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FLOOD CONTROL USING RESERVOIRS (CASE STUDY OF THE BENGARIS RIVER, MUARA TEWEH CITY)

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ABSTRAK

The Bengaris River is the longest river that passes through Muara Teweh. Heavy rain causes the Bengaris River to overflow, resulting in flooding. The objective of this research is to assess the capacity of the Bengaris River, design retention basin, and evaluate design effectiveness over a 20-year discharge return period at STA 4+248 (Pararawen II Street), STA 5+689 (Ronggolawe Street), and STA 6+049 (behind the BAPPEDALITBANG Office).

This research purposes to calculate design rainfall using various distribution methods, including Normal, Normal Log, Gumbel, and Log Pearson III. Hourly rainfall intensity distribution using the Mononobe Method with 20-year return period. Civil Engineering software, HEC-HMS 4.10, designed discharge was calculated using several methods as Rational, Derweduwen, Haspers, Melchior, Snyder-Alexejev, Snyder, Nakayasu Synthetic Unit Hydrograph (HSS), and Soil Conservation Service Curve Number (SCS-CN) methods. HEC-RAS 6.0 model was used for river hydraulic analysis in both steady flow and unsteady flow simulations models.

Two units are required to control water level of the Bengaris River at STA 4+248, STA 5+689, and STA 6+049 with the 20-year discharge return period, according to research findings. Reservoirs at STA 6+049 and STA 4+435 control storage quantities of 500 m^3 and 800 m^3, respectively. Simulation models showed a decrease in the wet cross-sectional area of the river at STA 4+248, from 112,030 m^2 to 5.29 and STA 5+689 decreased from 51,950 m^2 to 6.49 m^2 (87.507%), whereas STA 6+049 decreased from 91.710 m^2 to 3.91 m^2 (95.737%).

Key words: Flood, River Capacity, Reservoir, Flood Reduction and Bengaris River

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1. INTRODUCTION

The Bengaris River is the longest river that crosses the city of Muara Teweh and its condition is currently worrying, this can be seen from the damage or collapse of the river banks, there are many buildings located in the channel and riverbanks which during high intensity rains result in flooding (Vianus, 2019).

The last biggest flood disaster occurred on March 23 2021 which was caused by rain with an intensity of 181 mm (BMKG, 2021) which occurred from dawn to morning on Tuesday, causing the Bengaris River to overflow (Borneonews, 2021). As a result, dozens of houses and several roads in Muara Teweh City were flooded. Several residential areas were affected by flooding due to the overflowing of the Bengaris River, namely around Jalan Ronggolawe, behind the Regional Government Office, behind the Bappedalitbang Office, the Mekar Indah Housing complex on Jalan Wira Praja, Jalan Pararawen II and several areas around the Bengaris River route.

Based on these problems, a study is needed to evaluate the capacity of the Bengaris River to channel flood discharge, plan the dimensions, number and placement of reservoirs in the available locations to reduce peak flood discharge, evaluate the effectiveness of implementing embungs in reducing flood events on the Bengaris River for the 20th return period. year.

The benefits that will be obtained from this research are as material for consideration in preparing a flood control program plan for the city of Muara Teweh.

2. METHOD

The method used to calculate the planned rain is Method *Normal, Log Normal, Gumbel dan Metode Log Pearson III*, to calculate the hourly rainfall distribution using the Mononobe Method. to convert rain into discharge using the method *Soil Conservation Service Curve Number (SCS-CN)* in the HEC-HMS 4.10 application, HEC-RAS 6.0 modeling for river hydraulic analysis with running unsteadyflow mode.

This research was conducted on the Bengaris River which is a sub-watershed of Barito located in Muara Teweh City, North Barito Regency. The area of the Bengaris watershed is 8.6697 km2. The length of the Bengaris River is 10,335 km, while the river section used as the object of research is the Bengaris River section from upstream to STA 4+248 (Jalan Pararawen II), STA 5+689 (Jalan Ronggolawe), STA 6+049 (Behind the Bappedalitbang Office North Barito Regency) which is an area prone to Bengaris River flooding.

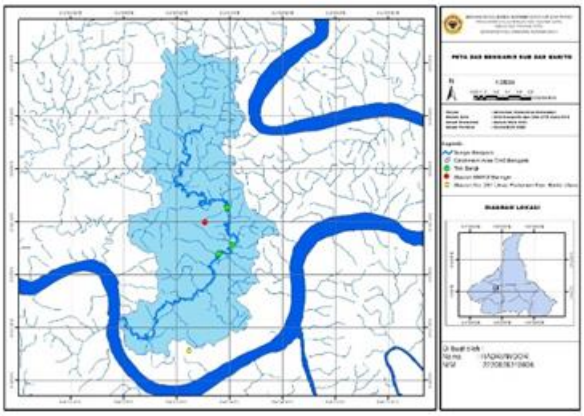


Figure 1. Bengaris Watershed

Hydrological Data Processing

a. Calculation of maximum daily rainfall
   The rain data used in this research is daily rainfall data from the BMKG Beringin Muara Teweh station and Station No. 297 North Barito District Agriculture Service.

b. Analysis of design rainfall
   - The design rainfall analysis uses the Normal, Normal Log, Gumbel and Pearson III Log Methods.
   - Data testing uses the Smirnov-Kolmogorof test and chi square.
   - calculate the hourly rainfall distribution using the Mononobe method and to graph hourly rainfall using the Alternating Block Method (ABM).

Flood Modeling with HEC-HMS

Analysis of the planned flood discharge to determine the peak flood discharge with the help of the HEC-HMS application to obtain the planned flood discharge for the 20 year return period for each point under consideration. The performance indicator of the model studied is the use of loss calculation methods *SCS Curve Number* and flow hydrograph calculations (*transform method*) by method *SCS Unit Hydrograph*, which is applied to the Bengaris watershed.

Flood Modeling with HEC-RAS

Hydraulic calculations are calculated using HEC-RAS software. *Outflow* river modeling in the form of flood water level elevation for each planned discharge. Next, a flood control scenario is carried out, namely the planned flood water level reduction method with embungs. River modeling analysis using HEC-RAS is a steadyflow and unsteadyflow calculation using the Standard Step Method. The flood water level elevation output is obtained through a profile plot from the simulation results.

3. RESULT AND DISCUSSION

Hydrological Analysis

The rainfall data used in this research is the maximum daily rainfall over a period of thirty years from 1994 to 2023 which was obtained from the BMKG Beringin Muara Teweh Station and Station No. 297 North Barito District Agriculture Service.

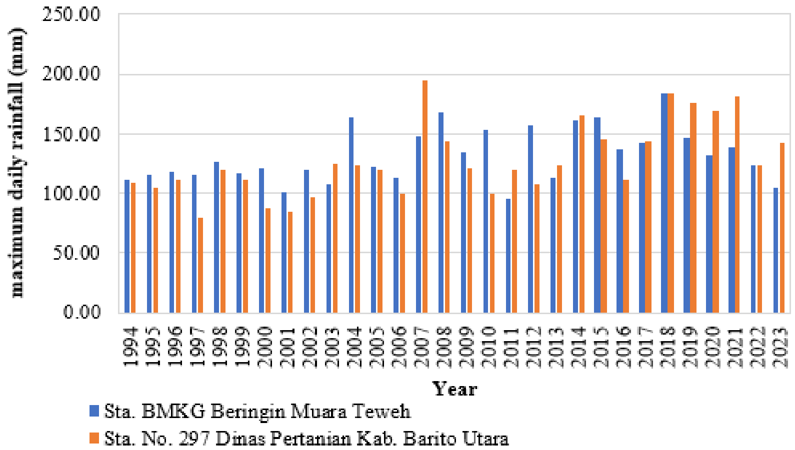


Figure 2 Maximum Daily Rainfall at BMKG station Beringin Muara Teweh and station No. 297 North Barito Regency Agricultural Service

Test Consistency

Table 1 Consistency Test with the RAPS Method

No.	Station	Q/√ n count	R/√ n count	Q/√ n table	R/√ n table	conclusion
1	Station of BMKG Beringin	2.354	3.988	1.240	1.500	Consistent
2	Station of No. 297 agriculture department	2.218	3.809	1.240	1.500	Consistent

Homogeneity Test

Table 2 Homogeneity Test with F Test

No.	Station	F count	F Table	conclusion
1	Station of BMKG Beringin and Stasiun of No. 297 agriculture department	0.533	1.858	homogeneous

Based on the results of the homogeneity test, the rainfall data from the two stations above is homogeneous, so for the next test the rainfall data used is from the BMKG Beringin Station because it already uses an automatic rain gauge (ARG) and its location is within the Bengaris watershed. while Station No. 297 The Department of Agriculture still records rain manually and the location is outside the Bengaris watershed.

Outlier Test

Table 3 Oulier test using the Grubs and Beck method

No.	Station	Log X̄i	Kn	X_L	X_H	conclusion (XL < Log X̄i < XH)
1	Station of BMKG Beringin Muara Teweh	2.110	2.563	2.300	1.930	No Outlier

No Trend Test

Table 4 No trend test using the rank correlation coefficient with the Spearman method

No.	Station	t_{count}	$t_{critical}$	conclusion $t_{count} < t_{critical}$
1	Station of BMKG Beringin Muara Teweh	-2.230	1.701	No Trend

Stationary Test

Table 5 Test the stability of variants with the F test

No.	Station	F_{count}	F_{table}	conclusion $F_{count} < F_{table}$
1	Station of BMKG Beringin Muara Teweh	0.696	2.400	Homogeneous / 95% of the variance values are stable

Table 6 Test the stability of the average value with the t test

No.	Station	t_{count}	t_{table}	conclusion $t_{count} < t_{table}$
1	Station of BMKG Beringin Muara Teweh	1.7908	2.048	the null hypothesis is accepted and the alternative hypothesis is rejected

By paying attention to the F-test and t-test, the periodic series of BMKG Beringin Muara Teweh Station Rainfall Data is stationary, meaning the average value and variance value are stable.

Planned Rainfall Analysis

Table 7 Recapitulation of Probability Distribution Calculations and Rainfall 14 th April, 2024

Return Period	Planned rainfall (mm)				Actual rainfall (mm)
	Normal	Gumble	Log Normal	Log Person III	
Rainfall 14th of April, 2024					53.70
2	131.733	128.272	129.915	129.083	
5	150.736	151.537	149.696	149.398	
10	160.690	166.586	161.231	161.869	
20	168.834	181.228	171.327	171.694	
25	170.379	184.380	173.314	176.828	
50	178.109	200.141	183.598	187.499	
100	184.443	214.376	192.480	197.867	

Probability Distribution Test

Table 8. Chi Square Test Summary

No.	Distribution of Probability	χ^2_{count}	χ^2_{cr}	conclusion
1	Normal	6.67	7.815	accepted
2	Gumble	5.00	7.815	accepted
3	Log Normal	4.67	7.815	accepted
4	Log Pearson III	1.67	7.815	accepted

Table 9 Test Resume *Smirnov-Kolmogorov*

No.	Distribution of Probability	Dmax	Do critical	conclusion
1	Normal	0.14	0.24	accepted
2	Gumble	0.07	0.24	accepted
3	Log Normal	0.11	0.24	accepted
4	Log Pearson III	0.39	0.24	rejected

Based on Table 9, the distribution chosen is the distribution that has the smallest deviation value compared to the others, namely the method *Gumble.*

From the return period rainfall data, the gumble method (Table 7) was converted into hourly return period rain intensity in this study which was calculated for 720 minutes (12 hours) using the Mononobe Equation. The complete results of rain intensity over time can be seen in Figure 3.

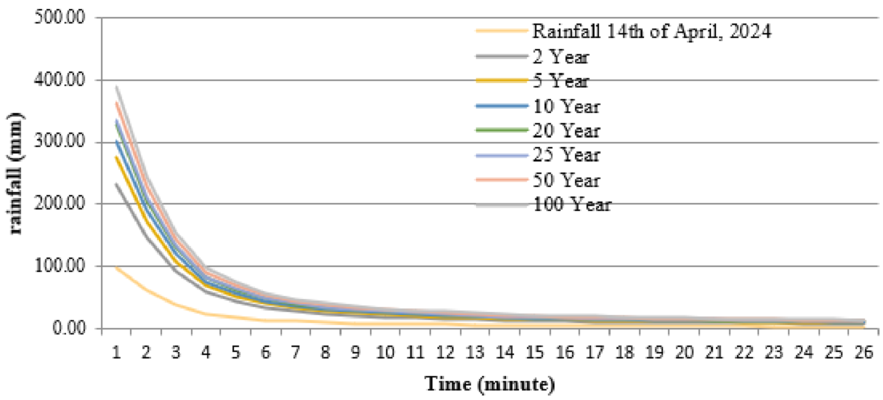


Figure 3 Curve of Intensity Duration Frequency (IDF) of Planned Rain against time

Hourly Rain Distribution with Alternating Block Method (ABM)

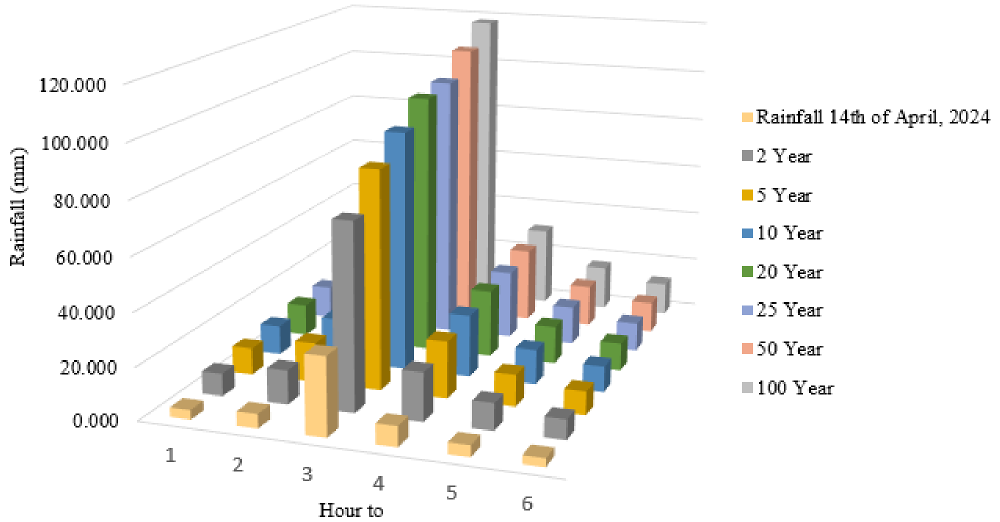


Figure 4 Hourly Rain Distribution Graph by Method *Alternating Block Method* (ABM) Per Return Period

Flood modeling with HEC-HMS

The HEC-HMS model is reliable for various hydrological simulations. Even though it looks easy, it is still considered accurate in predicting floods (Oleyiblo and Li 2010). Sarminingsih et al. (2019) agree that, based on their research in the Garang watershed, HEC-HMS shows relatively good performance in modeling rainfall-runoff processes. Ud Din et al, (2018) added that the same level of performance even applies to rural watersheds.

Table 10 Components of the HEC-HMS Model for maximum discharge analysis of the Bengaris watershed

No.	Model	Methode
1	Precipitation	Specified Hydrograph
2	Transformation	SCS Unit Hydrograph
3	Runoff Volume/Loss	SCS-CN
4	Baseflow	Not Calculated
5	Routing	Maskingum

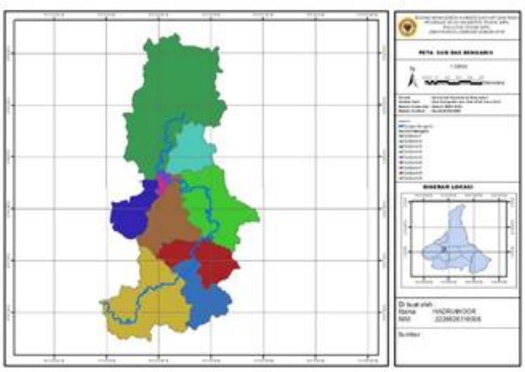


Figure 5 Bengaris sub-watershed

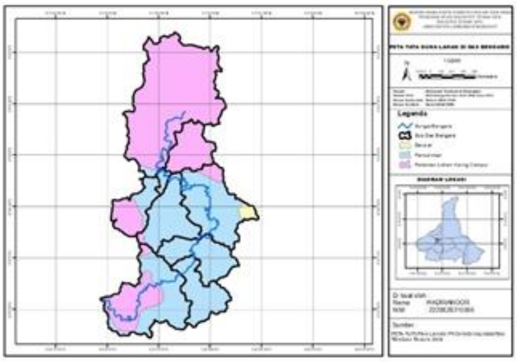


Figure 6 Land use in the Bengaris watershed

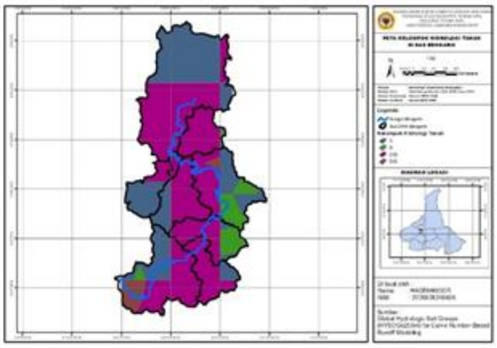


Figure 7 Soil Hydrology Groups in the Bengaris Watershed

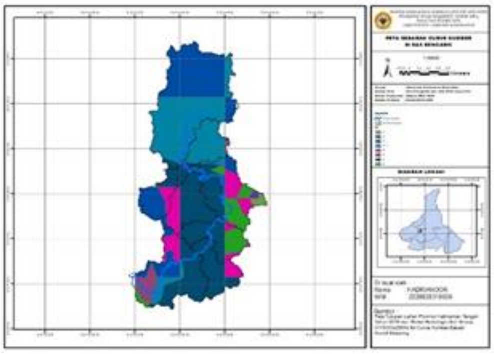


Figure 8 Curve Number Distribution in the Bengaris Watershed

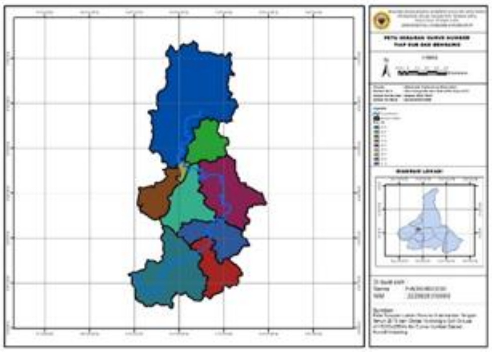


Figure 9 Curve Number for each Bengaris sub-watershed

Table 11 CN values for dry, moderate and wet conditions in the Bengaris sub-watershed

No.	Sub Basin	CN Composite		
		AMC I (dry)	AMC II (moderate)	AMC III (wet)
1	Subbasin1	67.10	82.93	91.78
2	Subbasin2	68.12	83.57	92.13
3	Subbasin3	71.25	85.51	93.14
4	Subbasin4	77.71	89.25	95.02
5	Subbasin5	80.64	90.84	95.80
6	Subbasin6	79.78	90.38	95.58
7	Subbasin7	79.93	90.46	95.62
8	Subbasin8	81.30	91.19	95.97
9	Subbasin9	74.97	87.70	94.25

Table 12 Calculation of Flood Hydrographs for the Bengaris Watershed using HEC-HMS

T	hour to	Flood discharge return period design (CMS)							
		Rainfall 14th april, 2024	2	5	10	20	25	50	100
00:00	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
01:00	1	0.1	0.2	0.30	0.30	0.30	0.30	0.40	0.40
02:00	2	0.7	1.7	2.00	2.20	2.40	2.40	2.70	2.80
03:00	3	2.8	6.8	8.00	8.80	9.60	9.80	10.60	11.40
04:00	4	7.7	18.3	21.60	23.80	25.90	26.30	28.60	30.60
05:00	5	12.8	30.5	36.10	39.70	43.20	43.90	47.70	51.10
06:00	6	11.1	26.6	31.40	34.50	37.60	38.20	41.50	44.40
07:00	7	4	9.5	11.20	12.40	13.40	13.70	14.90	15.90
08:00	8	1.2	2.8	3.40	3.70	4.00	4.10	4.40	4.70
09:00	9	1.2	2.8	3.30	3.60	3.90	4.00	4.40	4.70
10:00	10	0	0	0.00	0.00	0.00	0.00	0.00	0.00
11:00	11	0	0	0.00	0.10	0.10	0.10	0.10	0.10
12:00	12	0	0	0.00	0.00	0.10	0.10	0.10	0.10
13:00	13	0	0	0.00	0.00	0.00	0.00	0.00	0.00
14:00	14	0	0	0.00	0.00	0.00	0.00	0.00	0.00
15:00	15	0	0	0.00	0.00	0.00	0.00	0.00	0.00
16:00	16	0	0	0.00	0.00	0.00	0.00	0.00	0.00
17:00	17	0	0	0.00	0.00	0.00	0.00	0.00	0.00
18:00	18	0	0	0.00	0.00	0.00	0.00	0.00	0.00
19:00	19	0	0	0.00	0.00	0.00	0.00	0.00	0.00
20:00	20	0	0	0.00	0.00	0.00	0.00	0.00	0.00
21:00	21	0	0	0.00	0.00	0.00	0.00	0.00	0.00
22:00	22	0	0	0.00	0.00	0.00	0.00	0.00	0.00
23:00	23	0	0	0.00	0.00	0.00	0.00	0.00	0.00
24:00	24	0	0	0.00	0.00	0.00	0.00	0.00	0.00

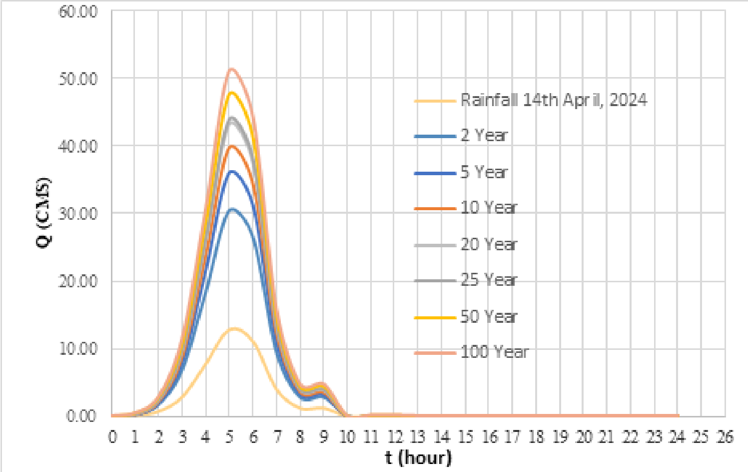


Figure 10 Bengaris Watershed Flood Hydrograph with HEC-HMS

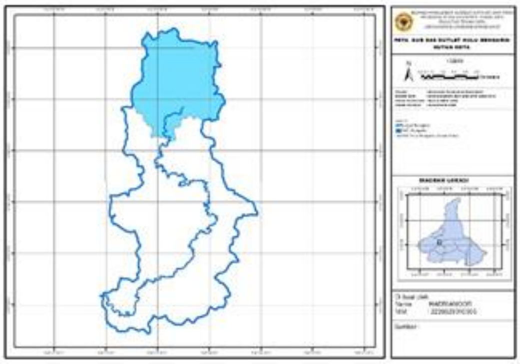


Figure 11 Upper Bengaris watershed

Table 13 Calculation of Flood Hydrographs in the Upper Bengaris River using HEC-HMS

T	hour to	Flood discharge return period design (CMS)							
		Rainfall 14th april, 2024	2	5	10	20	25	50	100
00:00	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
01:00	1	0	0	0.00	0.00	0.00	0.00	0.10	0.10
02:00	2	0	0.5	0.90	1.20	1.50	1.60	2.00	2.40
03:00	3	2.9	16.4	21.40	24.60	27.90	28.60	32.10	35.30
04:00	4	2.9	13.5	17.10	19.50	21.90	22.40	24.90	27.20
05:00	5	2	8	9.90	11.20	12.40	12.70	14.00	15.20
06:00	6	1.5	5.2	6.40	7.20	7.90	8.10	8.90	9.60
07:00	7	0.5	1.9	2.30	2.60	2.80	2.90	3.20	3.40
08:00	8	0.1	0.4	0.50	0.60	0.70	0.70	0.70	0.80
09:00	9	0	0.1	0.10	0.10	0.20	0.20	0.20	0.20
10:00	10	0	0	0.00	0.00	0.00	0.00	0.00	0.00
11:00	11	0	0	0.00	0.00	0.00	0.00	0.00	0.00
12:00	12	0	0	0.00	0.00	0.00	0.00	0.00	0.00
13:00	13	0	0	0.00	0.00	0.00	0.00	0.00	0.00
14:00	14	0	0	0.00	0.00	0.00	0.00	0.00	0.00
15:00	15	0	0	0.00	0.00	0.00	0.00	0.00	0.00
16:00	16	0	0	0.00	0.00	0.00	0.00	0.00	0.00
17:00	17	0	0	0.00	0.00	0.00	0.00	0.00	0.00
18:00	18	0	0	0.00	0.00	0.00	0.00	0.00	0.00
19:00	19	0	0	0.00	0.00	0.00	0.00	0.00	0.00
20:00	20	0	0	0.00	0.00	0.00	0.00	0.00	0.00
21:00	21	0	0	0.00	0.00	0.00	0.00	0.00	0.00
22:00	22	0	0	0.00	0.00	0.00	0.00	0.00	0.00
23:00	23	0	0	0.00	0.00	0.00	0.00	0.00	0.00
24:00	24	0	0	0.00	0.00	0.00	0.00	0.00	0.00

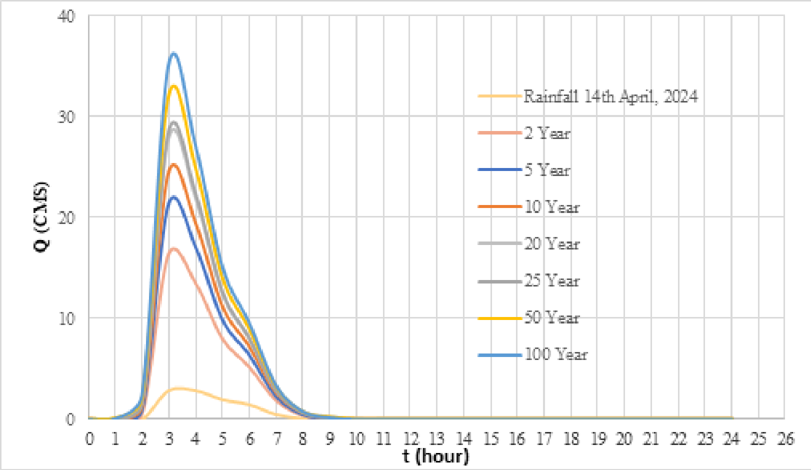


Figure 12 Upstream Flood Hydrograph of the Bengaris River with HEC-HMS

Hydraulic Analysis with HEC-RAS

Modeling Results of Existing Conditions in Unsteadyflow mode

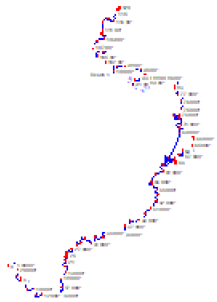
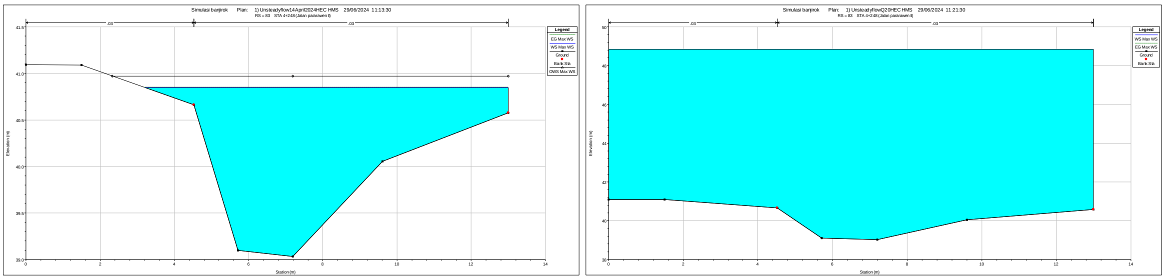
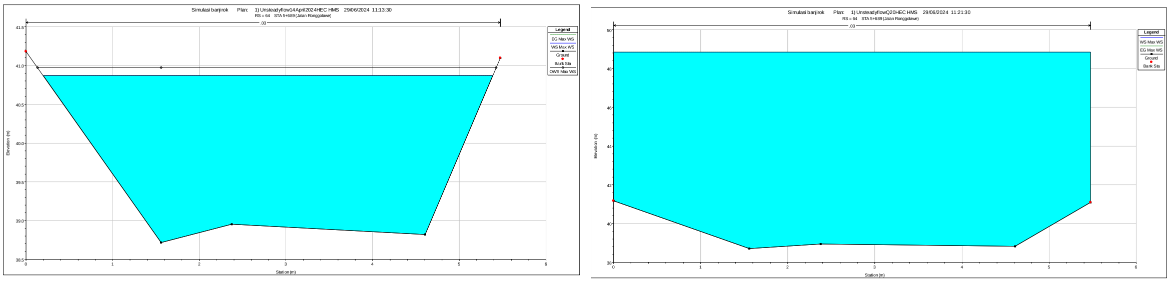


Figure 13 Schematic of the condition of the Bengaris River using HEC-RAS



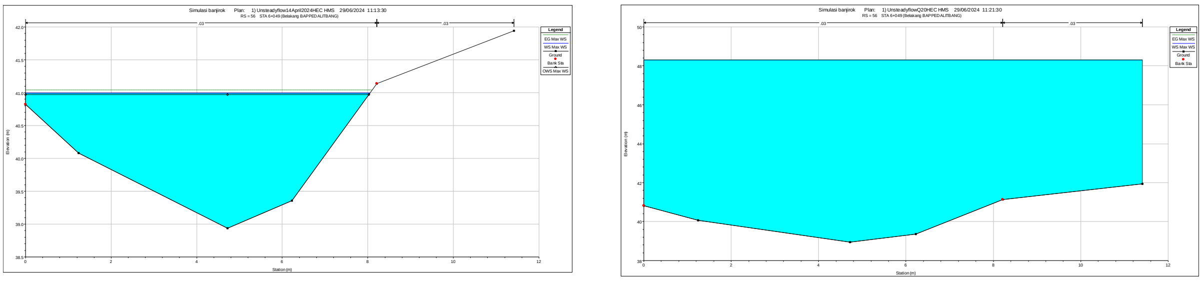
a b

Figure 14 HEC-RAS modeling of Bengaris River floods, existing conditions, rain on April 14 2024 (a) and 20 year return period (b) at STA 4+248 (Jalan Pararawen II)



a b

Figure 15 HEC-RAS modeling of Bengaris River floods, existing conditions, rain on April 14 2024 (a) and 20-year return period (b) at STA 5+689 (Jalan Ronggalawe)



a b

Figure 16 HEC-RAS modeling of Bengaris River floods, existing conditions, rain on April 14 2024 (a) and 20 year return period (b) at STA 6+049 (Behind BAPPEDALITBANG Office)

Modeling results after being given flood control with a reservoir with a return period of 20 years

Based on the Regulation of the Minister of Public Works and Public Housing of the Republic of Indonesia Number 28/PRT/M/2015 concerning the determination of river border lines and lake border lines, the provision for planned flood discharge for the design of flood control embankments in the district/city capital area is for a return period of 10 to with 20 years. And based on government regulation Number 38 of 2011 concerning rivers, the construction of flood control infrastructure which functions to reduce/reduce the level of possibility of flooding can be increased to a return period of 20 years.

There are two reservoir locations that are planned to control the 20 year return period of the Bengaris River flood, namely at STA 6+049 and STA 4+435 with reservoir storage volumes of 500 m3 and 800 m3 respectively.

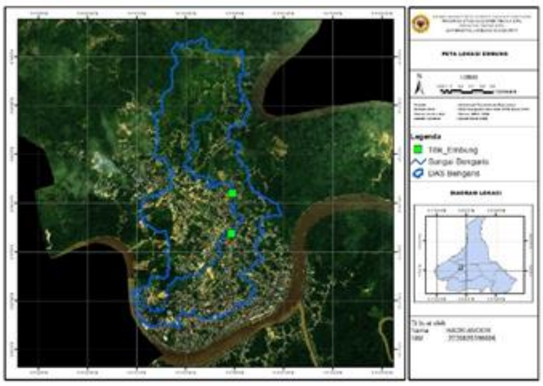


Figure 17 Reservoir Locations

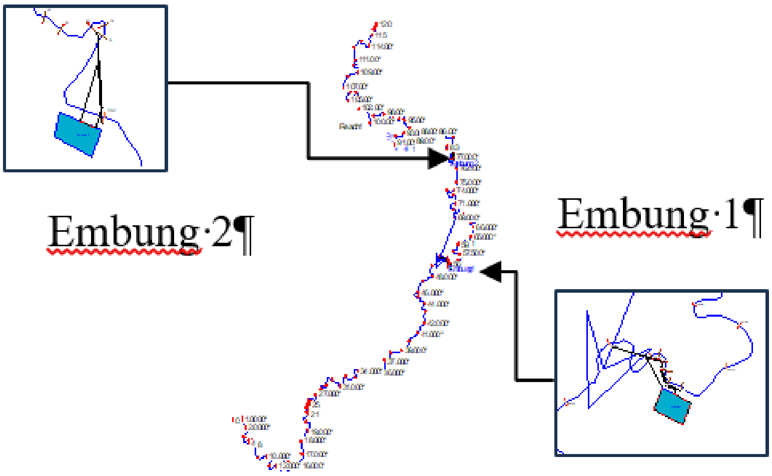


Figure 18 Schematic of the Bengaris River after being given flood control with reservoir analysis using HEC-RAS

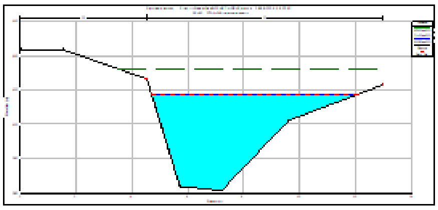


Figure 19 Bengaris River flood modeling with a return period of 20 years after being given flood control with a reservoir at STA 4+248 (Jalan Pararawen II)

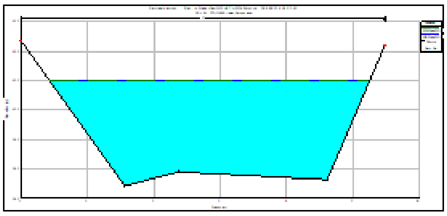


Figure 20 Bengaris River flood modeling with a return period of 20 years after being given flood control with a reservoir at STA 5+689 (Jalan Ronggolawe)

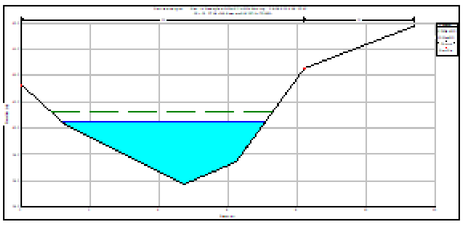


Figure 21 Bengaris River flood modeling with a return period of 20 years after being given flood control with a reservoir at STA 6+049 (behind the BAPPEDALITBANG office)

Based on the modeling results for conditions after being given a flood control scenario with reservoirs, Unsteadyflow mode, Soil Conservation Service Curve Number (SCS-CN) method in the HEC-HMS 4.10 application, for a return period of 20 years, there was a decrease in the wet area of the Bengaris River from 90% to. 96% at the locations reviewed.

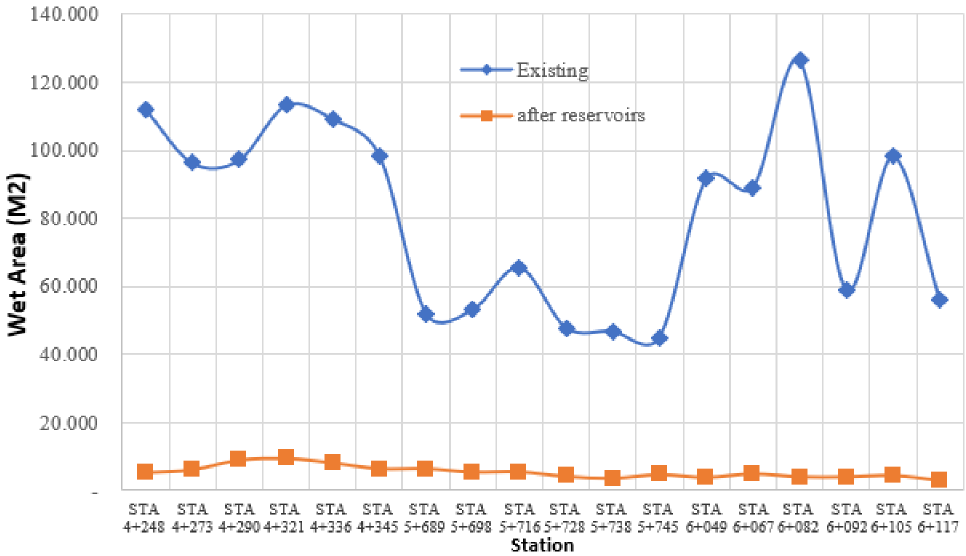


Figure 22 Modeled wet area with HEC RAS return period of 20 years before and after flood control with reservoirs

CONCLUSION

Based on research results, the capacity of the Bengaris River is only able to drain flood discharge from rain with an intensity of less than or equal to 53.70 mm, whereas to drain flood discharge with a planned return period of 20 years with a high rain intensity of 181.228 mm, a flood control system is needed.

To control the flooding of the Bengaris River during the 20 year return period at STA 4+248 (Jalan Pararawen II), STA 5+689 (Jalan Ronggolawe) and at STA 6+049 (behind the BAPPEDALITBANG Office), two reservoirs are needed, namely at STA 6+ 049 and STA 4+435 with volumes of 500 m^3 and 800 m^3 respectively.

Based on HEC-RAS modeling for a 20 year return period, there was a decrease in the river wet area at STA 4+248 (Jalan Pararawen II) from 112,030 m2 to 5.29 m2 or a decrease of 95.278%, STA 5+689 (Jalan Ronggolawe) from 51,950 m2 to 6.49 m2 or a decrease of 87.507% and STA 6+049 (behind the Bappedalitbang office) from 91,710 m2 to 3.91 m2 or a decrease of 95.737%, so that the reservoir is very effective in reducing the Bengaris River flood.

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