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ANALYSIS OF THE IMPACT OF CROSS-SECTIONAL MODIFICATION ON THE FLOOD POTENTIAL OF GUNTUNG PAYUNG RIVER USING HEC-RAS SOFTWARE

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ABSTRACT

The Guntung Payung River in Banjarbaru City has undergone a structural cross-section modification from a box culvert to a bridge to address flooding caused by the inability of the existing cross-section to accommodate peak rainfall discharge. This study employed a Steady Flow 1D hydraulic simulation using HEC-RAS version 6.5 to analyze the impact of structural cross-section changes on water surface elevation and flood inundation area. The data used included river cross-section measurements, maximum daily rainfall over the past 20 years, and a Digital Elevation Model (DEM) map. The design discharge was calculated using the Rational Method for return periods of 2, 5, 10, 20, and 25 years. The results indicated that, for a 25-year return period, the water surface elevation at the downstream section (STA 0+190.75) decreased from 5.05 m to 3.75 m, and the inundation area was reduced by 61.15%. Conversely, the upstream section (STA 0+3116) showed no significant changes in water surface elevation or inundation area. These results indicate that the cross-section structure change is more effective in reducing flood potential downstream but does not impact the upstream area.

Keywords: Guntung Payung River, HEC-RAS, Steady Flow 1D, cross-section structure change, water surface elevation, inundation area.

1. INTRODUCTION

Flooding is one of the common issues in river basins, particularly during the rainy season. In Banjarbaru City, especially in the upstream area of the Guntung Payung River, flood events often cause significant material and social losses for the community. According to a report from Pojokbanua.com, Muhammad Deny Pramudji, Head of the Water Resources Division at the Banjarbaru City Public Works and Housing Agency, stated that the primary cause of flooding in this area is the insufficient width of the box culvert cross-section, which hampers water flow downstream.

To address this issue, the box culvert was replaced with a composite bridge featuring a larger cross-section. This change aims to increase the river's flow capacity and reduce flood risks. The replacement of this infrastructure provides an opportunity to analyze the river's hydraulic performance before and after the modification, including its

impact on water surface elevation and inundation areas. The HEC-RAS software was employed to simulate these changes using a 1D Steady Flow hydraulic approach.

This study aims to evaluate the effectiveness of modifications to the river's cross-sectional structure in mitigating flood risks, particularly in upstream areas. Additionally, the findings are expected to serve as a reference for planning and managing flood control infrastructure.

2. THEORETICAL STUDY

Rainfall Frequency Analysis

Frequency analysis determines the frequency or recurrence period of extreme events like floods or heavy storms using probability distribution. The rainfall needed for water utilization and flood control design is the average rainfall across the area, not at a specific point (Sosrodarsono, 1976).

Statistical Parameters

The statistical parameters used in frequency analysis include mean, standard deviation, coefficient of variation, skewness, and kurtosis.

Design Rainfall

Design rainfall is the amount of rainfall used as a basis for calculating the design flood discharge. It can be calculated using the following equation:

$$X_T = \overline{X} + K_T.S$$

Where X_T is the rainfall for a T-year period, $\overline{X}$ is the average rainfall, K_T is the probability factor or Gaussian reduction variable, and S is the standard deviation.

Rainfall Intensity

Rainfall intensity is the amount of rainfall over a unit time, usually expressed in millimeters per hour (mm/hr). It can be calculated using Mononobe's formula:

$$I_t = \left[\frac{I_{24}}{24}\right].\left[\frac{24}{t}\right]^{\frac{2}{3}}$$

Where I_t is rainfall intensity in mm/hr, I_{24} is the 24-hour rainfall in mm, and t is the duration in hours.

Design Flood Discharge

Design flood discharge is the maximum discharge of a river or channel based on a specific return period. It can be determined using the Rational Method, which is suitable for small watersheds (<300) ha and is expressed as:

$Q = 0{,}278.C.I.A$

Where Q is peak discharge (m/s), C is the runoff coefficient (0–1), I is rainfall intensity (mm/hr), and A is the watershed area (km).

Channel Cross-Section

The channel cross-section refers to the section perpendicular to the flow direction. For trapezoidal cross-sections, the formulas are as follows:

a. Wet area : $A = y(B + my)$

b. Wetted perimeter : $P = B + 2y\sqrt{1 + m^2}$

c. Hydraulic radius : $R = \frac{A}{P}$

Where B is the channel base width (m) and y is the flow depth (m).

Flow Velocity

Flow velocity is the distance water travels per unit time, typically expressed in meters per second (m/s). It is influenced by the hydraulic radius, surface roughness, and slope gradient. Manning's equation expresses this relationship:

$V = \frac{1}{n} R^{2/3} I^{1/2}$

Where V is velocity (m/s), n is Manning's roughness coefficient, R is the hydraulic radius (m), and I is the slope.

Flow Discharge

According to Asdak (2014) in Salsabila (2010), flow discharge is the volume of water passing a cross-section per unit time. It is calculated using the formula:

$Q = A.V$

Where Q is discharge (m/s), A is the cross-sectional area (m), and V is velocity (m/s).

HEC-RAS Steady Flow 1D

The Steady Flow 1D hydraulic simulation in HEC-RAS is used to analyze steady flows in rivers. This analysis relies on several key parameters. The river geometry defines the shape of the channel cross-section and its bed slope. The Digital Elevation Model

(DEM) provides a detailed map of the river's surrounding topography. Channel roughness, represented by Manning's roughness coefficient, accounts for resistance to water flow. Flow discharge is considered constant during the simulation, ensuring a steady flow analysis. Lastly, boundary conditions are set to control the flow at the upstream and downstream ends of the river. These parameters collectively help in building an accurate model to predict water surface elevations and assess the effects of flow on the surrounding areas.

3. METHOD

Research Location

The research is conducted at the Guntung Payung River, located in Guntung Payung Village, Landasan Ulin Subdistrict, Banjarbaru City, South Kalimantan. The study area is limited from the point of the cross-section structure change (the intersection of the northern ring road) to 3,550 meters upstream, bordering the A. Yani road in Banjarbaru City.

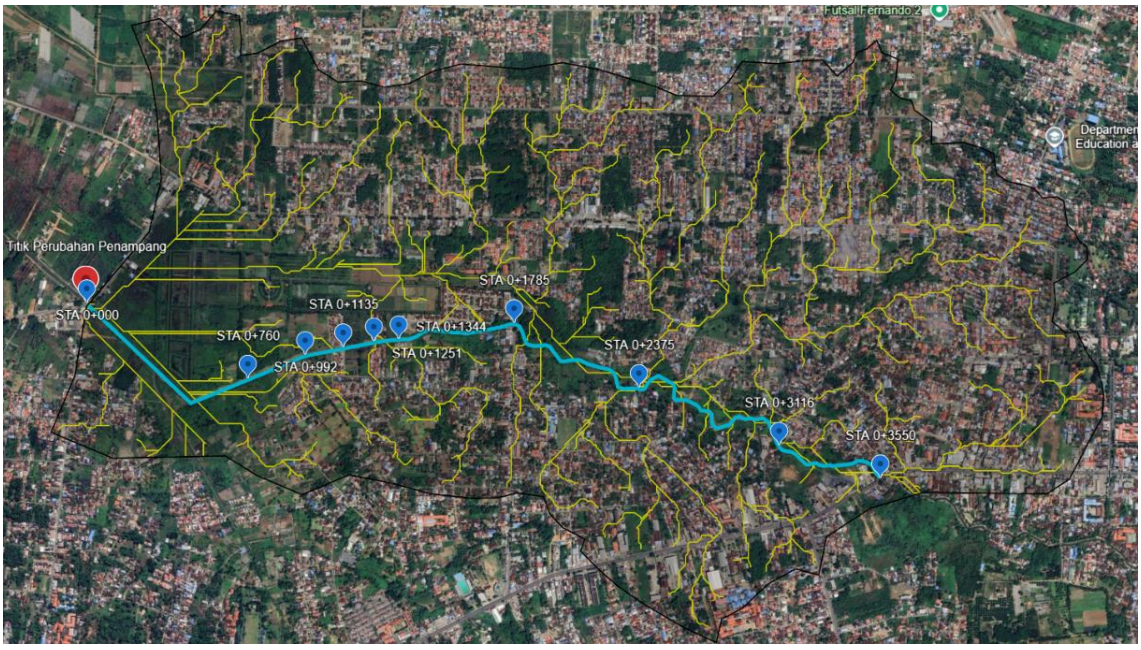

Figure 1 Study Area

Research Procedure

This research involves collecting primary data in the form of river cross-section measurements and secondary data, such as rainfall data from the last 20 years, a Digital Elevation Model (DEM) map, and information on the existing hydraulic structure. The

design flood discharge is calculated using the Rational Method based on hydrological analysis and rainfall frequency, while hydraulic modeling is carried out using HEC-RAS software version 6.5. This modeling includes two scenarios: one with a box culvert and the other after it is replaced by a composite bridge. Data analysis involves evaluating water surface elevation and flood area for instantaneous discharge and various return period flood discharge conditions, as well as comparing the conditions before and after the structural change. The results of the hydraulic simulation are used to assess the effectiveness of the structural replacement in reducing flood potential in the upstream area of the Guntung Payung River.

4. RESULT AND DISCUSSION

Instantaneous Discharge Analysis

The existing cross-section was measured during the day on October 30, 2024, under clear weather conditions, ensuring no rainfall disturbances that could affect the measurement results. Based on field observations and direct measurements at STA 0+1135, the existing cross-section data was found to have a trapezoidal shape. Using this data, the instantaneous discharge for the existing cross-section was calculated. The result of this calculation showed an existing instantaneous discharge of **6.071 m^3/s**.

Design Flood Discharge Analysis

The maximum annual daily rainfall data for the last 20 years was obtained from the Syamsudin Noor Meteorological Station. However, gaps in the data were found for the years 2010 and 2013 in the dataset downloaded from the BMKG Online Data website. To maintain the continuity of the analysis, a substitution approach was applied, where rainfall data from the previous year was used for the missing years. The resulting data is presented in Table 4.1 below.

Table 1 Maximum annual daily rainfall data

Tahun	Xi	Tahun	Xi
2001	78.90	2014	118.20
2002	119.80	2015	117.50
2004	136.10	2016	98.90
2005	62.20	2017	111.80
2006	80.00	2018	112.10
2007	109.30	2019	70.50
2008	145.00	2020	122.10
2009	105.20	2021	249.00
2011	113.00	2022	120.80
2012	92.40	2023	127.60

Sumber: Data Online - Pusat Database - BMKG

From Table 1, statistical calculations such as the mean, standard deviation, coefficient of variation, skewness, and kurtosis were performed to determine the type of design rainfall distribution. Subsequently, the hourly rainfall intensity and design flood discharge were calculated based on the return period, incorporating a runoff coefficient (C) of **0.30**, which is suitable for a rural watershed condition (C = 0.20–0.45). The drainage area (A) was analyzed using GIS, and for the Guntung Payung River watershed, the area was found to be **5.71 km²**.

Table 2 Results of Design Flood Discharge Calculation using the Rational Method

Durasi Hujan (Jam)	**Debit Puncak m^3/detik**				
	Kala Ulang 2 Tahun	Kala Ulang 5 Tahun	Kala Ulang 10 Tahun	Kala Ulang 20 Tahun	Kala Ulang 25 Tahun
1	17.605	22.892	26.702	30.594	31.880

From Table 2, the calculation results of the design flood discharge for various return periods were obtained. This peak discharge and the instantaneous discharge from the calculation were then used as inputs in the HEC-RAS simulation for flow analysis and flood modeling.

HEC-RAS Simulation Results

Table 3 Summary of the 25-Year Discharge Before and After Cross-Sectional Changes.

River Sta	Profile	Q Total (m^3/s)	Min Ch El (m)	W.S. Elev (m)	Flow Area (m^2)	River Sta	Profile	Q Total (m^3/s)	Min Ch El (m)	W.S. Elev (m)	Flow Area (m^2)
3550	25 Th	31.88	11.11	12.06	11.04	3550	25 Th	31.88	11.11	12.06	11.04
3333.00*	25 Th	31.88	9.55	11.9	22.13	3333.00*	25 Th	31.88	9.55	11.9	22.13
3116	25 Th	31.88	9.81	11	9.47	3116	25 Th	31.88	9.81	11	9.47
2930.75*	25 Th	31.88	8.83	11.36	107.98	2930.75*	25 Th	31.88	8.83	11.36	107.98
2745.50*	25 Th	31.88	6.62	11.36	144.54	2745.50*	25 Th	31.88	6.62	11.36	144.54
2560.25*	25 Th	31.88	8.65	11.36	126.17	2560.25*	25 Th	31.88	8.65	11.36	126.17
2375	25 Th	31.88	9	11.09	19.84	2375	25 Th	31.88	9	11.09	19.84
2178.33*	25 Th	31.88	5.77	8.92	42.37	2178.33*	25 Th	31.88	5.77	8.92	42.37
1981.67*	25 Th	31.88	3.31	8.94	275.89	1981.67*	25 Th	31.88	3.31	8.94	275.89
1785	25 Th	31.88	7.06	8.43	10.54	1785	25 Th	31.88	7.06	8.43	10.54
1638.00*	25 Th	31.88	6.26	7.69	12.25	1638.00*	25 Th	31.88	6.26	7.69	12.25
1491.00*	25 Th	31.88	6.22	6.69	66.2	1491.00*	25 Th	31.88	6.22	6.69	66.2
1344	25 Th	31.88	3.81	6.67	99.92	1344	25 Th	31.88	3.81	6.67	99.92
1135	25 Th	31.88	5.75	6.46	19.25	1135	25 Th	31.88	5.75	6.46	19.25
992	25 Th	31.88	3.71	4.77	11.09	992	25 Th	31.88	3.71	4.73	10.63
760	25 Th	31.88	1.01	5.04	111.46	760	25 Th	31.88	1.01	3.73	35.87
570.25*	25 Th	31.88	0.06	5.05	579.46	570.25*	25 Th	31.88	0.06	3.76	242.88
380.50*	25 Th	31.88	0.03	5.05	647.87	380.50*	25 Th	31.88	0.03	3.75	294.97
190.75*	25 Th	31.88	1.22	5.05	564.19	190.75*	25 Th	31.88	1.22	3.75	219.13
1	25 Th	31.88	2.07	4.83	20.21	1	25 Th	31.88	1.84	3.47	14.28

The simulation results show that most of the river stations (STA) in the upstream section did not experience changes in water surface elevation and flood area for the 25-year return period (discharge Q = 31.88 m^3/s). For instance, at STA 0+3550, STA 0+3333, and STA 0+3116, the water surface elevation and flood area remained constant before and after the structural change. However, in the downstream section, significant reductions were observed in both water surface elevation and flood area. At STA 0+760, the water surface elevation decreased by 1.31 meters with a 67.80% reduction in the flood area, and at STA 0+380.50 and STA 0+190.75, the water surface elevation dropped by 1.30 meters, with reductions in flood area of 54.47% and 61.15%, respectively. This indicates that the structural change had an impact only in the downstream section, while the upstream section was unaffected.

5. CONCLUSION

Based on the analysis results, the following conclusions can be drawn:

1. The design flood discharge in the Guntung Payung River watershed based on rainfall for the return periods of 2, 5, 10, 20, and 25 years are 17.605 m^3/s, 22.892 m^3/s, 26.702 m^3/s, 30.594 m^3/s, and 31.880 m^3/s, respectively.
2. The simulation results indicate that for the 25-year return period, the change in the river cross-section was able to reduce the water surface elevation by up to 1.31 meters in the downstream section of the river, as observed at STA 0+760. Furthermore, the flood area in the downstream section also experienced a significant reduction, with the largest reduction being 67.80%. In the upstream section, the simulation results showed no changes in water surface elevation or flood area before and after the structural change. For example, at STA 0+3550, the water surface elevation remained at 12.06 meters, and the flood area remained unchanged at 11.04 m^2. Similar results were observed at other upstream stations such as STA 0+3333 and STA 0+3116, indicating that the structural changes had no impact on the hydraulic conditions in the upstream section.
3. Based on the analysis of the simulation results, the structural change in the river cross-section is only effective in reducing the potential flood risk in the downstream section of the Guntung Payung River. The reduction in water surface elevation and flood area in the downstream section demonstrates the effectiveness of this intervention. However, the change had no impact on the upstream section, so the flood risk in the upstream area remains the same as before the structural changes were made.

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