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ANALYSIS OF PLANNED FLOOD DISCHARGE IN THE GROMPOL WATERSHED

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Abstract

The Grompol watershed is one of the sub-watersheds of Bengawan Solo located in Karanganyar Regency and Sragen Regency. When the intensity of rainfall is high, the area downstream of the Grompol River often floods to cause many losses. Therefore, analyzing the planned flood discharge as a reference in flood control efforts is necessary. This study aims to identify the most common problems in the Grompol River flow, identify flood points in the Grompol River and its countermeasures, analyze the size of the Grompol Watershed using QGIS 3.10.6 Software, and calculate the amount of planned flood discharge in the Grompol Watershed. The method in this study is the Nakayasu Synthesis Unit Hydrograph Method, with a repeat period of 25 years. The analysis stage begins with conducting a location survey and interviews and then conducting a planned flood discharge analysis. Based on the results of the research, it was found that the problems that occur a lot in the Grompol River flow are sediment, organic waste, and inorganic waste, as well as streams that have been flooded at 4 points out of 31 survey locations, namely in the settlements around the Gedangan Lor Bridge, Gading Grompol, Gantung Kedusan, and Pringanom, where flood control efforts are dominated in the form of community service, an area of the Grompol watershed is obtained using Software QGIS 3.10.6 is 164,95 km^2 while for flood discharge for the 25-year recurrence period using the Nakayasu Synthetic Unit Hydrograph Method of 623,32 m^3/s.

Keywords: QGIS, Grompol Watershed, Planned Flood Discharge, Nakayasu Method.

Introduction

The Grompol River is one of the tributaries of the Bengawan Solo River, which flows in two districts, namely Karanganyar Regency and Sragen Regency, where the upstream is on Mount Lawu and downstream in Masaran District, Sragen Regency. When rainfall intensifies, the area downstream of the Grompol River, precisely in Sragen Regency, often experiences flooding.

The flood problem once occurred in Sragen Regency at the end of 2022; the flood occurred due to high rainfall, so the Grompol River overflowed. The overflow of the Grompol River has caused several hamlets in Sidodadi Village, Masaran District, and Sragen Regency to be flooded. The hamlets that experienced the flood include Nogosari Hamlet, Driyan Hamlet, and Grompol Hamlet, which have water levels of 30 cm. In addition, the Bayur Bridge in Kliwonan Village, Masaran District, also collapsed due to the flood. The rapid flow of the Grompol River carries large clumps of bamboo materials, and then the material hits the bridge pillars, causing the pillars to break and the bridge to collapse.

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Based on the problems described above, it is necessary to calculate and analyze planned flood discharge for flood management and water infrastructure planning. Therefore, a study was conducted titled "Analysis of Planned Flood Discharge in the Grompol Watershed."

Research related to flood discharge analysis has been carried out a lot, including research on the analysis of the flood hydrographic model of the Ngotok River using the SCS, Snyder, and Nakayasu Methods. The results of the flood hydrograph calibration with a 25-year reage calculated using the Nash formula obtained a value of 0,88 for the SCS Method, 0,74 for the Snyder Method, and 0,43 for the Nakayasu Method. Based on these results, the value of the SCS hydrograph is close to the value of the field hydrograph (Id'fi, 2020).

Flood discharge analysis was also conducted in the Buntung River in Sidoarjo Regency using the Nakayasu Method. Based on the results of the calculation using this method, it was obtained that the amount of flood discharge of the Buntung River with a 25-year recurrence period of 196,923 m^3/s (Sulhan et al., 2020).

Comparison of estimated peak flood discharge using the Nakayasu and the Javanese Sumatra FSR methods in the Dombo Sayung watershed. Based on the results of the analysis, the flood discharge value using the Nakayasu Method for the Penggaron River was 270,4 m^3/s, the Dombo Sayung River was 296,4 m^3/s, and the Dolok River was 332,2 m^3/s. Meanwhile, with the Javanese Sumatra FSR Method, the flood discharge value for the Penggaron River was 112,7 m^3/s, the Dombo Sayung River was 239,7 m^3/s, and the Dolok River was 632,1 m^3/s (Syarifudin & Utomo, 2020).

Analysis of the flood discharge of the Palu River plan using the Nakayasu synthetic unit hydrograph. Based on the results of the study, it was found that the magnitude of flood discharge in the 2, 5, 10, 25 and 50-year re-periods was $Q_{2\ year}$ = 966,372 m^3/s, $Q_{5\ year}$ = 1131,194 m^3/s, $Q_{10\ year}$ = 1235,828 m^3/s, $Q_{25\ year}$ = 1364,332 m^3/s, dan $Q_{50\ year}$ = 1458,269 m^3/s (Ifginia, 2020).

Flood discharge analysis of the Uru Ino River, East Halmahera Regency, using the hydrographic approach of Gama I and Nakayasu synthetic units. Based on the results of the analysis, it was obtained that the amount of flood discharge using the Gama 1 Method with a 2-year recurrence period of 64,916 m^3/s, 5-year reage of 131,619 m^3/s, 10-year reage of 159,727 m^3/s, 25-year reage of 183,485 m^3/s, and the 50-year money period is 195,440 m^3/s. Meanwhile, the Nakayasu Method obtained a 2-year re-annual discharge of 124,15 m^3/s, 5-year reage of 157,91 m^3/s, 10-year reage of 172,15 m^3/s, 25-year reage of 184,19 m^3/s, and the 50-year reage of 190,25 m^3/s (Miradj & Rahman, 2020).

Analysis of the design flood discharge in the Tulang Bawang River, Lampung Province, using the Nakayasu Method. Based on the results of the study, it was found that the amount of flood discharge at the 2-year reage was 427.10 m3/s, the 5-year re-era was 631,29 m^3/s, the 10-year reage is 797,07 m^3/s, 20-year reage is 999,64 m^3/s, 25-year reage is 1045,96 m^3/s, 50-year reage of 1262,56 m^3/s, and the 100-year reage of 1508,82 m^3/s (Cambodia et al., 2022).

The design flood discharge analysis was conducted in the Tukad Mati Watershed using the Nakayasu, Snyder, and Rational Method. The results of the Nakayasu Method show a 10-year recurrent discharge value of 223,195 m^3/s and a 25-year reage of 243,370 m^3/s. The results of the Rational Method show that the discharge of the 10-year reage is 147,880 m^3/s, the 25-year reage is 16,248 m^3/s, while the results of the Snyder Method showed a 10-year reage discharge of 137,651 m^3/s, a 25-year reage of 150,095 m^3/s, so it can be said that the results of the Snyder Method show the lowest flood discharge value (Ardana et al., 2021).

Planned flood discharge analysis using the Nakayasu Synthetic Unit Hydrograph Method in the Cimandiri River Basin. Based on the results of the study, it was obtained that the planned flood discharge for the 2-year recurrence period was 2654,4 m^3/s, the 5-year recurrence period was 3815,3 m^3/s, the 10-year recurrence period was 4534,3 m^3/s, the 50-year recurrence period was 6133,9 m^3/s, and the 100-year recurrence period was 6833,2 m^3/s (Saputra & Saputri, 2021).

Analysis of design flood discharge in the Selabung watershed using the Nakayasu synthetic unit hydrograph method. Based on the calculation results, the amount of flood discharge of the Serabung watershed plan with a 100-year recurrence period of 36,89 m^3/s (Andayani & Umari, 2022) was obtained.

Flood analysis of the hydrographic method of SCS synthetic units and Nakayasu watershed Pesung, Batam. The calculation results show that the most significant flood discharge occurred in the SCS-CN Method with a flood discharge of 215,488 – 584,308 m^3/s for the 5-year recurrence period, while in the Nakayasu Method, it was 360,526 – 986,535 m^3/s (Ayuni et al., 2023).

Based on the literature study in the journal mentioned above, it is known that the analysis of flood discharge in the Grompol watershed has never been carried out. The difference between this study and previous research lies in the research location, rainfall data, and the rain station used.

The purpose of this study is to identify the most common problems in the Grompol River flow, identify flood points in the Grompol River and its countermeasure efforts, analyze the size of the Grompol Watershed using QGIS 3.10.6 Software, and calculate the amount of planned flood discharge in the Grompol Watershed.

Research Methods

This research stage begins by identifying the problems in the Grompol watershed, and then the background and formulation of the research problem are drawn; a preliminary study is also carried out. The location of the Grompol watershed can be seen in Figure 1.

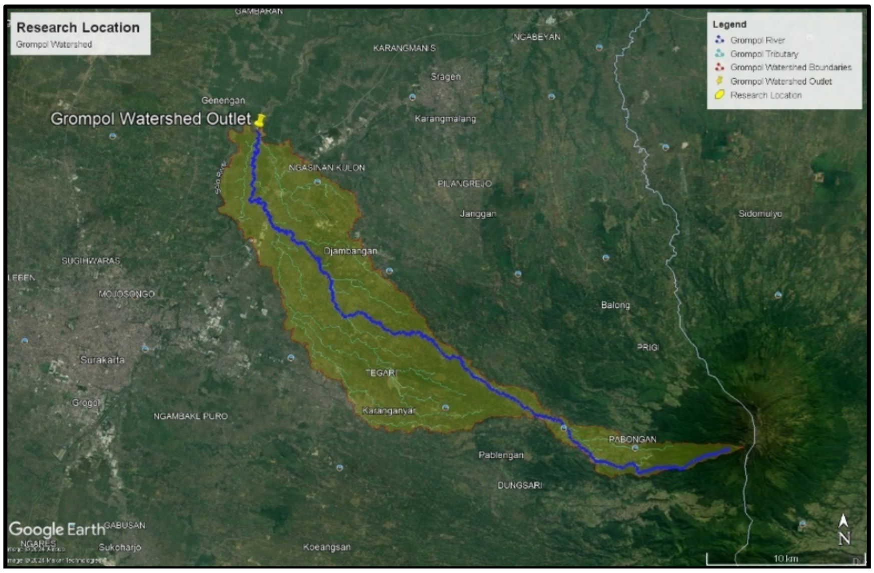


Figure 1. Research Location in the Grompol Watershed

(Source: Google Earth, 2024)

Furthermore, data collection was carried out using primary and secondary data. Surveys and interviews obtained primary data, while secondary data was obtained from related agencies and online data sites, including watershed maps, rainfall data, National Digital Elevation Model data, Indonesian Terrain Map, and HSGs Map.

The data analysis was divided into four stages, namely identifying problems that occur in the Grompol River flow from the results of the flow survey, identifying flood points in the Grompol River flow and countermeasures from the results of interviews, analyzing the area of the Grompol watershed using QGIS 3.10.6 Software from the National Digital Elevation Model data, and calculating the planned flood discharge from 4 data, namely rainfall data that had previously been tested for consistency, watershed area, Indonesian Terrain map to find land use, and HSGs map to find soil class. The final stage is drawing conclusions and suggestions from the discussion results at the data analysis stage.

Results and Discussion

Identification of Grompol River Flow Problems

The survey points taken are at bridge points and surrounding settlements along the Grompol River flow from upstream to downstream, with the number of survey points being 31. The Grompol River flow survey uses three parameters in its observations: sediment, waste (organic and inorganic waste), and wild plants on the river embankment. The Grompol River flow survey was completed within three days, from Monday, April 29, 2024, to Wednesday, May 01, 2024. The results of the river flow survey activities are presented in the form of a network scheme, which can be seen in Figure 2, while a recapitulation of river flow conditions can be seen in Figure 3.

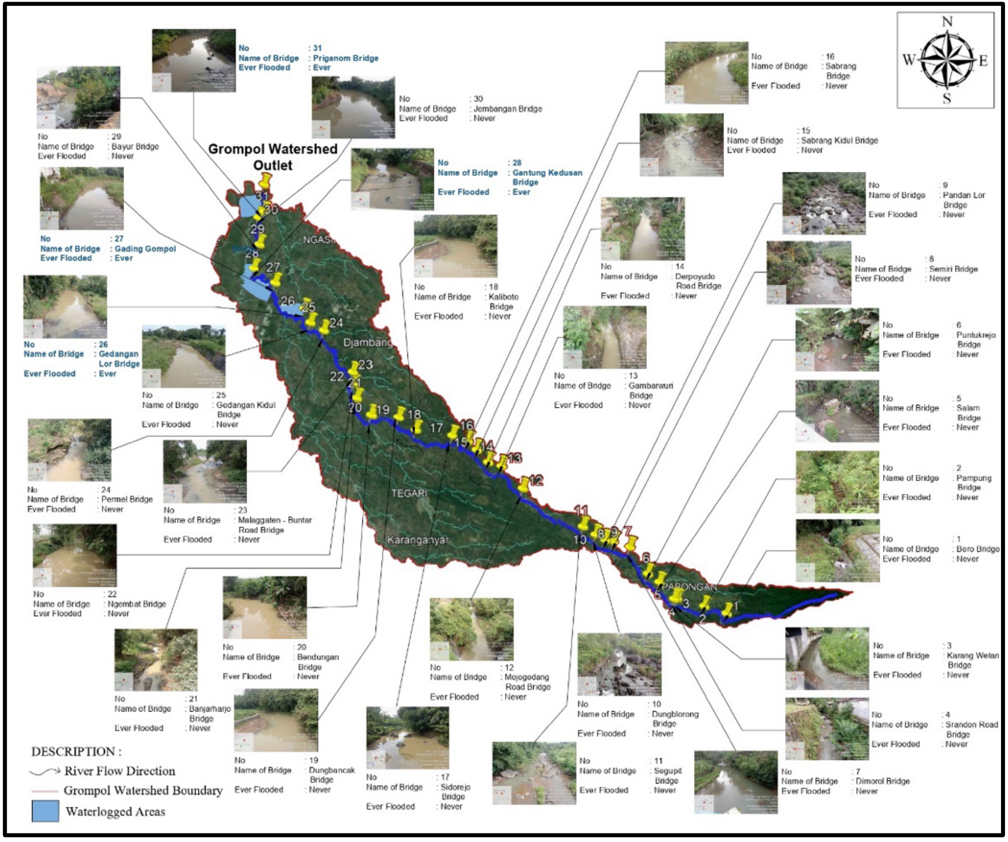


Figure 2. Network Schematic
(Source: Personal Documentation, 2024)

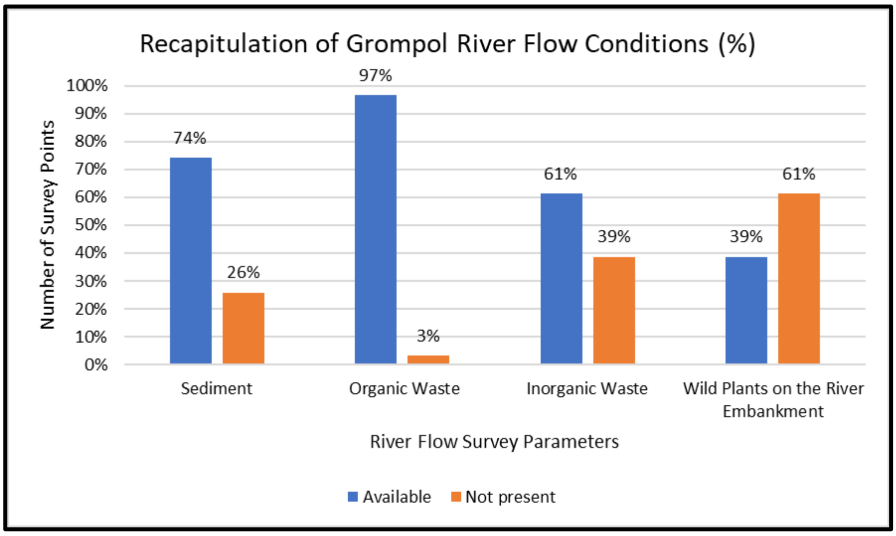


Figure 3. Recapitulation of Grompol River Flow Condition Data
(Source: Personal Calculations, 2024)

Based on Figure 3, it can be concluded that of the 31 survey points, 74% of the flow points contained sediment, 97% contained organic waste, 61% contained inorganic waste, and 39% contained wild plants in the river infrastructure.

Identification of Flood Points of the Grompol River Flow and Countermeasures

Interviews with residents around the bridge points can help identify flood points. The number of respondents from the interview was 31, and the bridge point reviewed them. The results of the interview recapitulation can be seen in Figure 4.

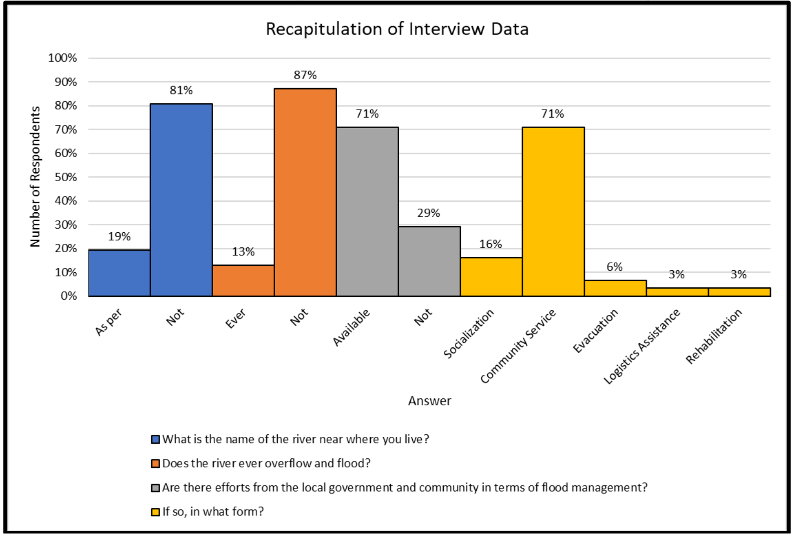


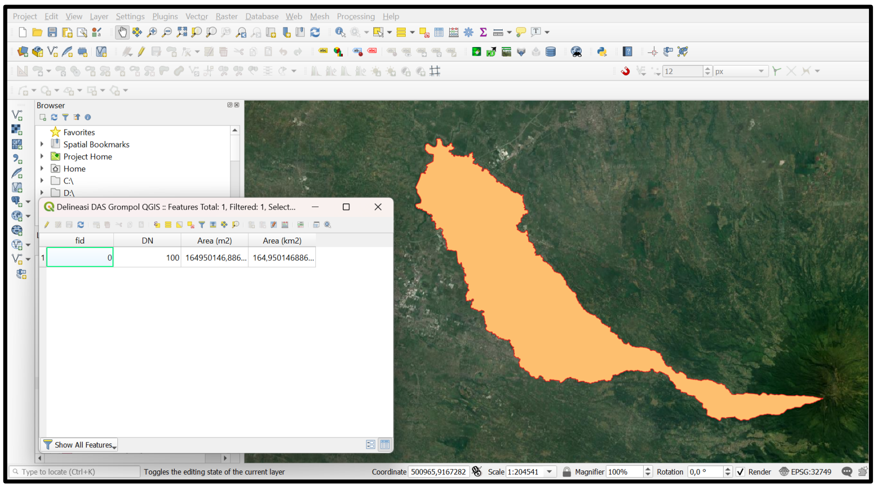
Figure 4. Recapitulation of Interview Data
(Source: Personal Calculations, 2024)

Based on Figure 4, it can be concluded that 13% of 31 respondents said that there had been overflows that caused flooding at 4 points, namely in settlements around the Gedangan Lor Bridge, Gading Grompol Bridge, Gantung Kedusan Bridge, and

Pringanom Bridge, where flood management efforts from the government and local communities were dominated in the form of community service.

Grompol Watershed Area Analysis Using QGIS 3.10.6 Software

The extensive analysis of the Grompol watershed was carried out using QGIS 3.10.6 Software, namely by entering the National Digital Elevation Model data obtained from the official website of the Indonesian homeland. The results of the Grompol watershed in QGIS 3.10.6 Software can be seen in Figure 5.



Delineasi DAS Grompol QGIS :: Features Total: 1, Filtered: 1, Select...

	fid	DN	Area (m2)	Area (km2)
1	0	100	164950146,886...	164,950146886...

Figure 5. Results of Grompol Watershed Area
(Source: QGIS 3.10.6, 2024)

Based on Figure 5, it can be seen that the area of the Grompol watershed using QGIS 3.10.6 Software is 164,95 km^2.

Calculation of Flood Discharge of the Grompol Watershed Plan

According to (Mulyandari & Susila, 2020), There are several stages of flood discharge analysis, including consistency tests, frequency analysis with four types of distributions and distribution compatibility tests, changing the rain again to hourly rain, and the last stage of calculating the flood discharge. In this regard, the stages of this research are as follows:

1) Rain Data Consistency Test

Rainfall data was taken from rainfall stations closest to the Grompol watershed, including the Tawangmangu Rainfall Post in 2004 - 2023, Delingan Rainfall Post in 2012 - 2023, and Karangpandan Rainfall Post in 2014 - 2023. The recapitulation of total annual rainfall from the three stations can be seen in Table 1.

Table 1 Recapitulation of Total Annual Rainfall

Year	Total Rainfall (mm)		
	Tawangmangu Station	Delingan Station	Karangpandan Station
2004	2960	-	-
2005	3387	-	-
2006	2542	-	-
2007	2970	-	-
2008	2240	-	-
2009	3106	-	-

Year	**Total Rainfall (mm)**		
	Tawangmangu Station	**Delingan Station**	**Karangpandan Station**
2010	4682	-	-
2011	3334	-	-
2012	2217	1864	-
2013	2770	2268	-
2014	2571	1244	2510
2015	3171	2218	3097
2016	4759	3717	5006
2019	2889	1842	2526
2020	4157	2231	3210
2021	4084	2820	3148
2022	4154	3060	4129
2023	2394	1743	1812

(Source: Bengawan Solo River Region Headquarters, 2024)

According to (Sri Harto BR, 2022), Before rain data is used in the analysis, it is necessary to conduct a data consistency test, one of which can use the RAPS Method. The results of the consistency test of Tawangmangu, Delingan, and Karangpandan rain stations with the RAPS Method can be seen in Table 2.

Table 2. Consistency Test Results

Rain Station	**Consistency Test Requirements**	**Information**
Tawangmangu	1. $Q_{count} < Q_{critics}$	Consistent
	$4.03 < 5.46$	
	2. $R_{count} < R_{critics}$	
	$5.15 < 6.40$	
Delingan	1. $Q_{count} < Q_{critics}$	Consistent
	$2.19 < 4.00$	
	2. $R_{count} < R_{critics}$	
	$2.99 < 4.54$	
Karangpandan	1. $Q_{count} < Q_{critics}$	Consistent
	$1,68 < 3,60$	
	2. $R_{count} < R_{critics}$	
	$2,29 < 4,05$	

(Source: Personal Calculations, 2024)

Based on Table 2, the data from Tawangmangu Station, Delingan Station, and Karangpandan Station are consistent.

2) Determination of Regional Rainfall

According to (Suripin, 2004), Regional rainfall determination for small watersheds (< 500 km^2) was carried out by the Arithmetic Average Method. In this study, the area of the Grompol watershed is 164,95 km^2, less than 500 km^2, so the rainfall in the region is determined using the Arithmetic Average Method. The maximum rainfall recapitulation of the Arithmetic Average Method can be seen in Table 3.

Table 3. Maximum Rainfall Recapitulation

k	Year	P max
1	2004	127,00
2	2005	171,00
3	2006	89,00
4	2007	194,00
5	2008	107,00
6	2009	121,00
7	2010	128,00
8	2011	116,00
9	2012	100,50
10	2013	65,50
11	2014	58,00
12	2015	82,67
13	2016	106,33
14	2017	95,33
15	2018	102,33
16	2019	108,33
17	2020	108,00
18	2021	111,33
19	2022	100,67
20	2023	90,33

(Source: Personal Calculations, 2024)

3) Distribution Fit Test

According to (Mulyandari et al., 2024), the distribution fit test is an essential stage in hydrological analysis to determine the most appropriate rainfall distribution to ensure the accuracy of the analysis. In this study, the distribution fit test was carried out by three methods as follows:

a) Parameters Statistics

The results of the Distribution Fit Test with Statistical Parameters can be seen in Table 4.

Table 4. Statistical Parameter Distribution Match Test

No	Distribution	Requirement	Condition	Calculation Results	Information
1	Normal	$(X_{\text{average}} \pm s) = 68{,}27\%$	68,27%	80,00%	Rejected
		$(X_{\text{average}} \pm 2s) = 95{,}44\%$	95,44%	95,00%	Rejected
		$Cs \approx 0$	0	1,19	Rejected
		$Ck \approx 3$	3	5,81	Rejected
2	Log-Normal	$Cs = Cv^3+3Cv$	1,19	0,88	Rejected
		$Ck = Cv^8+6Cv^6+15Cv^4+16Cv^2+3$	5,81	4,39	Rejected
3	Gumbel	$Cs = 1{,}14$	1,14	1,19	Rejected
		$Ck = 5{,}4$	5,4	5,81	Rejected

No	Distribution	Requirement	Condition	Calculation Results	Information
4	Log Pearson Type III	Others	Others		Accepted
	Possible distribution:		**Log Pearson Type III**		

(Source: Personal Calculations, 2024)

Based on Table 4, the statistical parameter requirements for the Normal, Log Normal, and Gumbel distributions are not met, so it is estimated that the appropriate distribution type is the Log Pearson Type III distribution.

b) Smirnov Klomogorov

By (Badan Standarisasi Nasional, 2016) about Procedures for Calculating Flood Discharge, Smirnov Kolmogorov's distribution test plan can be accepted if the value of $\Delta_{max} < \Delta_{critics}$. The results of the Smirnov Kolmogorov Test can be seen in Table 5.

Table 5. Smirnov Kolmogorov Distribution Compatibility Test

No	Distribution Type	Smirnov Kolmogorov Test Requirements			
		Δ max	**<**	**Δ critics**	**Conclusion**
1	Normal Distribution	0,14	<	0,29	Accepted
2	Normal Log Distribution	0,10	<	0,29	Accepted
3	Gumbel Distribution	0,12	<	0,29	Accepted
4	Distribusi Log Pearson Type III	0,10	<	0,29	Accepted

(Source: Personal Calculations, 2024)

Based on Table 5, it can be said that the Smirnov Kolmogorov test for all types of distributions is accepted with the smallest Δmax value, namely the Gumbel and Log Pearson Type III distributions.

c) Chi-Squared

According to (Badan Standarisasi Nasional, 2016) about Flood Discharge Calculation Procedures, The Chi-Squared distribution test plan is acceptable if the value is $x^2 < x_{cr}^2$. The results of the Chi-Squared Test can be seen in Table 6.

Table 6. Chi-Squared Distribution Fit Test

No	Distribution Type	Requirements for Quadratic Chi Test			
		x^2	**<**	x_{cr}^2	**Conclusion**
1	Normal Distribution	4,00	<	5,99	Accepted
2	Normal Log Distribution	5,50	<	5,99	Accepted
3	Gumbel Distribution	5,50	<	5,99	Accepted
4	Distribusi Log Pearson Type III	5,50	<	5,99	Accepted

(Source: Personal Calculations, 2024)

Based on Table 6, the Chi-Square Test for all types of distributions is accepted with the smallest chi-squared value, namely the normal distribution.

The recapitulation of the distribution match test of the three methods can be seen in Table 7.

Table 7. Recapitulation of Distribution Fit Test

No	Distribution Type	Distribution Fit Test		
		Parameters Statistics	Smirnov Kolmogorov	Chi Kuadrat
1	Normal Distribution	Rejected	Accepted	Accepted
2	Normal Log Distribution	Rejected	Accepted	Accepted
3	Gumbel Distribution	Rejected	Accepted	Accepted
4	**Distribusi Log Pearson Type III**	**Accepted**	**Accepted**	**Accepted**

(Source: Personal Calculations, 2024)

Based on Table 7, the distribution type of Log Pearson Type III was taken for the following calculation because the distribution was accepted in the three distribution match tests.

d) Rainfall Distribution

The type of rainfall distribution used is Pearson Log Distribution Type III with a re-period of 25 years. The calculation of rainfall Log Pearson Type III can be seen in Table 8.

Table 8. Calculation of Pearson Type III Log

k	Year	P_{max}	ln P_{max}	(ln P_{max} - ln P_{rerata})	(ln P_{max} - ln $P_{rerata})^2$	(ln P_{max} - ln $P_{rerata})^3$
1	2004	127,00	4,84	0,19	0,04	0,01
2	2005	171,00	5,14	0,49	0,24	0,11
3	2006	89,00	4,49	-0,17	0,03	0,00
4	2007	194,00	5,27	0,61	0,37	0,23
5	2008	107,00	4,67	0,02	0,00	0,00
6	2009	121,00	4,80	0,14	0,02	0,00
7	2010	128,00	4,85	0,20	0,04	0,01
8	2011	116,00	4,75	0,10	0,01	0,00
9	2012	100,50	4,61	-0,05	0,00	0,00
10	2013	65,50	4,18	-0,47	0,23	-0,11
11	2014	58,00	4,06	-0,60	0,36	-0,21
12	2015	82,67	4,41	-0,24	0,06	-0,01
13	2016	106,33	4,67	0,01	0,00	0,00
14	2017	95,33	4,56	-0,10	0,01	0,00
15	2018	102,33	4,63	-0,03	0,00	0,00
16	2019	108,33	4,69	0,03	0,00	0,00
17	2020	108,00	4,68	0,03	0,00	0,00
18	2021	111,33	4,71	0,06	0,00	0,00
19	2022	100,67	4,61	-0,04	0,00	0,00
20	2023	90,33	4,50	-0,15	0,02	0,00
Sum		**2182,33**	**93,13**	**0,00**	**1,42**	**0,02**

(Source: Personal Calculations, 2024)

Standard deviation (Sd) $= \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} = \sqrt{\frac{1}{20-1}\ 1{,}42} = 0{,}27$

Coefficient of skewness (Cs) $= \frac{n\sum_{i=1}^{n}(x_i - \bar{x})^3}{(n-1)(n-2){s_d}^3} = \frac{20 \ x \ 0{,}02}{(20-1)(20-2)1{,}42^3} = 0{,}05$

The K_T value is obtained from the K_T table of the Pearson III Log Distribution, where for a value of Cs = 0.05 with a return period of 25 years, the KT value = 1.769 is obtained.

$Y_T \quad = \bar{Y} + K_T \,. S_y$

$Y_{25\text{ years}} \quad = 4{,}657 + 1{,}769 \ x \ 0{,}274$

$= 5{,}140$

X_{25} years = exp (5,140)

X_{25} years = 170,775 mm ≈ 170,77 mm

So, from the Pearson Type III Log Distribution calculation, the 25-year planned rainfall was obtained at 170,77 mm.

e) *Rain Hyetograph* Design

Daily rainfall data is changed by changing the depth of hourly rainfall using a rainfall distribution model Alternating Block Method (ABM). According to (Fauziyah et al., 2013), the more frequent rain that results in flooding occurs within 4 hours, so for this calculation, the duration is 4 hours. The results of the hyetograph ABM draft rain can be seen in Table 9.

Table 9 . Draft *Rain Hyetograph* (ABM)

T_d (jam)	Δt (jam)	I_t (mm/him)	I_t T_d (mm)	Δp (mm)	P_t (%)	*hyetograph* (%)	(mm)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
1	0~1	59,20	59,20	59,20	63,00	11,49	19,62
2	1~2	37,30	74,59	15,39	16,37	63,00	107,58
3	2~3	28,46	85,39	10,79	11,49	16,37	27,96
4	3~4	23,50	93,98	8,59	9,14	9,14	15,62
		Sum		**93,98**	**100**	**100**	**170,77**

(Source: Personal Calculations, 2024)

Based on Table 9, the rain hyetograph value with the ABM method for the first hour is 19,62 mm, the second hour is 107,58 mm, the third hour is 27,96 mm, and the fourth hour is 15,62 mm, where the rain value is then used for the calculation of adequate rain.

f) Effective Rain

The stage of calculating adequate rain begins with calculating the composite CN value, which is then used in the basic equation to determine the amount of proper rainfall. The data needed to determine the composite CN value are land use data and soil type. The land use map and soil type map of the Grompol watershed using QGIS 3.10.6 Software can be seen in Figure 6 and Figure 7.

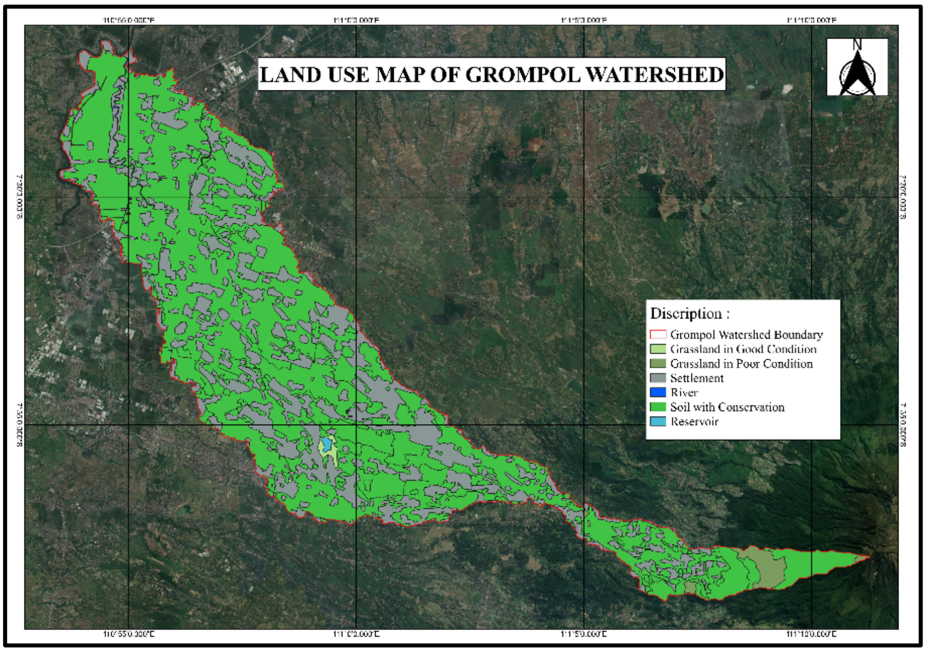


Figure 6. Land Use Map of Grompol Watershed
(Source: Personal Calculations, 2024)

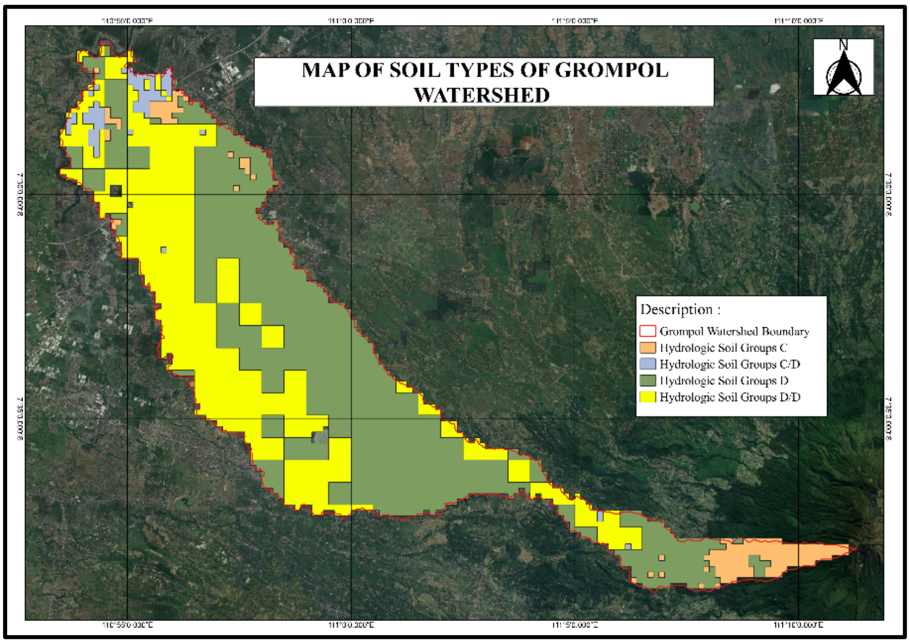


Figure 7. Map of Soil Types of Grompol Watershed
(Source: Personal Calculations, 2024)

Based on these two figures, the calculation of composite CN and adequate rain is then carried out, where, for the soil class, the soil class most commonly used is soil class D. The calculation of composite CN can be seen in Table 10.

Table 10. Calculation of Composite CN

Land Use		Soil Classification		Broad	CN x Area
BIG	**CN**	**Soil Type**	**CN Value**	**km^2**	
Plantations/Gardens	Soil with Conservation	D	91	11,73	1067,24
Tegalan/Farm			91	20,12	1830,64
Sawah			91	79,53	7237,41
Rainfed Rice Fields			91	0,44	40,45
Building/Building	Settlement	D	84	0,06	5,17
Settlements and Activity Places			84	49,62	4167,70
Meadow	Grassland (Good Condition)	D	78	0,65	50,52
Bushes	Grassland (Poor Condition)	D	89	2,30	205,09
Sum			**699**	**164,45**	**14604,23**

(Source: Personal Calculations, 2024)

$$CN_k = \frac{\sum(CN\ x\ Luas)}{\sum Luas}$$
$$= \frac{14604{,}23}{164{,}45} = 88{,}81$$

Maximum potential retention (S) = $\frac{25400}{CN} - 254 = \frac{25400}{88{,}81} - 254$ = 32,02 mm

t = 1 jam
P = 19,62 mm
ΣP = 19,62 mm
$\Sigma P_{eff} = \frac{(P-0{,}2\,S)^2}{P+0{,}8\,S} = \frac{(19{,}62 - 0{,}2.\ 32{,}02)^2}{19{,}62 + 0{,}8.\ 32{,}02}$ = 3,86 mm
$P_{eff} = \Sigma Peff_{(i)} - \Sigma Peff_{(i-1)}$ = 3,86 – 0 = 3,86 mm

The full results of the practical rain calculation can be seen in Table 11.

Table 11. Effective Rainfall Calculation

t	P	ΣP	ΣP$_{eff}$	P$_{eff}$
1	19,62	19,62	3,86	3,86
2	107,58	127,20	95,49	91,63
3	27,96	155,16	122,41	26,93
4	15,62	170,77	137,57	15,16
Σ	**170,77**		**Σ**	**137,57**

(Source: Personal Calculations, 2024)

Based on Table 11, the practical rainfall value obtained with the SCS-CN method for the first hour was 3.86 mm, the second hour was 91.63 mm, the third hour was 26.93 mm, and the fourth hour was 15.16 mm.

g) Nakayasu Synthesis Unit Hydrograph Method

The Nakayasu Synthesis Unit Hydrograph Method was developed by its inventor in Japan based on several rivers in Japan (Bambang Triatmodjo, 2013). The calculation of the Hydrograph of the Nakayasu Synthesis Unit in this study is as follows:

Watershed area (A) = 164,95 km^2
Length of Main River (L) = 54,83 km

King = 1 mm
tg = 0,4 + 0,058 L = 0,4 + 0,058 . 54,83 = 3,58 hours
Tr = 0,75. 3,58 = 2,68 hours
Tp = $t_g + 0{,}8\,T_r$= 3,58 + 0,8. 2,68 = 5,73
T0,3 = $\alpha\, t_g$ = 2 . 3,58 = 7,16

$$Qp = \frac{1}{3{,}6}\left(\frac{A\,R_e}{0{,}3\,T_p + T_{0,3}}\right) = \frac{1}{3{,}6}\left(\frac{164{,}95.\ 1}{0{,}3.\ 5{,}73 + 7{,}16}\right) = 5{,}16\ \text{m}^3/\text{s}$$

The hydrograph parameters of the Nakayasu unit above are used to calculate the coordinates of the hydrograph several times (t) as follows:
On an upward curve (0 < t < 5,7)

$$\text{Qt}_{\text{initial}} = Q_p \left(\frac{t}{T_p}\right)^{2,4}$$

On the downward curve (5,73 < t < 12,89)

$$\text{Qt}_{\text{initial}} = Q_p\ x\ 0{,}3^{\frac{t-T_p}{T_{0,3}}}$$

On the downward curve (12,89 < t < 23,63)

$$\text{Qt}_{\text{initial}} = Q_p\ x\ 0{,}3^{\frac{[(t-T_p)+(0{,}5\,T_{0,3})]}{1{,}5T_{0,3}}}$$

On the downward curve (t < 23,63)

$$\text{Qt}_{\text{initial}} = Q_p\ x\ 0{,}3^{\frac{[(t-T_p)+(1{,}5\,T_{0,3})]}{2T_{0,3}}}$$

The results of the Nakayasu Unit Hydrograph can be seen in Figure 8.

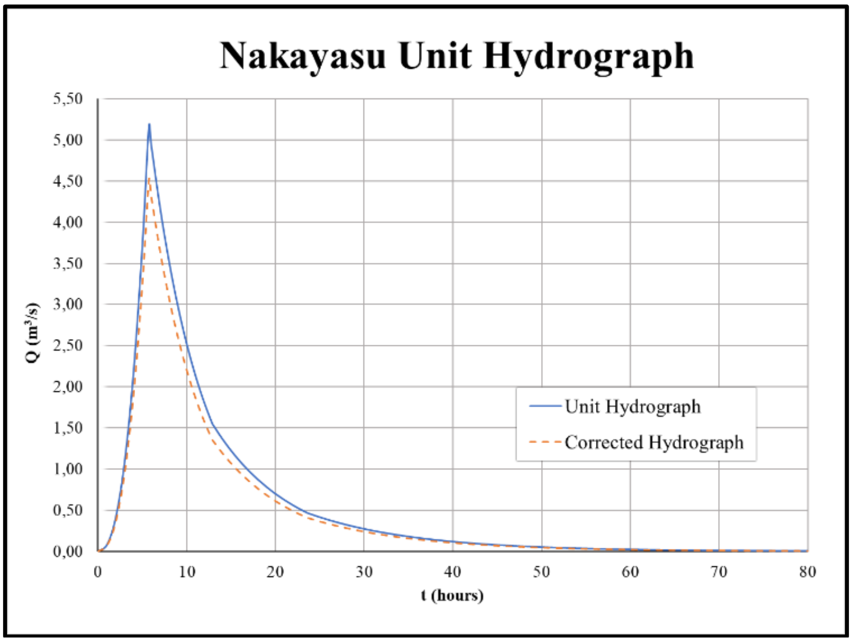


Figure 8. Nakayasu Unit Hydrograph
(Source: Personal Calculations, 2024)

Next, the flood hydrograph value is calculated, where the flood hydrograph value is the amount of direct runoff hydrograph with the bottom flow.
Watershed area (A) = 164,95 km^2
Length of rivers of all levels = 612,26 km
Drain tissue density (D) = $\frac{612{,}26}{164{,}95}$ = 3,71
Base Flow (BF)

$$BF = 0{,}4751\ A^{0{,}6444}\ D^{0{,}9430}$$
$$BF = 0{,}4751.\ (164{,}95)^{0{,}6444}.\ (3{,}71)^{0{,}9430} = 43{,}93\ m^3/s$$

The results of the Nakayasu Flood Hydrograph can be seen in Figure 9.

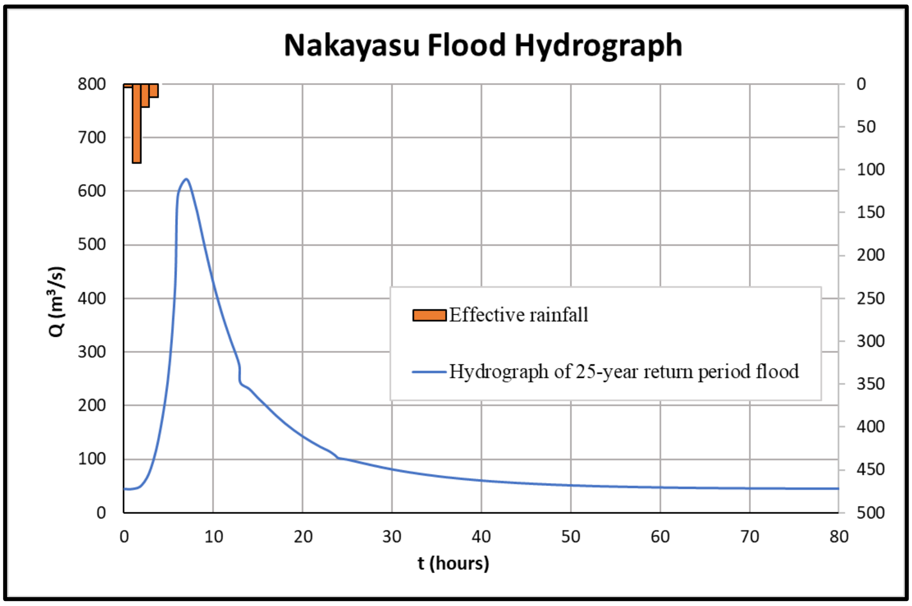


Figure 9. Nakayasu Flood Hydrograph
(Source: Personal Calculations, 2024)

Based on the calculation step with the Nakayasu Method, the planned flood discharge value in the Grompol watershed for the 25-year renewal period was 623,32 m^3/s.

Conclusion

Based on the results of the analysis and discussion in this study, the following conclusions can be drawn: (1) The problems that occur in the Grompol River are the presence of sediment, organic waste, and inorganic waste. (2) The flow of the Grompol River has been flooded at 4 points out of 31 survey locations, namely in the settlements around the Gedangan Lor Bridge, the Gading Grompol Bridge, the Gantung Kedusan Bridge, and the Pringanom Bridge, where flood control efforts from the government and local communities are dominated in the form of community service. (3) The area of the Grompol watershed using QGIS 3.10.6 Software is 164,95 km^2. (4) The amount of planned flood discharge in the Grompol watershed with a re-period of 25 years using the Nakayasu Synthesis Unit Hydrograph Method is 623,32 m^3/s.

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