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Flood Modeling of the Batang Sungai Lengayang Area with Hec-Ras Program

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ABSTRACT

Floods are disasters that disrupt human life caused by human and natural factors. Natural conditions that affect flooding in West Sumatra are rainfall patterns in water areas, sea surface temperature patterns, and whirlpool patterns in the Indian Ocean. Batang Lengayang is a river that is prone to flooding. Floods in the Batang Lengayang river occur every year, especially during the rainy season. According to the Central Statistics Agency of Pesisir Selatan Regency, in Lengayang District, floods were recorded 5 times throughout 2020, 8 times in 2021, and 10 times in 2022. Meanwhile, in 2024, there was also a flash flood on March 7 which was caused by very high rainfall intensity and on a long time scale. This study aims to determine the flood discharge of the Batang Lengayang river with a return period of 50 and 100 years. Furthermore, this study also aims to model the Batang Lengayang river flood using HEC RAS. And to determine the area of flood inundation of the Batang Lengayang river for a return period of 50 and 100 years. The results of the study showed that the 50-year return period produced a maximum flood discharge of 399 m^3/second and the 100-year return period produced a maximum flood discharge of 444.46 m^3/second. The modeling results showed that the flood area increased with the addition of the return period. The flood area obtained was 376 ha or 3.7 km^2 for the 50-year return period and 412 ha or 4.12 km^2 for the 100-year return period.

Keywords: *Floods; HEC-RAS; River; Batang Lengayang; Return Period.*

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INTRODUCTION

A river is an open flow that has geometric dimensions, namely a cross-section, longitudinal profile, and a valley slope that changes over time, depending on the discharge, base material and cliffs.[1]. Lengayang River is one of the rivers located in Lengayang District, Pesisir Selatan Regency. Geographically, Lengayang River is located at 1°40'7.18" South Latitude and 100°45'26.68" East Longitude, with a river length of 48 km^2. The Lengayang River Basin has a hilly topography with an altitude ranging from 0-1000 meters above sea level. The topography of this area includes plains, mountains, and hills which are an extension of the Barisan Mountains. Many benefits can be obtained from rivers such as irrigation for agriculture, water sources for living needs, wastewater transport, rainwater storage, and even tourist attractions. Despite its many benefits, rivers can also cause disasters such as floods.

Floods are disasters that disrupt human life in the form of pools of water from the smallest to the largest caused by both human and natural factors or high water discharge, and cannot be accommodated by river flow so that the water overflows to higher and lower land.[2].

According to[3]explains the natural conditions that affect flooding in West Sumatra are rainfall patterns in water areas, temperature patterns on the sea surface and whirlpool patterns in the Indian Ocean that affect weather and flooding in West Sumatra. Lengayang River is a river that is prone to flooding. Flooding in Batang River Flooding in Lengayang River occurs every year, especially during the rainy season. This has become a concern for people living on the banks of the river.

According to the Central Statistics Agency of Pesisir Selatan Regency, in Lengayang District, there were 5 floods throughout 2020, 8 in 2021, and 10 in 2022. Meanwhile, in 2021-2024, there was also a flash flood on March 7 which was caused by very high rainfall intensity and on a long time scale. The impact of the flood incident was the damage to facilities and infrastructure in the form of houses and their equipment, environmental pollution due to waste carried by the current flood, crop failure, and the death of livestock.[4], [5], [6]. The flood problem in this area really needs attention because it disrupts various activities of the surrounding community and causes a lot of losses. In addition, high rainfall[7], river shallowing[8], and illegal logging[9], [10]considered as one of the causes of flooding.

Mitigation is a series of activities carried out to minimize and reduce the impact of risks caused by a disaster.[11]. Mitigation steps are needed to reduce the impact of risks that may occur if a flood occurs.[12]. To anticipate disaster management, flood modeling is needed. This is important because it can provide an overview of flood events that may occur in the future so that losses and victims can be minimized. This can be modeled using Hec-Ras.

HEC-RAS is an application designed to model the hydraulic behavior of water in all types of river flows.[13]. Including for river overflow simulation. This program is the next generation program from HEC which stands for Hydraulic Engineering Center. HEC itself develops a lot of software to analyze various modeling related to hydrology and hydraulics problems. The software designed by HEC such as, HEC-HMS, HECRessim and HEC-FDA.

METHOD

The type of research used in this study is quantitative. The research method is in the form of hydrological calculations and hydraulic modeling using HEC-RAS. This study uses a Geographic Information System (GIS) integrated with Arcgis and Hec-Ras software. Arcgis is used for DEM data processing. In the form of making topography, boundaries and watershed areas to be studied. While Hec-Ras can be used to model floods at certain return periods.

This research was conducted in several stages as follows:

1. Literature Study
   Literature study is a library study to obtain theories or materials related to the main problem including simulation, flooding, mitigation, calculations and hydrology.
2. Data collection
   The type of data used in this study is secondary data in the form of rainfall and DEM. Rainfall data was obtained from PSDA and taken from the nearest rainfall station to the research location. While DEM data was obtained from the Geographic Information Agency (BIG).
3. Hydrological Analysis
   The initial step in conducting a hydrological analysis is to process the rainfall data that has been obtained. After the rainfall data is processed, the next step is to determine the statistical parameters to select the appropriate frequency distribution method. The

methods in question are the EJ Gumbel method and the Log Pearson III method. Then the accuracy of the frequency distribution results is tested. The method for testing data accuracy is to use the Chi-Square test method or the Smirnov-Kolmogorov test. Next, find the planned flood discharge. Then the results obtained are entered into HEC-RAS on the Unsteady Flow data input.

4. River Hydraulic Analysis
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RESULTS AND DISCUSSION

Hydrological Analysis

1. Rainfall Calculation
   The rainfall data used in this study is rainfall data from the research location, namely Surantih Station, obtained from the Center for Water Resources Development. The rainfall data used in this study was conducted over the past 10 years (2013-2022). The rainfall data for Surantih Station can be seen in the table.

Table 1. Rainfall Data

Year	Jan	Feb	Mar	Apr	May	June	Jul	Agus	September	Oct	Nov	Dec
2013	81	58	23	69	25	40	56	163	46	50	79	152
2014	51	18	54	38	37	11	30	71	175	55	165	70
2015	77	164	65	75	34	110	141	160	66	53	70	61
2016	92	102	70	81	107	16	38	35	26	55	57	42
2017	44	15	63	23	49	56	42	87	63	41	39	63
2018	27	130	18	29	67	24	38	33	47	41	43	37
2019	29	20	38	30	27	15	78	22	20	7	10	14
2020	85	19	34	26	17	23	24	4	62	55	43	15
2021	52	34	68	49	35	15	21	38	90	86	23	87
2022	51	33	12	35	54	55	29	34	64	39	86	41

Based on the daily rainfall table at Surantih station, the maximum daily rainfall was obtained according to the table.

Table 2. Maximum Daily Rainfall Data

no	Year	Maximum Daily Rainfall (mm)
1	2013	163
2	2014	175
3	2015	164
4	2016	107
5	2017	87
6	2018	130
7	2019	78
8	2020	85
9	2021	90
10	2022	86

2. Frequency Analysis
   Frequency analysis is obtained by using calculations in Microsoft Excel using existing formulas and data. The calculation results can be seen in the table.

Table 3. Maximum Rainfall Data Testing

No	Year	Size (mm)	(RR)	(RR ')^2	(Rp ')^3	(RR ')^4
1	2013	163	46.50	2162.25	100544.625	4675325.0625
2	2014	175	58.50	3422.25	200201.625	11711795.0625
3	2015	164	47.50	2256.25	107171.875	5090664.0625
4	2016	107	-9.50	90.25	-857,375	8145.0625
5	2017	87	-29.50	870.25	-25672.375	757335.0625
6	2018	130	13.50	182.25	2460.375	33215.0625
7	2019	78	-38.50	1482.25	-57066.625	2197065.0625
8	2020	85	-31.50	992.25	-31255.875	984560.0625
9	2021	90	-26.50	702.25	-18609.625	493155.0625
10	2022	86	-30.50	930.25	-28372.625	865365.0625
Total		year 1165	0.00	13090.50	248544.000	26816624.6250
Average (R')		116.50			Amount of Data	10
Standard Deviation (S)		38.14			Kurtosis Coefficient (Ck)	2.52
Slope (Cs)		0.62			Coefficient of Variance (Cv)	0.33

Based on the results of the maximum rainfall data test, it is continued by determining the type of distribution using the Skewness value, kurtosis coefficient, and variation coefficient used to determine the type of distribution to be used. The calculation can be seen in the table.

Table 4. Testing of Maximum Rainfall Distribution Types

<table>
<tr><th colspan="6">Distribution Requirements</th></tr>
<tr><th>No</th><th>Distribution Type</th><th>Condition</th><th colspan="2">Calculation Results</th><th>Information</th></tr>
<tr><td rowspan="4">1</td><td rowspan="4">Normal Distribution</td><td>Tsk ~ 3</td><td rowspan="5">Ck =</td><td rowspan="5">3.11</td><td rowspan="4">Does not meet the</td></tr>
<tr><td></td></tr>
<tr><td></td></tr>
<tr><td>Cs ~ 0</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Log-Normal Distribution</td><td>Temperature ~ 0.06</td><td rowspan="2">Does not meet the</td></tr>
<tr><td>Equation Cs ~ 3Cv + Cv2 = 0.1482</td><td rowspan="2">Cs =</td><td rowspan="2">0.62</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">Gumbel Distribution</td><td>Cs ~ 1.1396</td><td rowspan="2">Does not meet the</td></tr>
<tr><td>Check ~ 5.4002</td><td rowspan="3">Cv =</td><td rowspan="3">0.07</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Type III Log-Person Distribution</td><td>Cs ~ free</td><td rowspan="2">Fulfil</td></tr>
<tr><td>Cv ~ free</td></tr>
</table>

3. Log Period Return of Rainfall Pearson Type III Method
   The Log Pearson Type III method calculation takes into account the Slope Coefficient to obtain the K value (Log Pearson Type III coefficient). The Log-Pearson Type III calculation is as follows.

Table 5. Pearson Type III log calculation

PUH	KTR	Max Rainfall
2	-0.114	107,329
5	0.824	144,328
10	1,370	171,495
50	2.326	231,925
100	2,668	258,357

4. Chi-Square Equation
   After the calculation is done using Microsoft Excel by entering the formula and data, the results obtained are as in the table.

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Table 6. Chi-Square Method

Class	Interval	Hey	Hey	Ei Oi	(Ei- Oi)² /Ei
1	>145,545	2	3	1	0.5
2	118,717-145,545	2	1	-1	0.5
3	108,646-118,717	2	number 0	-2	2
4	103.526-108.646	2	2	number 0	number 0
5	<103,526	2	4	2	2
Amount		10	10		5

Table 7. Calculation Requirements for the Chi-Square Test Method

Condition	X^2	<	Xcr^2	Fulfil
	5	<	5,991 years	

Based on the calculation results above, it can be concluded that the test distribution on log person type III using the chi-square equation has met the requirements. So that the value for the planned rainfall at a 2-year return period of 107,329 mm, a 5-year return period of 144,328 mm, a 10-year return period of 171,495 mm, a 10-year return period of 171,495 mm, a 50-year return period of 231,925 mm, and a 100-year return period of 258,357 mm. However, in this study the author only conducted flood modeling at a return period of 50 and 100 years.

5. Rain Intensity Analysis

In processing rainfall intensity data, the formula used is Mononobe to calculate the rainfall that occurs. Planned rainfall data obtained through Pearson Log Distribution Type III produces rainfall intensity values in tabular form.

Table 8. Calculation of Rainfall Intensity

	Planned rainfall with return period (mm)	
	50 years	100 years
Rt	231,925	258,357
Duration of Rain	Rain Intensity With Recurrence Period	
	lt 50 years	lt 100 years
1	80,404	89,567
2	50,651	56,424
3	38,654	43,060
4	31,908	35,545
5	27,498	30,632

	Planned rainfall with return period (mm)	
	50 years	100 years
Rt	231,925	258,357
Duration of Rain	Rain Intensity With Recurrence Period	
	lt 50 years	lt 100 years
13	14,543	16,200
14	13,842	15,419
15	13,220	14,726
16	12,663	14.106
17	12.161	13,547

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6	24,351	27.126
7	21,972	24,477
8	Number 20.101	22,392
9	18,583	20,701
10	17,322	19,297
11	16.256	18.109
12	15,340	17,088

18	11,707	13,041
19	11,292	12,579
20	10,912	12.156
21	10,563	11,767
22	10,241	11,408
23	9,942	11,075
24	9,664	10,765

6. Planned Debit Plan

   In determining the design discharge, the rational method is used. As seen in the table, it can be seen that the flood discharge at the time of the 50-year return period is 399 m³/s and 444.46 m³/s year.

Table 9. Flood Discharge Calculation

PUH	Max Rainfall	I	C	A(Km²)	Q (m³/day)
50	231.93	285.34	0.6	8.39	399.00
100	258.36	317.85	0.6	8.39	444.46

Hydraulic Analysis

1. Flood Map of Lengayang River Basin 50 Year Return Period

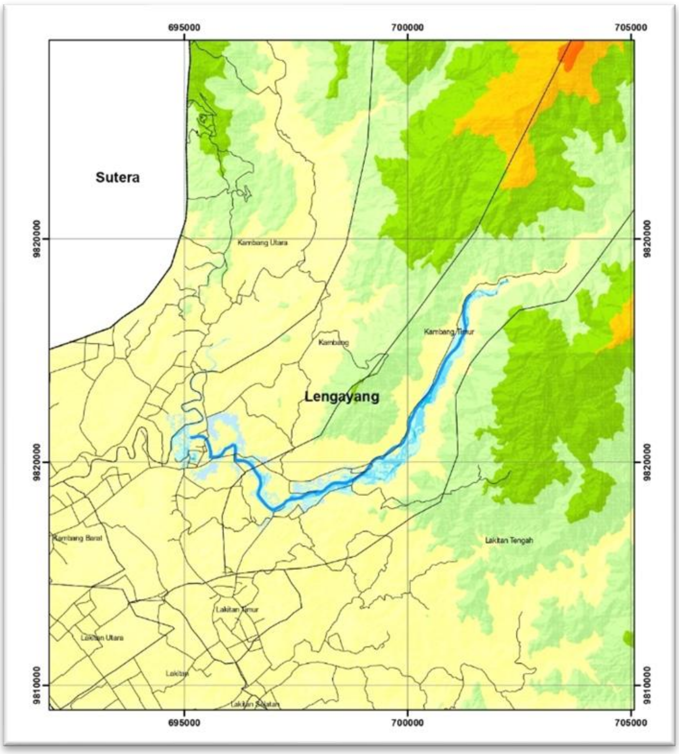

Figure 2. Lengayang River Flood Map, 50 Year Return Period

The 50-year return period models the flood area overflowing from the area's rivers. The flood inundation area that occurred in this return period was 3.7 km2. Meanwhile, the flood discharge obtained based on the results of the hydrological analysis was 399 m3/s. The inundated areas were Nyiurgading with a depth of 1.7 meters at 23:00, Koto Baru with a depth of 1.3 meters at 23:00, Tampunik with a depth of 1.57 meters at 15:00, Kapau with a depth of 1.22 meters at 04:00, and Koto Kandis with a depth of 1.6 meters at 04:00.

2. Flood Map of 100 Year Return Period of Lengayang River Basin

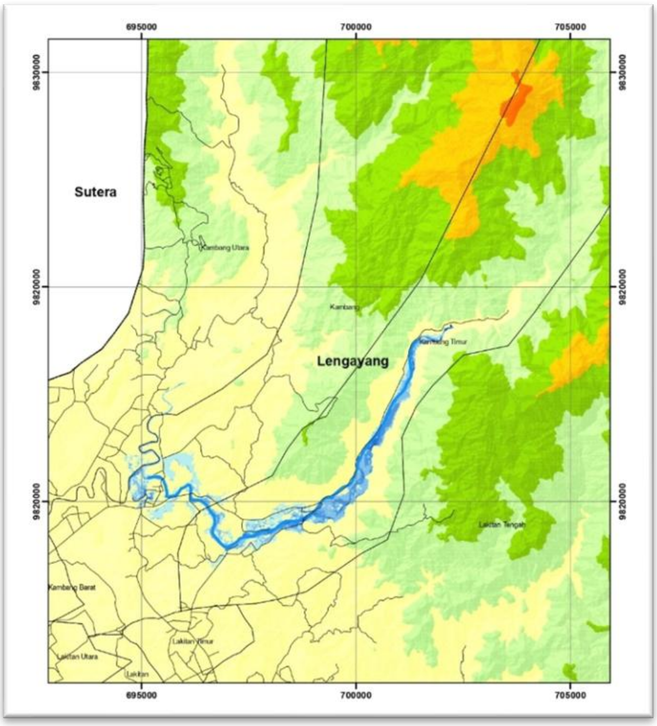

Figure 3. Flood Map of Lengayang River 50 Year Return Period

The 100-year return period models the flood area overflowing from the river area. The flood inundation area that occurred in this return period was 4.12 km2. Meanwhile, the amount of flood discharge obtained based on the results of the hydrological analysis was 444.46 m3/s. The areas inundated by floods were Nyiurgading with a depth of 1.8 meters at 23:00, Koto Baru with a depth of 1.4 meters at 23:00, Tampunik with a depth of 1.93 meters at 15:00, Kapau with a depth of 1.3 meters at 04:00, and Koto Kandis with a depth of 1.7 meters at 04:00.

CONCLUSION

Based on the results of the research and discussion, the following conclusions were obtained from the flood modeling research in Lengayang District, Pesisir Selatan Regency which is empty. The prediction results show that the flood discharge increases along with the addition of the return period. The maximum flood discharge or peak discharge obtained is a 50-year return period of 399 m^3/s and a 100-year return period of 444.46 m^3/s. The modeling results show that the flood area increases along with the increase in the return period. The flood area obtained is 376 ha or 3.7 km^2 on the 50th anniversary and 412 ha or 4.12 km^2 on the 100th anniversary. Hydraulic modeling using HEC-RAS shows that the Batan Lengayang River is unable to channel the water discharge produced by calculating the 50 and 100-year return periods.

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