
Downtown	0.70 – 0.95	Flat, 2 %	0.05 – 0.1
Neighborhood	0.50 – 0.70	Average, 2 % –7 %	0.1 – 0.15
Residential		Steep, > 7 %	0.15 – 0.20
Single-family	0.30 – 0.50	**Lawns, heavy soil**	
Multiunits, detached	0.40 – 0.60	Flat, 2 %	0.17 – 0.17
Multiunits, attached	0.60 – 0.75	Average, 2 % – 7 %	0.18 – 0.22
Residential (suburban)	0.25 – 0.4	Steep, > 7 %	0.25 – 0.35
Industrial		**Agricultural area**	
Light	0.50 – 0.80	Open land	
Heavy	0.60 – 0.90	Flat	0.30 – 0.60
Parks, cemeteries	0.10 – 0.25	Rough	0.20 – 0.50
Playground	0.20 – 0.35	**Cultivated area**	
Railroad yard	0.20 – 0.35	Heavy soil, no vegetation	0.30 – 0.60
Unimproved	0.10 – 0.30	Heavy soil, vegetation	0.20 – 0.50
Pavements		Sandy soil, no vegetation	0.20 – 0.25
Asphalt	0.70 – 0.85	Sandy soil, vegetation	0.10 – 0.25
Concrete	0.70 – 0.95	**Meadow**	
Stone/brick	0.70 – 0.85	Heavy soil	0.15 – 0.45
Pedestrian	0.75 – 0.85	Sandy soil	0.05 – 0.25
Roofs	0.75 – 0.95	Forest, vegetation	0.05 – 0.25
		Bare land	
		Flat, impervious	0.70 – 0.90
		Rough	0.50 – 0.70

Figure 6. Flow Coefficient Table (C) [24]

3. Results and Discussion

This section presents the results of the analysis based on the field data and methods previously described. The analysis includes calculations of reservoir storage capacity, rainfall intensity using three methods (Talbot, Sherman, and Ishiguro), flood discharge hydrographs using the Rational and Nakayasu SUH method approaches, and flood routing to assess the effectiveness of the reservoir in reducing and delaying peak flood discharge.

3.1 Reservoir Capacity

The calculation of the reservoir capacity was carried out using the contour method (1), which is based on the area of each reservoir segment and the value of the elevation interval used. Details of the number of segments, areas, and intervals used to calculate the capacity of the reservoir can be seen in Table 3. The storage volume is calculated using the contour formula, where n indicates the number of segments, Li is the area of each segment, and ΔH is the elevation difference between contours. Based on the available data, with two sections, an average area of 1,063.50 m², and an elevation interval of 4.55 meters, the storage capacity of the reservoir was 2,418.14 m³.

Table 3. Reservoir Capacity

Section	Area (m^2)	Volume (m^3)
1	1,153.38	2,418.14
2	973.62	
Average		1,063.50

3.2 Short-term Rainfall Analysis of PNP Reservoir

Rainfall intensity calculations were conducted using the Talbot, Sherman and Ishiguro methods, which require a minimum duration of two hours. Therefore, the highest rainfall intensity data can only be taken in the two-hour time span. This study examines short-term rainfall at the PNP reservoir, Batu Busuk Hulu Sub-watershed, Kuranji Watershed, Padang City. Rainfall data obtained from the field was then analyzed using the Talbot method, and the results are presented in Table 4.

The IDF curve in Figure 7 displays the results of the calculation of rainfall intensity using the Talbot method. The value of 27.22 mm/hour indicates the intensity of rainfall with a duration of two hours that occurred on January 21.

Table 4. Talbot Method Rainfall Intensity (Jan - Feb)

Time	Rainfall Intensity (mm/hour)								
	21/01	25/01	26/01	27/01	28/01	29/01	31/01	02/02	03/02
5	37.14	106.24	2.04	13.71	0.03	3.40	0.43	0.13	0.42
10	36.56	85.57	1.78	10.74	0.03	2.96	0.40	0.11	0.37
15	36.00	71.63	1.59	8.83	0.03	2.62	0.36	0.10	0.33
30	34.41	48.11	1.19	5.76	0.02	1.95	0.29	0.08	0.25
45	32.96	36.22	0.95	4.27	0.02	1.55	0.25	0.07	0.20
60	31.63	29.04	0.79	3.40	0.02	1.29	0.21	0.06	0.17
120	27.22	16.20	0.48	1.86	0.01	0.77	0.14	0.04	0.10
180	23.89	11.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00
360	17.48	5.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00
720	11.37	2.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5. Sherman Method Rainfall Intensity (Jan - Feb)

Time	Rainfall Intensity (mm/hour)								
	21/01	25/01	26/01	27/01	28/01	29/01	31/01	02/02	03/02
5	34.49	17.36	0.63	0.71	0.61	0.57	0.69	0.62	0.82
10	32.06	17.34	0.42	0.47	0.43	0.36	0.51	0.44	0.68
15	30.72	17.32	0.33	0.37	0.35	0.28	0.44	0.36	0.61
30	28.55	17.30	0.22	0.24	0.25	0.18	0.33	0.26	0.51
45	27.36	17.28	0.18	0.19	0.20	0.13	0.28	0.22	0.46
60	26.54	17.27	0.15	0.16	0.18	0.11	0.25	0.19	0.42
120	24.67	17.25	0.10	0.10	0.13	0.07	0.18	0.14	0.35
180	23.63	17.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
360	21.97	17.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
720	20.42	17.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00

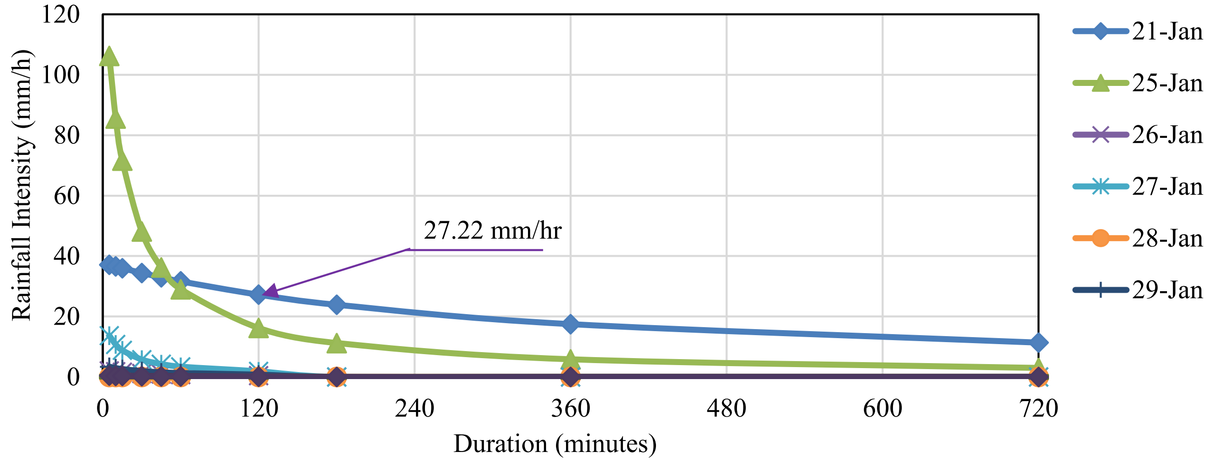

Figure 7. Talbot Method IDF Curve

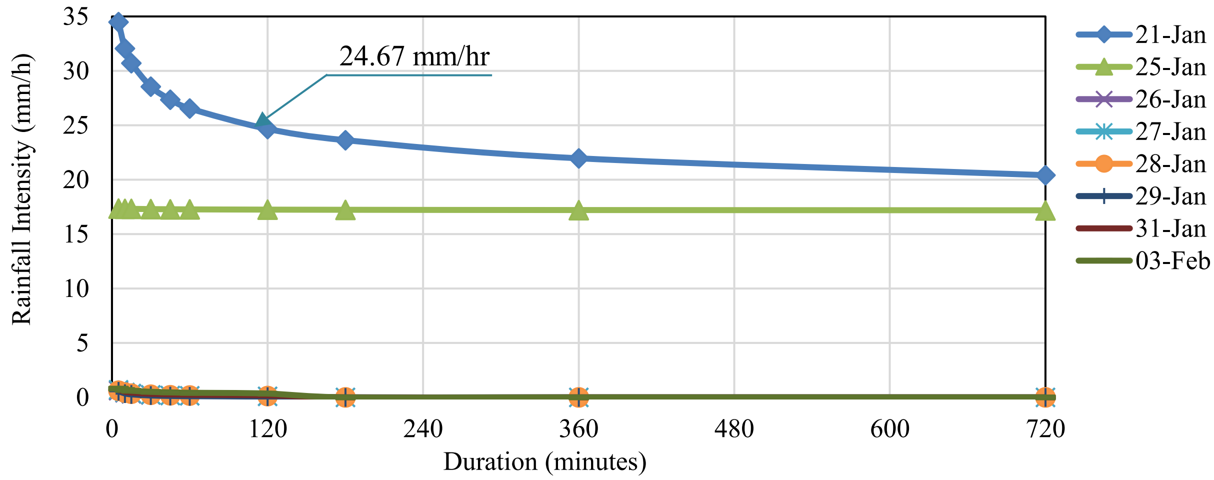

Figure 8. Sherman Method IDF Curve

The rainfall data collected in the field was then analyzed using the Sherman method, resulting in the rainfall intensity table presented in Table 5. The results of this analysis show that the Sherman method provides a description of rainfall intensity at a given duration with values suitable for rainfall periods of more than two hours, so it can be used as a basis in the calculation of runoff discharge and water management planning in the study area.

The IDF curve in Figure 8 shows the results of the calculation of rainfall intensity based on the Sherman method. The rainfall intensity for two hours on January 21 was recorded at 24.67 mm/hour.

Rainfall data collected in the field was then analyzed using the Ishiguro method, resulting in the rainfall intensity table listed in Table 6. This analysis shows that the Ishiguro method is effective for calculating short-duration rainfall intensity, providing an accurate picture of local rainfall patterns that play an important role in water resource management planning and flood mitigation in the reservoir area.

Based on Figure 9, the IDF curve illustrates the results of the calculation of rainfall intensity using the Ishiguro method. On January 21, the rainfall intensity for two hours was recorded at 23.49 mm/hour.

To compare the results of the three methods of calculating rainfall intensity for two hours on January 21 — Talbot (27.22 mm/h), Sherman (24.67 mm/h), and Ishiguro (23.49 mm/h) — the three curves from each method are combined and presented in Figure 10. This specific date was selected because the recorded rainfall data on January 21 represented the highest rainfall event compared to other days, thus producing the highest rainfall intensity values, which are suitable for analysis and comparison purposes.

Table 6. Ishiguro Method Rainfall Intensity (Jan - Feb)

Time	Rainfall Intensity (mm/hour)								
	21/01	25/01	26/01	27/01	28/01	29/01	31/01	02/02	03/02
5	55.77	0.78	0.61	3.67	0.13	0.90	0.90	0.90	0.90
10	48.66	0.72	0.57	3.15	0.12	0.79	0.79	0.79	0.79
15	44.33	0.69	0.50	2.85	0.11	0.73	0.73	0.73	0.73
30	36.91	0.62	0.42	2.34	0.10	0.62	0.62	0.62	0.62
45	32.71	0.57	0.38	2.05	0.09	0.56	0.56	0.56	0.56
60	29.84	0.57	0.35	1.86	0.08	0.51	0.51	0.51	0.51
120	23.49	0.46	0.28	1.45	0.07	0.41	0.41	0.41	0.41
180	20.19	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00
360	15.33	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
720	11.43	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00

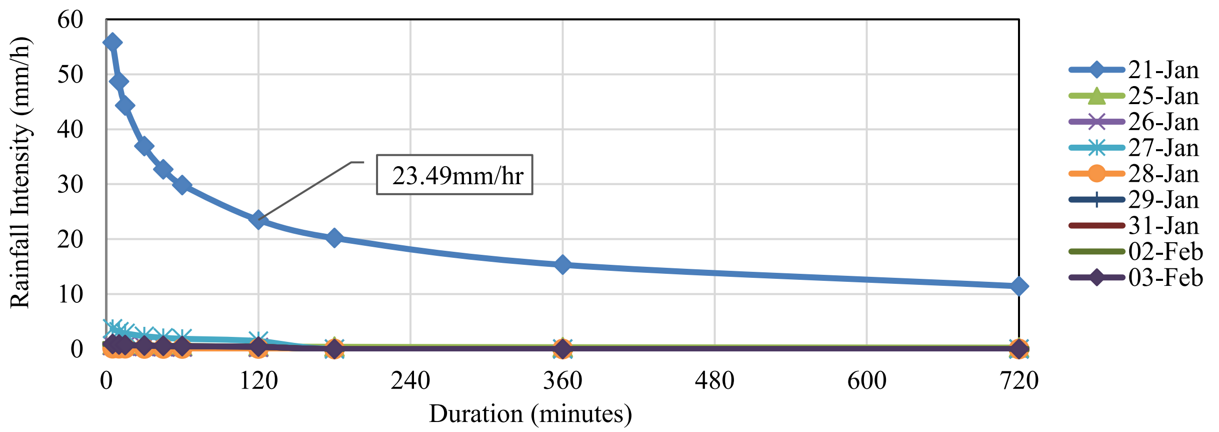

Figure 9. IDF (Intensity, Duration, Frequency) Curve of Ishiguro Method

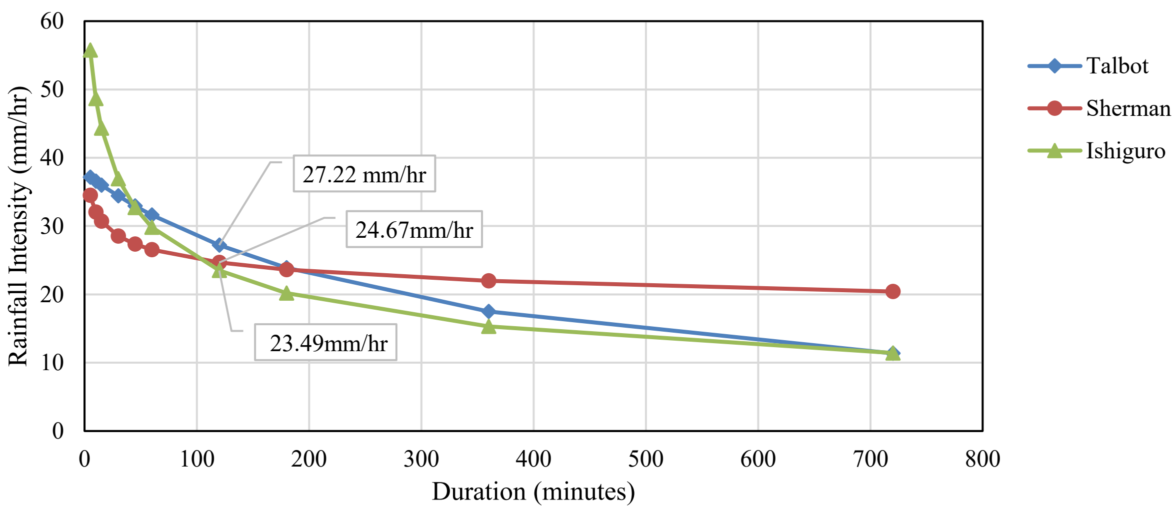

Figure 10. IDF Curve of All Methods

3.3 Flood Discharge Hydrograph

The field data collected was then analyzed to determine the flood discharge hydrograph of the $Q_{(PNP)}$ (Q Politeknik Negeri Padang) Reservoir system. The analysis focused on the critical duration of 0.5 hours, which represents the initial response of the system to rainfall intensity. Data analyzed included flow discharge (Q_t), correction discharge, and actual discharge Q_{PNP}. The highest discharge was recorded in the time range between 0.49 to 0.50 hours, with a discharge value Q_{PNP} of 2.247-2.27 m³/s. This value represents the peak surface runoff resulting from the combination of rainfall and hydrological characteristics of the catchment.

The analysis was conducted using two main approaches. First, the Rational method produced a maximum discharge of 2.247 m³/s at a duration of 0.5 hours. This value became the reference for calculating the Reservoir inflow which was then compared with the outflow to assess the effectiveness of the Reservoir in reducing the flood peak. Secondly, analysis using the Nakayasu SUH method showed a maximum correction discharge value of 0.064 m³/s at the same duration. This correction discharge was used to estimate the system response to the flood event. The flood discharge hydrograph table can be seen in Table 7.

The results of data analysis with the Rational method are shown in the flood discharge hydrograph in Figure 11. At a duration of 0.5 hours, the Q_{PNP} discharge was recorded at 2.247 cubic meters per second (m³/s). This value is used as a reference for inflow in the analysis and comparison with outflow to assess the capacity and performance of flow regulation in the QPN reservoir system.

The results of data analysis with the Nakayasu SUH method produced a flood discharge hydrograph graph as shown in Figure 12. At a duration of 0.5 hours, a correction discharge value of 0.064 cubic meters per second (m³/s) was recorded.

Table 7. Flood discharge hydrograph

Time (Hours)	Q_t (m³/s)	$Q_{Correction}$ (m³/s)	Q_{PNP} (m³/s)
0	0	0.000	0.000
0.250	0.065	0.012	0.441
0.495	0.332	0.064	2.268
0.500	0.69	0.064	2.247
0.750	0.215	0.042	1.468
1.000	0.140	0.027	0.959
1.201	0.100	0.019	0.680
1.250	0.094	0.018	0.644
1.500	0.071	0.014	0.485
1.750	0.053	0.010	0.365
2.000	0.040	0.008	0.275
2.261	0.030	0.006	0.204
Total Q (m³/s)	1.469	0.284	
VLL (m³)	5,289.7	1,022.2	
TLL (mm)	5.2	1	

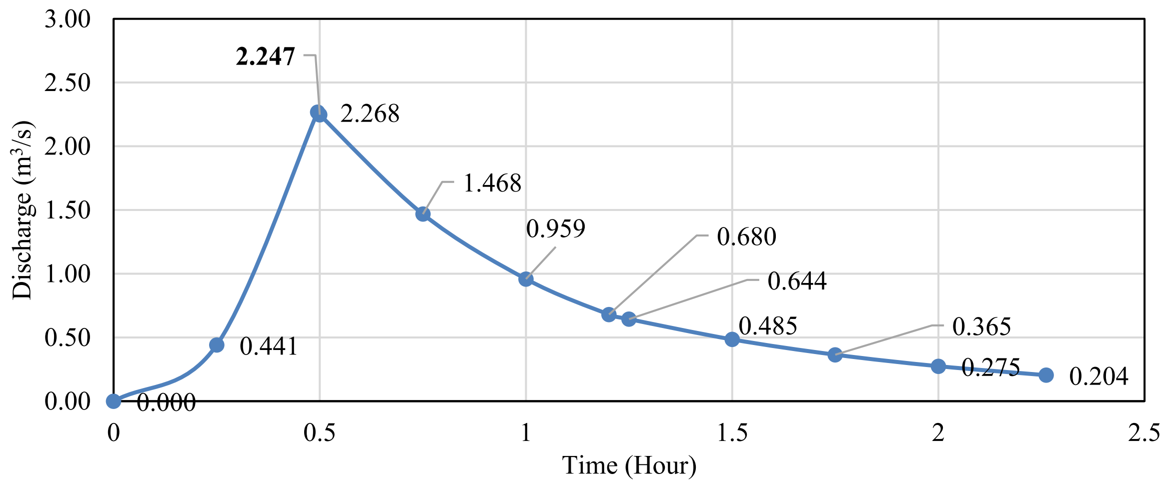

Figure 11: Flood discharge hydrograph of PNP Reservoir by rational method

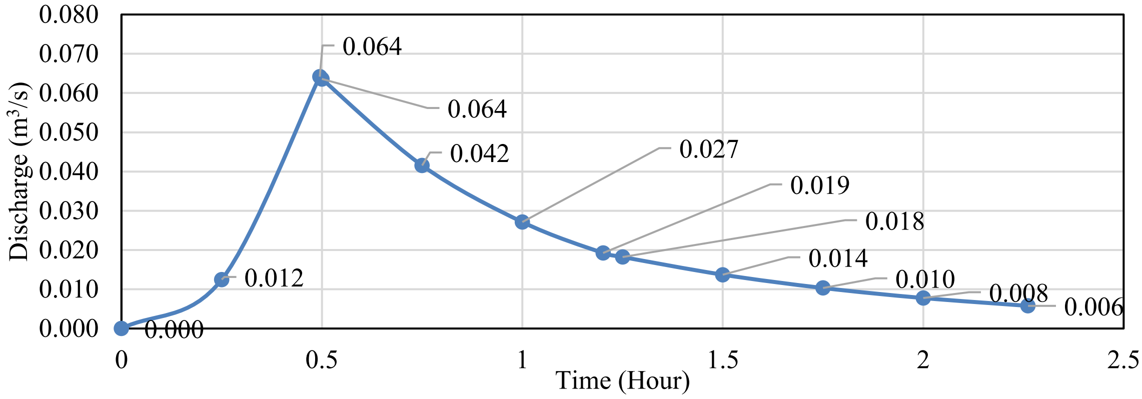

Figure 12. Nakayasu Synthetic Unit Hydrograph of PNP Reservoir

The outflow value of the PNP reservoir was calculated using the Muskingum method, which is a hydrologic routing method that estimates outflow discharge based on inflow discharge and flow storage characteristics. The calculation is done iteratively over time, starting from time zero. At hour 0.50, the reservoir inflow (I_2) was recorded as 2.247 m³/s, the previous inflow (I_1) as 1.36 m³/s, and the previous outflow (O_1) as -0.45 m³/s. After multiplying by the respective coefficients, namely C_0 = 1.35; C_1 = 1.36; and C_2 = -0.45, an outflow value (Q_2) of 2.26 m³/s was obtained as can be seen in Table 8.

Table 8. Inflow and Outflow of PNP Reservoir

Time (Hours)	$Q_{(PNP)}$ (Inflow) (m³/s)	C_0I_2 (Hours)	C_1I_1 (m³/s)	C_2O_1 (m³/s)	$Q_{(2)}$ (Outflow) (m³/s)
0.00	0.00	-	-	-	0.00
0.25	0.44	0.26	0.00	0.00	0.26
0.49	2.27	1.36	0.26	-0.09	1.54
0.50	2.247	1.35	1.36	-0.45	2.26
0.75	1.47	0.88	1.35	-0.45	1.78
1.00	0.96	0.58	0.88	-0.29	1.16
1.20	0.68	0.41	0.58	-0.19	0.79
1.25	0.64	0.39	0.41	-0.14	0.66
1.50	0.48	0.29	0.39	-0.13	0.55

The outflow value at the PNP reservoir was recorded at 2.26 cubic meters per second (m³/s) which occurred at 0.50 hours, at the same time as the peak inflow discharge. In general, the inflow showed higher values than the outflow at the beginning of the flood event, for example at 0.25 and 0.49 hours. However, this condition changes after the peak discharge is reached. After the Reservoir holds a sufficient volume of water, the water begins to flow back gradually.

As a result, the outflow value becomes greater than the inflow in the next period, which is between hour 0.75 to 1.50. This phenomenon illustrates the basic principle of flood routing, whereby the Reservoir functions to hold the peak discharge while managing the release of outflow in a controlled manner to reduce the risk of flooding downstream. The comparison between inflow and outflow shows the effectiveness of the Reservoir in regulating the distribution of water flow and indicates that the Reservoir's storage capacity is adequate to reduce peak discharge surges. A more detailed explanation of this comparison can be seen in Figure 13.

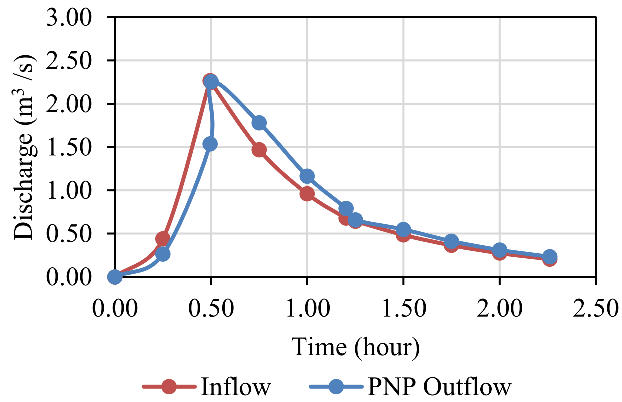

Figure 13. Inflow and Outflow Hydrograph of PNP Reservoir

It is acknowledged that the calculated outflow at 0.50 hours (2.26 m³/s) slightly exceeds the inflow (2.247 m³/s). This discrepancy arises due to the numerical nature of the Muskingum method, which utilizes a weighted combination of inflow and outflow values at previous time steps. The negative value in the C_2O_1 component at that time step (-0.45) contributed to a higher calculated outflow, even though the reservoir functions as a detention facility. This result does not necessarily indicate failure in reducing flood peaks, but rather reflects a minor modeling artifact resulting from parameter sensitivity and discretization. When viewed as a whole, the hydrograph still shows a clear attenuation and temporal delay of the flood peak, confirming the reservoir's regulating role

The reduction in peak flood discharge was calculated from the difference between the maximum inflow value of

2.247 m³/s at hour 0.50 and the peak outflow discharge that occurred thereafter. This value then analyzed as a percentage decrease in the peak inflow discharge, resulting in a reduction of 0.57%. This shows the ability of the reservoir to reduce the peak flow rate through temporary storage.

The peak discharge delay is obtained from the time difference between the inflow peak (at hour 0.50) and the time when the peak outflow discharge is reached, which is 0.6 minutes. Thus, the reservoir is not only able to reduce peak discharge, but also delay the occurrence of flood peaks. These two parameters are important indicators in assessing the effectiveness of the reservoir as a means of flood control, which are summarized in Table 9.

Table 9. Decrease and Delay in Peak Discharge of PNP Reservoir

No.	Rational Inflow (m^3/s)	Muskingum Outflow (m^3/s)	Reduction
1	2.247	2.26	0.57%
	Inflow Peak Time (hours)	Outflow Peak Time (hours)	Delay
2	0.49	0.50	0.6

4. Conclusions

Based on the results of the analysis of short-term rainfall data at Reservoir PNP Batu Busuk Sub-watershed Upper Kuranji Watershed, Padang City, it can be concluded that the three rainfall intensity calculation methods, namely Talbot (27.22 mm/hour), Sherman (24.67 mm/hour), and Ishiguro (23.49 mm/hour), provide relatively consistent values with insignificant variations. The Reservoir proved to be able to reduce the peak flood discharge by 0.57% and delay the peak flow time by 0.6 minutes through the flood routing process.Simulations using the Rational and Nakayasu SUH methods show the important role of the Reservoir in flood control in the area, although the peak discharge reduction is still relatively small. This finding suggests that the reservoir configuration can be used as a reference model in water resources management in tropical urban areas with intense and evenly distributed rainfall characteristics, as is the case in West Sumatra. Therefore, the reservoir not only functions as a water reservoir, but also as a flood mitigation infrastructure that supports environmental sustainability and the sustainability of the hydrological system in the watershed.

References

[1] Ministry of Public Works and Housing, *Pedoman Pembangunan Embung Kecil dan Bangunan Penampung Air Lainnya di Desa*, Surat Edaran Menteri PUPR. Jakarta, Indonesia, 2018.

[2] A. R. Aditiya, V. Dermawan, and R. Asmaranto, "Studi perencanaan embung sebagai upaya pengendalian banjir Sungai Kemuning Kabupaten Sampang Madura Provinsi Jawa Timur," Jurnal Teknologi dan Rekayasa Sumber Daya Air, vol. 3, no. 2, pp. 26–39, 2023, doi: 10.21776/ub.jtresda.2023.003.02.03.

[3] H. A. Utami, G. S. Nalendra, Sriyana, and P. N. P., "Perencanaan Embung Somosari di Jepara," Jurnal Karya Teknik Sipil, vol. 4, no. 4, pp. 529–537, 2015.

[4] K. D. Pertiwi and I. P. Lestari, "Kualitas mutu perairan Sub DAS Kaligarang Desa Gogik ditinjau dari parameter nitrat, BOD, COD, dan DO," Pro Health Jurnal Ilmiah Kesehatan, vol. 4, no. 2, pp. 274–279, 2022, doi: 10.35473/prohealth.v4i2.1816.

[5] R. T. Palar, L. Kawet, E. M. Wuisan, and H. Tangkudung, "Studi perbandingan antara hidrograf SCS (Soil Conservation Service) dan metode rasional pada DAS Tikala," Jurnal Sipil Statik, vol. 1, no. 3, pp. 171–176, 2013.

[6] E. R. Syofyan, A. S., B. I., and R. H., "Model hidrograf akibat perubahan tata guna lahan DAS Batang Kuranji (studi kasus Sub DAS Danau Limau Manis)," Jurnal Ilmiah Poli Rekayasa, vol. 13, no. 1, pp. 1–8, 2017, doi: 10.30630/jipr.13.1.46.

[7] A. Kumar, S. Bora, N. Sharma, and S. Singh Bisht, "A study on the influences of rainfall on agriculture using the IDF curve," International Journal for Research in Applied Sciences and Biotechnology, vol. 9, 2022.

[8] A. M. Takeleb, Q. R. Fajriani, and M. A. Ximenes, "Determination of rainfall intensity formula and intensity-duration-frequency (IDF) curve at the Quelicai administrative post, Timor-Leste," Journal of Engineering and Science, vol. 3, no. 1, pp. 1–11, 2022.

[9] H. V. T. Minh et al., "Developing intensity-duration-frequency (IDF) curves based on rainfall cumulative distribution frequency (CDF) for Can Tho City, Vietnam," Earth, vol. 3, no. 3, pp. 866–880, 2022, doi: 10.3390/earth3030050.

[10] M. S. Shamkhi, M. K. Azeez, and Z. H. Obeid, "Deriving rainfall intensity-duration-frequency (IDF) curves and testing the best distribution using EasyFit software 5.5 for Kut City, Iraq," Open

Engineering, vol. 12, no. 1, pp. 834–843, 2022, doi: 10.1515/eng-2022-0330.

[11] M. G. Sam et al., “Modeling rainfall intensity-duration-frequency (IDF) and establishing climate change existence in Uyo, Nigeria using non-stationary approach,” Journal of Water Resource and Protection, vol. 15, no. 5, pp. 194–214, 2023, doi: 10.4236/jwarp.2023.155012.

[12] R. Mínguez and S. Herrera, “Spatial extreme model for rainfall depth: application to the estimation of IDF curves in the Basque Country,” Stochastic Environmental Research and Risk Assessment, vol. 37, no. 8, 2023, doi: 10.1007/s00477-023-02440-1.

[13] S. K. Al-Jalili, H. M. Zwain, and A. M. Hayder, “Generating rainfall IDF curves using IMD reduction formula and choosing the best distribution for Babylon City, Iraq,” Engineering Reports, 2024, doi: 10.1002/eng2.13053.

[14] M. B. Ansori, U. Lasminto, and A. A. G. Kartika, “Runoff hydrograph analysis of HEC-RAS 2D flow hydrodynamics meteorological rain-on-grid on observed watershed,” International Journal on Advanced Science, Engineering and Information Technology, vol. 14, no. 2, pp. 575–581, 2024.

[15] P. Khansa, E. S. Sofiyah, and I. W. K. Suryawan, “Determination of rain intensity based on rain characteristics observed from rain observation stations around South Jakarta,” Journal of Advanced Civil and Environmental Engineering, vol. 3, no. 2, pp. 94–106, 2020, doi: 10.30659/jacee.3.2.106-115.

[16] Andriani et al., “Optimization of land use to reduce surface runoff and erosion in Kuranji Watershed,” International Journal of GEOMATE, vol. 22, no. 90, pp. 102–109, 2022, doi: 10.21660/2022.90.j2310.

[17] M. Kencanawati, D. Iranata, and M. A. Maulana, “Hydrologic modeling system HEC-HMS application for direct runoff determination,” Journal of Human, Earth, and Future, vol. 4, no. 2, pp. 153–165, 2023, doi: 10.28991/HEF-2023-04-02-02.

[18] M. E. Suripin, *Sistem Drainase Perkotaan yang Berkelanjutan*. Yogyakarta, Indonesia: Andi, 2004.

[19] S. Rahmadani et al., “Hydrological study of Deli River flood discharge using the HSS Nakayasu model,” Journal of Physics: Conference Series, vol. 2908, no. 1, 2024, doi: 10.1088/1742-6596/2908/1/012016.

[20] J. Jenny et al., “The bibliometric study of flood discharge by unit hydrograph method Nakayasu synthetic (HSS) and soil conservation service (SCS),” Journal of Social Research, vol. 3, no. 7, pp. 1–10, 2024, doi: 10.55324/josr.v3i7.2095.

[21] M. Safriani, A. Amir, and M. F. Ikhwali, “Evaluation of Krueng Tripa River capacity in Ujung Krueng Village, Nagan Raya Regency, Indonesia,” IOP Conference Series: Earth and Environmental Science, vol. 1203, no. 1, 2023, doi: 10.1088/1755-1315/1203/1/012033.

[22] R. Karamma et al., “Flood modelling due to dam failure using HEC-RAS 2D with GIS overlay: Case study of Karalloe Dam, South Sulawesi, Indonesia,” Civil Engineering and Architecture, vol. 10, no. 7, pp. 2833–2846, 2022, doi: 10.13189/cea.2022.100704.

[23] R. Barati, “Application of Excel Solver for parameter estimation of nonlinear Muskingum models,” KSCE Journal of Civil Engineering, vol. 17, no. 5, pp. 1139–1148, 2013, doi: 10.1007/s12205-013-0037-2.

[24] A. Suharyanto, “Estimating flood inundation depth along the arterial road based on the rainfall intensity,” Civil and Environmental Engineering, vol. 17, no. 1, pp. 66–81, 2021, doi: 10.2478/cee-2021-0008.