International Journal of Engineering and Science Applications

ISSN 2406-9833
Journal Homepage: http://pasca.unhas.ac.id/ijesca
Vol. 12, No. 1, May., 2025., pp 14-17

Hydrological Study of The Remu River Flood Control System in Sorong City

Rakhtim Akuba[1], Asep Huddiankuwera[2], Adri Raidyarto[3], irianto[4]

[1] Master of Civil Engineering Student, Postgraduate Program, Yapis University, Papua
[2] Lecturer of Master of Civil Engineering Postgraduate Program, Yapis University of Papua
[3] Lecturer of Master of Civil Engineering Postgraduate Program, Yapis University of Papua
[4] Lecturer of Master of Civil Engineering Postgraduate Program, Yapis University of Papua

Corresponding Author Email: asephuddiankuwera@gmail.com

https://doi.org/10.18280/ijesca.123456

Received: 1 Februari 2025
Accepted: 20 April 2025

Keywords:
Remu River, Flood Control, HEC-HMS, HEC-RAS

ABSTRACT

Sorong City is located in West Papua Province and is known as one of the most active cities on Papua Island, due to its abundant natural resources. However, the Remu River, which flows through the city, is one of the main causes of annual flooding, resulting in significant social and economic losses. This study aims to design an effective flood control system for the Remu River through river integration, in order to increase its flow capacity to accommodate a larger water discharge. The proposed plan includes the construction of embankments and sheet piles along the riverbanks, as well as the development of reservoirs and dam structures as flood mitigation measures. Hydraulic modelling was carried out using HEC-HMS and HEC-RAS software. In the HEC-RAS modelling, a one-dimensional approach was used to compare the flood water level with the elevation of the riverbanks. The modelling results identify river sections that are prone to overflow and guide the planning of embankments and sheet piles, which are adjusted based on the spatial constraints observed in the field.

1. Introduction

One of the areas in Indonesia that experiences flooding issues is the Remu River in Sorong City, West Papua Province. The flooding problem in the Remu River is partly due to high rainfall, which is a significant factor contributing to the overflow of the river. According to data from the Meteorology, Climatology, and Geophysics Agency (BMKG), the annual rainfall in Sorong City reaches 2500 mm per year, while the maximum daily rainfall can reach 100 mm.

The presence of the Remu River plays an important role in the lives of the surrounding community. When the river overflows into residential areas, community activities come to a halt, resulting in losses. Based on the description above, it is necessary to conduct a study for flood management through hydrological and hydraulic approaches to determine the planned rainfall, planned flood discharge, and alternative flood management strategies for the Remu River. Considering the points outlined in the background, the issues to be discussed can be formulated as follows:

1. In addressing the flooding of the Remu River, an analysis is required to determine the design flood discharge.
2. An analysis is needed to identify alternative flood control structures for the Remu River.

Analysis of Planned Rainfall

In determining planned rainfall, data from rain gauges only provide rainfall measurements at specific points (point rainfall). To obtain area-wide rainfall, several methods can be used, including (Algebra, Thiessen Polygon, and Isohyet).

Flood Control System

Flood control systems can be implemented through various methods from upstream to downstream. Flood control measures can be carried out using both structural and non-structural approaches. Structural (Improvement and Regulation of River Systems, Dams, Retention Ponds, Construction of Check Dams [Sediment Traps], etc.) Non-Structural (Watershed Management, Land Use Regulation, etc.)

2. Research Methodology

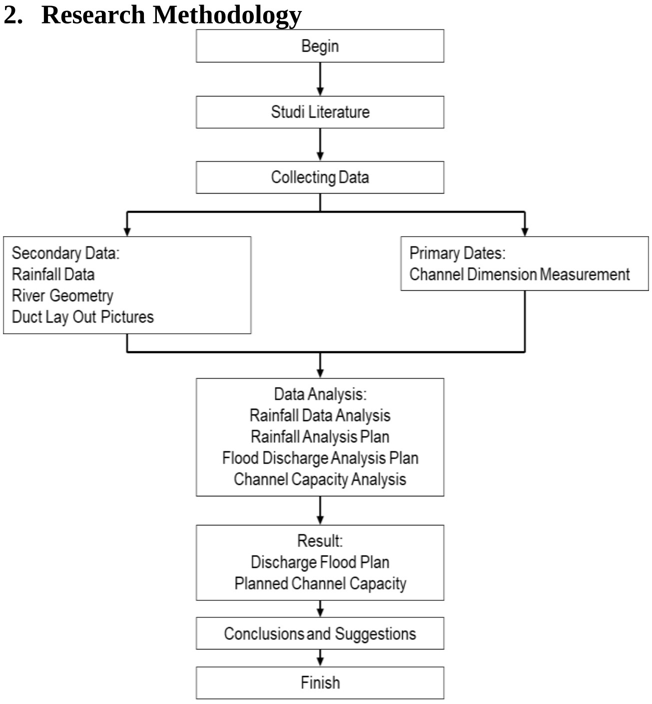

Figure 1. Research Flowchart

3. Results and Discussion

Hydrological Analysis

The river water level data recorded at the AWLR (Automatic Water Level Recorder) is one of the essential elements in river cross-section planning. This data can be converted into discharge data. In this study, the discharge data for the Remu River was obtained from the AWLR station managed by the West Papua River Basin Organization (Balai Besar Wilayah Sungai Papua Barat).

Table 1. Table of Maximum Discharge Data

No	Date	Year	TMA (m)	Flowrate (m^3/sec.)
1	2010	11/02/2012	5.66	124.668
2	2011	10/01/2013	6.88	274.443
3	2012	08/01/2014	5.79	148.806
4	2013	20/01/2015	5.60	112.341
5	2014	17/11/2016	4.74	86.390
6	2015	12/01/2017	5.80	152.973
7	2016	14/02/2018	5.75	147.920
8	2017	11/11/2019	5.03	90.171
9	2018	23/12/2020	5.84	155.541
10	2019	25/01/2021	6.98	279.866

Source: West Papua River Basin Organization

Analysis of Return Period Discharge

Return period is defined as the hypothetical time frame in which a discharge or rainfall of a certain magnitude (xT) will be equaled or exceeded once within a specified period. The design return period discharge is one of the processes in hydrological analysis. The method used in this study is the Log Pearson Type III, considering that this distribution is more flexible as it does not have constraints on the skewness coefficient or the kurtosis coefficient.

Tabel 2. Table of Annual Maximum Discharge of the Remu River Using the Log Pearson Type III Method

No	Rmax (mm)	Opportunity (%)	Log X	[Log X - Log Xaverage]	[Log X - Log Xaverage] 2	[Log X - Log Xaverage] 3
1	79.00	9.09	1.898	-0.171	0.02922	-0.00499
2	81.00	18.18	1.908	-0.160	0.02562	-0.00410
3	99.00	27.27	1.996	-0.073	0.00532	-0.00039
4	107.00	36.36	2.029	-0.039	0.00153	-0.00006
5	107.00	45.45	2.029	-0.039	0.00153	-0.00006
6	111.00	54.55	2.045	-0.023	0.00054	-0.00001
7	112.00	63.64	2.049	-0.019	0.00037	-0.00001
8	125.00	72.73	2.097	0.028	0.00080	0.00002
9	201.00	81.82	2.303	0.235	0.05506	0.01292
10	214.00	90.91	2.330	0.262	0.06857	0.01796
	Average Log x			2.0686		
	Yn			0.5202		
	Sn			1.0493		
	SD			0.1447		
	Cs			0.9742		

Tabel 3. Table of Design Flood Discharge Analysis Calculation Using the Log Pearson Type III Method

No	Tr	P(%)	G tabel	Xt (mm)
1	1.01	99.0	-2.381	52.96
2	2	50.0	0.013	117.59
3	5	20	0.845	155.19
4	10	10	1.273	178.99
5	25	4	1.725	208.09
6	50	2	2.014	229.12
7	100	1	2.271	249.63

The value of G is obtained from the Log Pearson Type III table, which is a function of Cs (skewness coefficient) and probability (return period)

Goodness of Fit Test for Frequency Distribution

The frequency distribution used to estimate design floods may not necessarily conform to the selected distributions. Therefore, it is essential to conduct a goodness of fit test. To ensure that the empirical approach can be accurately represented by the theoretical curve, a distribution fit test must be performed. There are two tests that can be conducted in this regard: the Smirnov-Kolmogorov test or the Chi-Square test.

Table 4. Uji Smirnov Kolmogorov

No	Rmax (mm)	Pe (%)	Log X	Average Log X	SD	G	P (%)	Pt (%)	D
1	79.00	9.09	1.898	2.0686	0.1447	-1.1809	92.29	7.71	0.014
2	81.00	18.18	1.908	2.0686	0.1447	-1.1059	87.56	12.44	0.057
3	99.00	27.27	1.996	2.0686	0.1447	-0.5038	72.61	27.39	0.001
4	107.00	36.36	2.029	2.0686	0.1447	-0.2706	60.00	40.00	0.036
5	107.00	45.45	2.029	2.0686	0.1447	-0.2706	60.00	40.00	0.054
6	111.00	54.55	2.045	2.0686	0.1447	-0.1605	56.11	43.89	0.107
7	112.00	63.64	2.049	2.0686	0.1447	-0.1336	55.16	44.84	0.188
8	125.00	72.73	2.097	2.0686	0.1447	0.1959	43.53	56.47	0.163
9	201.00	81.82	2.303	2.0686	0.1447	1.6210	-6.76	106.76	0.249
10	214.00	90.91	2.330	2.0686	0.1447	1.8090	-14.75	114.75	0.238
D max									0.249

Table 4. Uji Chi Square-1

No	P (%)	Tr	K	Log x	CH Design (mm)
1	20	1.25	0.851	2.192	155.49
2	40	1.67	0.308	2.113	129.77
3	60	2.50	-0.251	2.032	107.68
4	80	5.00	-0.829	1.949	88.84

Table 5. Uji Chi Square-2

Class interval	Ej	Oj	(Oj-Ej)^2/Ej
0 - 88.84	2.0	4	2.000
88.84 - 107.68	2.0	2	0.000
107.68 - 129.77	2.0	1	0.500
129.77 - 155.49	2.0	1	0.500
155.49 -	2.0	2	0.000
	10.0	10	
$X_{2\ calculation}$			3.000

Return Period of Existing Maximum Discharge

Based on the available maximum discharge data for 10 years, it was found that the maximum discharge in 2011 was the largest, recorded at 214 m³/s.

Log X = Log Xaverage + (G x Sd)

Log 214 = 2,0686 + (G x 0,1447)

G = 1,809

With a skewness coefficient (Cs) of 0.9742, the value of G = 1.809 falls between the return periods of 5 years and 25 years. By using interpolation, the discharge of 214 m³/s is found to be close to the return period of 20 years.

Rainfall Frequency Analysis

Rainfall Frequency Analysis The purpose of frequency distribution analysis is to obtain the design rainfall amounts established based on specific design criteria. For the analysis, rainfall with return periods of 2, 5, 10, 25, 50, and 100 years is determined.

Table 6. Table of Recapitulation of Design Rainfall Calculation Results

No	Repeat Period	Method	Method	Method	Method
	(Year)	Normal	Log Normal	E.J Gumbel	Log Pearson III
1	2	123.60	117.10	116.80	117.59
2	5	162.69	155.02	166.97	155.19
3	10	183.13	179.50	200.19	178.99
4	25	204.92	209.88	242.16	208.09
5	50	219.00	232.19	273.30	229.12
6	100	231.66	254.27	304.21	249.63
				Smirnov Kolmogorov test	
DP Maximum, P Max (%)		0.2350	0.321655423	0.17	0.249
Degree of Significance, a (%)		5	5	5	5
D Critical (%)		0.309	0.409	30	0.409
Hypothesis		Accepted	Accepted	Accepted	Accepted
				Uji Chi Square	
Chi Square Calculation		3.00	3.00	3.00	3.00
Chi Square Critical		5.991	5.99	5.99	5.991
Degrees of Freedom		2	2	2	2
Degree of Significance		5.00	5.00	5.00	5.00
Hypothesis		Accepted	Accepted	Accepted	Accepted

Recapitulation of Design Rainfall Calculation Results

Based on the analysis of the design rainfall, it was found that the method is accepted by both the Smirnov and Chi-Square tests. The Log Pearson III method provides the maximum D value in the Smirnov-Kolmogorov test that is closest to the critical D value, thus the design rainfall is taken from the Log Pearson III method. The results of this frequency analysis are verified against the isohyet map issued by the Dam Office.

Based on calculations using the Normal method, the value of R100 is obtained as 231.66 mm, while according to the isohyet map, the value of R100 for the Remu watershed is between 300 mm and 350 mm. Therefore, the calculation results are considered sufficiently valid.

Rainfall Distribution

In river planning, to estimate the design flood hydrograph using the unit hydrograph method, it is necessary to first know the hourly rainfall distribution over a specific interval. Since hourly rainfall data is not available, the Mononobe method is used for determining rainfall distribution, employing the Alternate Block Method (ABM) with the assumption that the rainfall occurs over a duration of 4 hours.

Table 7. Table of Hourly Rainfall Distribution in the Remu Watershed

Repeat period	Rn	Rainfall Distribution Ratio					
		0.550	0.143	0.100	0.080	0.067	0.059
2	88.20	48.54	12.62	8.85	7.05	5.95	5.20
5	116.39	64.05	16.65	11.68	9.30	7.85	6.86
10	134.24	73.88	19.20	13.47	10.72	9.06	7.92
20	156.07	85.89	22.32	15.66	12.47	10.53	9.20
50	171.84	94.57	24.58	17.24	13.73	11.59	10.13
100	187.22	103.03	26.78	18.79	14.96	12.63	11.04

Capture Model

Table 8. Table of Sub-Watershed Forming Parameters in the Watershed

Catchment	Wide (km^2)	Length of Channel/River (m)	Time	lag	CN
D01	0.05423	0.27	6.61	Minutes	75.00
D02	0.12346	0.49	4.96	Minutes	74.91
D03	0.08028	0.49	9.85	Minutes	74.48
D04	0.25259	0.67	12.87	Minutes	70.88
D05	0.26283	1.00	7.35	Minutes	75.00
D06	0.04655	0.41	3.76	Minutes	69.31
D07	0.84951	2.05	13.25	Minutes	74.16
D08	0.08028	0.21	4.84	Minutes	74.95
D09	0.14244	0.78	9.06	Minutes	75.00
D10	0.76040	1.87	13.43	Minutes	70.64
D11	0.34313	1.65	14.66	Minutes	69.35
D12	0.01714	0.26	4.72	Minutes	71.75
D13	0.59505	1.30	18.73	Minutes	75.00
D14	0.05655	0.54	24.18	Minutes	75.00
D15	0.20149	0.69	6.07	Minutes	75.00
D16	0.23913	1.02	22.20	Minutes	70.38
D17	0.02769	0.33	9.55	Minutes	75.00
D18	0.09227	0.51	10.49	Minutes	60.00
D19	0.07107	0.28	8.28	Minutes	75.00
Remu Hulu	50.30	18.12	4.62	Hour	63.68

Flood Control Techniques

Essentially, flood control is a complex matter. Its engineering dimension involves many technical disciplines, including hydrology, hydraulics, land erosion in catchment areas, river engineering, river morphology and sedimentation, flood control system engineering, urban drainage systems, hydraulic structures, and others.

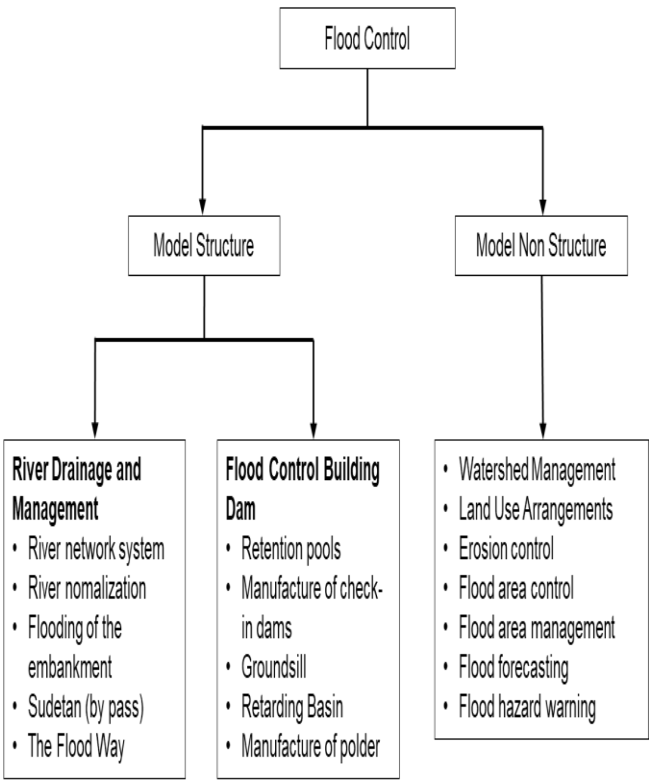

Figure 2. Flood Control Diagram

period (TR25) and reduce flood risks along the Remu River.

Sungai Remu River Flood Control Concept

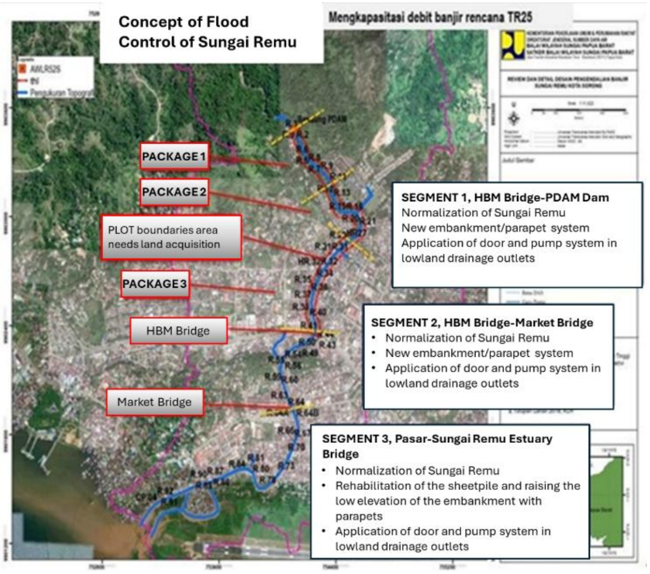

Figure 3. Flood Control Concept

4. Conclusion

1. Based on the land cover analysis, the conversion of land from forest to non-forest areas has the potential to increase the runoff coefficient, thereby raising the flood peak discharge. The land cover in the Remu watershed is still relatively good, with secondary forest area in 2018 covering 34.06 km² (62.36%), compared to 37.21 km² in 2011. An increase in rainfall intensity-whether due to higher rainfall over the same duration, the same rainfall amount in a shorter duration, or both increased rainfall and shorter duration-can also elevate the flood peak discharge. The current design flood discharge is now significantly higher than in previous studies, with a TR25 value of 198.2 m³/second compared to the previous 75.62 m³/second. Sedimentation in the Remu River has resulted in a reduced cross-sectional capacity of the river. This sediment originates from riverbank collapse and watershed erosion. Although the erosion rate in the Remu watershed is still considered low, the potential volume of sediment entering the Remu River remains substantial.
2. The flood management of the Remu River is carried out by increasing the river's capacity to accommodate the design discharge up to the TR25 flood event. This includes: Enhancing the river capacity in Segment 1 (PDAM Weir – HBM Bridge) through normalization of the Remu River, construction of new embankments/parapets, and implementation of gate and pump systems at drainage outlets in the lowland areas. Similarly, in Segment 2 (HBM Bridge – Pasar Bridge), river normalization and capacity improvements are conducted. In Segment 3 (Pasar Bridge – River Mouth), normalization activities are performed, while in areas with low or damaged embankments, the river cross-sectional capacity is increased and riverbanks are reinforced using sheet piles. Existing sheet piles are maintained, and gate and pump systems are also applied in the lowland drainage areas. These measures aim to effectively manage flood discharge up to the 25-year return period (TR25) and reduce flood risks along the Remu River.

REFERENCES

Ahira Anne. 2011. How to Overcome Floods. [on-line]. (www.anneahira.com/cara-menanggulangi-banjir.html)

Asdak, Chay. 2010. Hydrology and Watershed Management. Gadjah Mada University Press: Yogyakarta.

Limantara, Montarcih. 2010. Practical Hydrology, CV. Lubuk Agung, Bandung.

Loebis, et al. 1987. River Hydrology. Yayasan Badan Penerbit Pekerjaan Umum.

Soemarto, C.D. 1999. Hydrology – Measurement and Processing of River Flow Data – Hydrometry. Nova: Bandung.

Soewarno. 1991. Hydrology: Measurement and Processing of River Flow Data. PT Nova, Bandung.

Soewarno. 1995. Hydrology: Measurement and Processing of River Flow Data (Hydrometric). Nova: Bandung.

Soewarno. 1995. Hydrology for the Application of Statistical Methods for Data Analysis Volume 1. NOVA. Bandung.

Sosrodarsono, S. and Takeda, K. 1987. Hydrology for Irrigation. PT. Pradnya Paramita: Jakarta.

Sosrodarsono, Suyono and Kensaku Takeda. 1977. Hydrology for Irrigation. PT Pradnya Paramita. Jakarta.

Sri Harto. 1993. Hydrological Analysis, Gramedia Pustaka Utama, Jakarta.

Subarkah Imam, Ir. 1978. Hydrology for Water Structure Planning. Idea Dharma, Bandung.

Suripin. 2004. Sustainable Urban Drainage System, Andi, Yogyakarta.

Triatmodjo, Bambang. 2008. Hydrology.