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# Flood Control Structure (Canal) in River Basin of Air Bengkulu River

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**ABSTRACT**

The Air Bengkulu River Basin experiences a frequency of flooding twice a year due to the increase in water discharge during the rainy season. The purpose of this study is to determine the amount of peak discharge of the Air Bengkulu River and to know how to plan dimensions of floodway control buildings in the Air Bengkulu River Basin. Rainfall data used in the purposes of this study are rainfall data for the last 10 years (2010-2019). Regional rainfall analysis is calculated using the maximum data method (annual maximum series). Rainfall analysis plans calculated by statistical methods. The analysis of the planned flood peak discharge was calculated using the Nakayasu Synthetic Unit Hydrograph method with the results of the peak discharge of the Air Bengkulu River for the 2nd, 5th, 10th, 20th, 25th, 50th and 100th year anniversary periods, respectively 557.68 $m^3/s$; 732.85 $m^3/s$; 845.18 $m^3/s$; 955.15 $m^3/s$; 978.80 $m^3/s$; 1074.35 $m^3/s$; and 1166.71 $m^3/s$. Flood canal design analysis is calculated using the manning equation method (try error) using a return period of 25 years with a discharge of 955.15 $m^3/s$; circular canal with a cross-sectional diameter of 18.5 m; with a water level of 14.68 m and a height of 3.82 m; while the canal is square in shape with a base width of 25 m; water level of 5.55 m; and height of 1.45 m guard; able to accommodate the debit plan return period of 25 years.

**Keywords**: DAS, Canal, Flood, Discharge, Rain.

## Introduction

Bengkulu Province has an area of 19,788.70 square km² or 1,978,870 hectares (ha). The main land area extends from the border of West Sumatra Province in the north to the border of Lampung Province in the south, geographically Bengkulu Province is located at 101 degrees 01′-103 degrees 46′ East Longitude and 2 degrees 16′-2 degrees 16′-5 degrees 31′ South Latitude with direct borders on the North: West Sumatra Province, East: Jambi Province and South Sumatra Province, South: Lampung Province, West: Indonesian Ocean with a distance of 567 km. Bengkulu Province has ± 90 River Basin Areas [RBA or *Daerah Aliran Sungai (DAS)*] with a coverage area of 2,007,058.58 Ha which is the working area of BPDAS (*Balai Pengelola Daerah Aliran Sungai*) [1-3].

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The Air Bengkulu RBA covers an area of 51,500 ha and is located in two districts in Bengkulu (Central Bengkulu and Bengkulu City). The Air Bengkulu RBA borders the Tanjung Aur RBA and Babat RBA to the east; the Indian Ocean to the south; the Air Hitam and Air Lemau RBA to the west; and the Musi River RBA to the north. The main river in this RBA is the Air Bengkulu River. This RBA is divided into 3 Sub-watersheds (BPDAS Ketahun, 2006), namely: 1) Rindu Hati Sub-RBA covers an area of 19,207 ha; 2) Susup Sub-RBA covers an area of 9,890 ha; and 3) Bengkulu Hilir Sub-RBA covers an area of 22,402 ha. In addition, there are six tributaries that flow into the Air Bengkulu River, namely: 1) Susup River; 2) Rindu Hati River; 3) Kemumu River; 4) Pasemah River; 5) Sialang River; and 6) Muara Kurung River. The Susup River is part of the Susup Sub-RBA. The Rindu Hati and Kemumu rivers form the Rindu Hati Sub-RBA. The Pasemah, Sialang, and Muara Kurung rivers form the Bengkulu Hilir Sub-RBA [4].

Flood Canal (Floodway) Flood control structure that functions to control the flow of water from the upstream and regulate the volume of water entering residential areas. Generally, a canal is part of a river flow with widening or deepening in certain parts. Based on the background above, it is necessary to conduct research on the planning of flood control structures in the Air Bengkulu River Basin [5].

The purpose of this study is to plan a flood control building to reduce the risk of overflow/water runoff in the Air Bengkulu RBA.

## Literature Review

The hydrological cycle is the movement of water from the Earth's surface [6]. During the hydrological cycle, which is the journey of water from the sea to the atmosphere, then to the land surface and back to the sea, the water will be retained (temporarily) in rivers, lakes, or reservoirs, and in the soil so that it can be used by humans or other living things [7].

River Basin Area (RBA) is an area that is bounded by mountain ridges or mountains where rainwater that falls in the area will flow towards the main river at a point or station that is being examined [8].

To find out the dimensions that are able to withstand the discharge, the calculation is the same as calculating the channel capacity, with trapezoidal and square cross-section types [9].

The cross section of a trapezoidal channel is formulated as follows.

$$A = (b + z\,y)y$$
$$P = b + 2y\sqrt{1 + z2}$$
$$R = \frac{A}{P} \quad \text{.........................................[1]}$$

The cross-section of a rectangular channel is formulated as follows.

$$A = b.y$$
$$P = b + 2y \quad \text{.......................................[2]}$$

The most influential hydrological factor is rainfall (precipitation). Rainfall in an area is one of the factors that determines the amount of flood discharge that occurs in the area that receives it [10-11].

### Analysis of the area's annual maximum rainfall

Rainfall and discharge data are the most relevant data in analyzing the planned flood discharge in an RBA [12]. Rainfall data analysis is intended to obtain the amount of rainfall that is calculated in the calculation of peak discharge. According to [13], frequency analysis aims to determine the type of distribution that is appropriate for obtaining the planned rainfall. In general, the frequency analysis that is calculated includes: statistical parameters, continuous probability distribution, and suitability tests.

### Continuous probability distribution analysis

Types of continuous probability distributions. There are several forms of continuous (theoretical) distribution functions, which are often used in frequency analysis for hydrology, such as the Gumbel, Log Normal and Log Person III distributions [14].

### Flow coefficient analysis (C)

Analysis of the flow coefficient (C) based on land cover is used to calculate the planned flood discharge in the next stage. Land cover data in this study based on related agencies is considered valid. It can be seen in the following table:

$$C = C_{average} = \frac{\sum_{i=1}^{n} C_i A_i}{\sum_{i=1}^{n} A_i} \qquad \text{[3]}$$

$$I_t = \frac{R_{24}}{24} \times \left[\frac{24}{t}\right]^{2/3} \qquad \text{[4]}$$

**Hourly rainfall distribution/effective rainfall**

To obtain hourly rainfall of various return periods, the planned rainfall is multiplied by the percentage of hourly rainfall patterns. The calculation of effective rainfall distribution is the return period rainfall multiplied by the flow coefficient, then the result will be effective rainfall which will become runoff with the following formula

Rn = I x C ....................................................[5]

**Calculation of planned flood discharge using the Nakayasu HSS method**

The Nakayasu method was developed in Japan by Dr. Nakayasu in 1940 and is one of the methods frequently used in watersheds in Indonesia, combined with other methods for comparison [15].

$$Q_p = \frac{A \times Ro}{3{,}6(0{,}3\ Tp + T_{0,3})} \qquad \text{[6]}$$

**Field river discharge analysis**

$$Q = V \times A \qquad \text{[7]}$$

**Methods**

Data processing is done after the data is collected using formulas taken from references from books, previous studies and the internet [16-17]. The following are the stages in the data processing process.

1. Calculation of annual maximum rainfall analysis of the region
2. Calculation of planned rainfall frequency analysis
3. Calculation of planned rainfall using statistical methods (continuous probability distribution)
4. Calculation of distribution suitability test
5. Calculation of hourly rainfall distribution
6. Calculation of peak flood discharge using the Nakayasu synthetic unit hydrograph method
7. Calculation of canal channel dimension hydraulics with equations (manning try error)

The research location is located in the Air Bengkulu river basin, as seen in Figure 1.

**Figure 1.** Air Bengkulu river basin

**Results and Discussion**

**Analysis of Maximum Annual Rainfall of the Region**

The analysis of the annual maximum daily rainfall was carried out based on the maximum rainfall that occurred each year of the available data for 10 years (2010-2019). The results of the recapitulation of the annual maximum rainfall data from the Tanjung Jaya rain station are presented in Table 1 and Figure 1.

**Table 1.** Annual Rainfall of Tanjung Jaya

| No | Year | Rf Max (mm) |
|---|---|---|
| 1 | 2010 | 122.2 |
| 2 | 2011 | 95 |
| 3 | 2012 | 223.5 |
| 4 | 2013 | 80.2 |
| 5 | 2014 | 131 |
| 6 | 2015 | 113 |
| 7 | 2016 | 198 |
| 8 | 2017 | 175 |
| 9 | 2018 | 186 |
| 10 | 2019 | 130.8 |

The results of the analysis shown in Table 1 show that the maximum rainfall occurred in 2012 at 223.5 mm and the minimum rainfall occurred in 2013 at 80.2 mm. From these data, it can be concluded that the average rainfall of

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145.47 mm has the potential to cause flooding because the average rainfall is quite large.

**Planned rainfall frequency analysis**
The analysis of hydrological data frequency in the Bengkulu Water RBA aims to determine the magnitude of extreme rainfall events related to the frequency of occurrence through the application of probability distribution.

**Statistical Parameter**
The magnitude of dispersion can be measured by calculating the statistical parameters for (Xi-X), $(Xi-X)_2$, $(Xi-X)_3$, $(Xi-X)_4$ first.

Where:
Xi = The amount of rainfall in the area (mm)
X = Average maximum rainfall (mm)

**Table 2.** Statistical Parameter

| Year | Xi | (Xi-X) | $(Xi-X)^2$ | $(Xi-X)^3$ | $(Xi-X)^4$ |
|---|---|---|---|---|---|
| 2013 | 80.2 | -65.27 | 4260.173 | -278061 | 18149073 |
| 2011 | 95 | -50.47 | 2547.221 | -128558 | 6488334 |
| 2015 | 113 | -32.47 | 1054.301 | -34233.2 | 1111550 |
| 2010 | 122.2 | -23.27 | 541.4929 | -12600.5 | 293214.6 |
| 2019 | 130.8 | -14.67 | 215.2089 | -3157.11 | 46314.87 |
| 2014 | 131 | -14.47 | 209.3809 | -3029.74 | 43840.36 |
| 2017 | 175 | 29.53 | 872.0209 | 25750.78 | 760420.5 |
| 2018 | 186 | 40.53 | 1642.681 | 66577.86 | 2698401 |
| 2016 | 198 | 52.53 | 2759.401 | 144951.3 | 7614293 |
| 2012 | 223.5 | 78.03 | 6088.681 | 475099.8 | 37072035 |
| **Total** | **1454.7** | **0** | **20190.56** | **252739.5** | **74277477** |
| **Average** | **145.47** | | | | |

From the results of statistical parameters in Table 2, the data is then used to calculate statistical parameters by finding the value of Standard Deviation (SD), Coefficient of Skewness (Cs), Coefficient of Cortosis (Ck) and Coefficient of Variation (Cv). Calculation of statistical parameters using the Equation can be seen in the calculation below:

Average

$$\bar{X} = \frac{\sum_{i=1}^{n} Xi}{n} = \frac{1454.7}{10} = 145.47$$

Standard Deviation

$$Sd = \sqrt{\frac{\sum_{i=1}^{n} (X_i-\bar{X})^2}{n-1}} = \sqrt{\frac{20190.56}{10-1}} = 47.36$$

Tilt Coefficient (Skewness)

$$Cs = \frac{n \sum_{i=1}^{n} \{(X_i)-\bar{X}\}^3}{(n-1)(n-2)Sd^3}$$

$$= \frac{10 \times 252739.5}{(10-1)(10-2) \times 47.36^3} = 0.33$$

Curtosis Coefficient

$$Ck = \frac{\frac{1}{n} \sum_{i=1}^{n} \{(X_i)-\bar{X}\}^4}{Sd^4}$$

$$= \frac{\frac{1}{10} \times 74277477}{47.36} = 1.476$$

Variation Coefficient

$$Cv = \frac{Sd}{\overline{X}} = \frac{47.36}{145.47} = 0.326$$

Based on the calculations above, it is obtained that the average maximum rainfall value is Standard deviation (SD) 47.36, skewness coefficient value 0.33, variation coefficient value (Cv) 0.326 and kurtosis coefficient value (Ck) 1.476 (less than 3) where the value is less than 3 included in the pleticurtic distribution, which is a distribution that has an almost horizontal peak and then the value will be used to determine the selection of the type of distribution.

**Distribution Type Analysis**

The distribution analysis method used to analyze the planned rainfall amount must meet several parameters that are the requirements for using a distribution method. The distribution analysis method used to analyze the planned rainfall amount must meet several parameters that are the requirements for using a distribution method.

**Gumbel Tipe I Distribution**

Calculate rainfall using the formula:

$$X_t = \bar{X} + \frac{S}{S_n}(Y_t - Y_n) \quad .....................................[8]$$

**Table 3.** Distribution of Gumbel Method Spread

| T | Yt | Yn | Sn | Sd | XT (mm) |
|---|---|---|---|---|---|
| 2 | 0.3665 | 0.495 | 0.949 | 47.364 | 139.05 |
| 5 | 1.4999 | 0.495 | 0.949 | 47.364 | 195.58 |
| 10 | 2.2503 | 0.495 | 0.949 | 47.364 | 233.01 |
| 20 | 2.9701 | 0.495 | 0.949 | 47.364 | 268.92 |
| 25 | 3.1985 | 0.495 | 0.949 | 47.364 | 280.31 |
| 50 | 3.9019 | 0.495 | 0.949 | 47.364 | 315.39 |
| 100 | 4.6001 | 0.495 | 0.949 | 47.364 | 350.22 |

The Yn value is obtained from Table 3 by looking at the number of data (n) in the table, which is 0.4952, and the Sn value is obtained from Table 3 by looking at the number of data (n), which is 0.9496. The Yt value can be found using the basic formula, the Yt value depends on the return period being searched.

**Recapitulation of Planned Rainfall**

**Table 5.** Recapitulation of Planned Rainfall

| Yearly Periode | Gumbel | Log Normal | Log Person III |
|---|---|---|---|
| 2 | 139 | 137 | 139 |
| 5 | 196 | 183 | 183 |
| 10 | 233 | 214 | 211 |
| 20 | 269 | 244 | 239 |
| 25 | 280 | 251 | 245 |
| 50 | 315 | 285 | 269 |
| 100 | 350 | 318 | 292 |

**Table 6.** Terms of use of distribution types

| No | Distribution type | Terms | Summarize results |
|---|---|---|---|
| 1 | Gumbel Method | Ck = 5.4 | Ck = 1.48 |
| | | Cs = 1.14 | Cs = 0.33 |
| 2 | Log Normal Method | Cs = $Cv^3+3Cv$ = 0 | Cs = -0.13 |
| | | Ck = $Cv^8+6Cv^6+15Cv^4+16Cv^2+3$ = 3.07 | Ck = 3.05 |
| 3 | Log Pearson Type III Method | In addition to the above values | Cs = -0.13 |
| | | In addition to the above values | Ck = 3.0 |

**Planned Rainfall**

Rain distribution that often occurs in Indonesia with concentrated rain for 1-6 hours. With the flow coefficient can be seen in Table 6 Calculation of effective rain, Hourly rain distribution from concentrated rain for 6 hours as seen in Table 7.

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**Table 7.** Hourly rainfall distribution

| Yearly Periode | Planned Rainfall | Coefficient C | (%) |
|---|---|---|---|
| 2 | 139 | 0.34 | 47.09 |
| 5 | 183 | 0.34 | 61.88 |
| 10 | 211 | 0.34 | 71.36 |
| 20 | 239 | 0.34 | 80.64 |
| 25 | 245 | 0.34 | 82.64 |
| 50 | 269 | 0.34 | 90.71 |
| 100 | 292 | 0.34 | 98.51 |

Effective rainfall analysis is the part of rainfall that produces direct runoff. Assuming that the process of transformation of rainfall into direct runoff follows a linear process and does not change over time. The calculation results for effective rainfall can be seen in table 7.

The analysis results shown in Table 7, obtained effective rainfall for the 25-year return period R1 = 28.65 mm/hour, R2 = 18.05 mm/hour, R3 = 13.77 mm/hour, R4 = 11.37 mm/hour, R5 = 9.80 mm/hour and R6 = 8.68 mm/hour.

**Flood Discharge Analysis Design HSS Nakayasu Method**

Calculation of planned discharge is needed for flood control planning purposes. In this study, the method of determining planned flood discharge will be carried out using the Nakayasu Synthetic Unit Hydrograph method.

The calculation of the Nakayasu Synthetic Unit Hydrograph of Air Bengkulu RBA uses the following parameters :
RBA Coverage (A)= 500.449 $km^2$
Main River Length (L)= 55.6 km
Effective rainfall (Ro)= 1.0 mm
Hydrograph Coefficient (α)= 2
Finding the consentration of time value (tg) (for L > 15 km)

$t_g = 0.4 + 0.058 \times L = 3,625$ hour

Finding time value of rainfall ($t_r$)

$t_r = 0.5 \times t_g = 0.5 \times 3.625 = 2.719$ hour

Finding the time from the start of the flood to the peak of the flood hydrograph ($T_p$)
$T_p = t_g + 0.8 \times t_r = 3.625 + 0.8 \times 2.719 = 5.8$ hour

Find the peak flood time up to 0.3 times the peak flood ($T_{0.3}$)
$T_{0.3} = \alpha \times t_g = 2 \times 3.625 = 7.25$ *hour*

Find the hydrograph value for each given interval:

$$Q_p = \frac{A \times Ro}{3.6 \times (0.3 \times Tp + T_{0.3})}$$

$$= \frac{500499 \times 1}{3.6 \times (0.3 \times 5.8 + 7.25)} = 15.466\ m^3/s$$

**Table 8.** Nakayasu Synthetic Unit Hydrograph of Air Bengkulu RBA

| t (hour) | Q ($m^3/s$) | Q Correction ($m^3/S$) |
|---|---|---|
| 0 | 0.00 | 0.00 |
| 1 | 0.23 | 0.21 |
| 2 | 1.20 | 1.09 |
| 3 | 3.18 | 2.88 |
| 4 | 6.34 | 5.75 |
| 5 | 10.83 | 9.82 |
| 5.79968 | 15.47 | 14.03 |
| 6 | 14.96 | 13.57 |
| 7 | 12.67 | 11.49 |
| 8 | 10.73 | 9.73 |
| 9 | 9.09 | 8.24 |
| 10 | 7.70 | 6.98 |
| 11 | 6.52 | 5.91 |
| 12 | 5.52 | 5.01 |
| 13 | 4.68 | 4.24 |
| 13.04928 | 4.64 | 4.21 |
| 14 | 4.18 | 3.79 |
| 15 | 3.74 | 3.39 |
| 16 | 3.35 | 3.04 |
| 17 | 3.00 | 2.72 |
| 18 | 2.68 | 2.43 |
| 19 | 2.40 | 2.18 |
| 20 | 2.15 | 1.95 |
| 21 | 1.92 | 1.74 |
| 22 | 1.72 | 1.56 |
| 23 | 1.54 | 1.40 |
| 23.92368 | 1.39 | 1.26 |

| t (hour) | Q ($m^3$/s) | Q Correction ($m^3$/S) |
|---|---|---|
| 24 | 1.38 | 1.25 |
| 25 | 1.27 | 1.15 |
| 26 | 1.17 | 1.06 |
| 27 | 1.08 | 0.98 |
| 28 | 0.99 | 0.90 |
| 29 | 0.91 | 0.83 |
| 30 | 0.84 | 0.76 |
| 31 | 0.77 | 0.70 |
| 32 | 0.71 | 0.65 |
| 33 | 0.66 | 0.59 |
| 34 | 0.60 | 0.55 |
| 35 | 0.55 | 0.50 |

| t (hour) | Q ($m^3$/s) | Q Correction ($m^3$/S) |
|---|---|---|
| 36 | 0.51 | 0.46 |
| **Total Q ($m^3$/s)** | **153.29** | **139.03** |
| **VLL ($m^3$)** | **551829.76** | **500499.00** |
| **TLL (mm)** | **1.10** | **1.00** |

Bengkulu RBA Coverage= 500.499 $km^2$
Qt total = 153.29 ($m^3$/s)
Hydrograph Height= Qt x 3600 x $10^9/10^{12}$/ A
= 153.29 x 3600 x $10^9/10^{12}$/ 500.499
= 1.10 mm
UH Corrected = Value UH Nakyasu that corrected / Hydrograph Height
= 15.47/1.10 = 14.03 $m^3$/s (t = 5.8)

**Table 9.** Recapitulation of Flood Discharge in Air Bengkulu RBA Design

| Time (t) (hour) | Repeat Periode (Year) | | | | | | |
|---|---|---|---|---|---|---|---|
| | $Q_2$ $m^3$/s | $Q_5$ $m^3$/s | $Q_{10}$ $m^3$/s | $Q_{20}$ $m^3$/s | $Q_{25}$ $m^3$/s | $Q_{50}$ $m^3$/s | $Q_{100}$ $m^3$/s |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1.00 | 3.37 | 4.43 | 5.11 | 5.77 | 5.91 | 6.49 | 7.05 |
| 2.00 | 19.91 | 26.16 | 30.17 | 34.10 | 34.94 | 38.35 | 41.65 |
| 3.00 | 59.89 | 78.70 | 90.76 | 102.57 | 105.11 | 115.38 | 125.29 |
| 4.00 | 133.41 | 175.32 | 202.19 | 228.50 | 234.16 | 257.02 | 279.11 |
| 5.00 | 250.35 | 328.99 | 379.41 | 428.78 | 439.40 | 482.30 | 523.75 |
| 5.80 | 400.91 | 526.84 | 607.59 | 686.65 | 703.66 | 772.35 | 838.74 |
| 6.00 | 501.56 | 659.10 | 760.13 | 859.03 | 880.30 | 966.24 | 1049.30 |
| 7.00 | 547.19 | 719.07 | 829.29 | 937.19 | 960.40 | 1054.15 | 1144.77 |
| 8.00 | 557.68 | 732.85 | 845.18 | 955.15 | 978.80 | 1074.35 | 1166.71 |
| 9.00 | 539.61 | 709.12 | 817.81 | 924.21 | 947.10 | 1039.56 | 1128.92 |
| 10.00 | 494.67 | 650.06 | 749.69 | 847.24 | 868.22 | 952.98 | 1034.89 |
| 11.00 | 427.32 | 561.55 | 647.62 | 731.88 | 750.01 | 823.22 | 893.99 |
| 12.00 | 361.93 | 475.62 | 548.52 | 619.89 | 635.24 | 697.26 | 757.19 |
| 13.00 | 306,55 | 402.84 | 464.59 | 525.04 | 538.04 | 590.57 | 641.33 |
| 13.05 | 269.68 | 354.39 | 408.70 | 461.88 | 473.32 | 519.53 | 564.19 |
| 14.00 | 238.38 | 313.26 | 361.27 | 408.28 | 418.39 | 459.23 | 498.71 |
| 15.00 | 212.01 | 278.60 | 321.30 | 363.11 | 372.10 | 408.42 | 443.53 |
| 16.00 | 189.85 | 249.48 | 287.72 | 325.15 | 333.21 | 365.74 | 397.18 |
| 17.00 | 171.18 | 224.95 | 259.43 | 293.18 | 300.44 | 329.77 | 358.12 |
| 18.00 | 155.38 | 204.19 | 235.48 | 266.12 | 272.71 | 299.34 | 325.07 |
| 19.00 | 139.20 | 182.92 | 210.96 | 238.41 | 244.31 | 268.16 | 291.21 |
| 20.00 | 124.61 | 163.75 | 188.85 | 213.42 | 218.70 | 240.05 | 260.69 |
| 21.00 | 111.55 | 146.59 | 169.05 | 191.05 | 195.78 | 214.90 | 233.37 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 22.00 | 99.86 | 131.22 | 151.34 | 171.03 | 175.26 | 192.37 | 208.91 |
| 23.00 | 89.39 | 117.47 | 135.48 | 153.10 | 156.89 | 172.21 | 187.01 |
| 23.92 | 80.20 | 105.39 | 121.54 | 137.35 | 140.76 | 154.50 | 167.78 |
| 24.00 | 73.93 | 97.15 | 112.04 | 126.62 | 129.76 | 142.42 | 154.67 |
| 25.00 | 68.06 | 89.44 | 103.14 | 116.56 | 119.45 | 131.11 | 142.38 |
| 26.00 | 62.77 | 82.48 | 95.13 | 107.50 | 110.16 | 120.92 | 131.31 |
| 27.00 | 58.03 | 76.26 | 87.95 | 99.40 | 101.86 | 111.80 | 121.41 |
| 28.00 | 53.81 | 70.71 | 81.54 | 92.15 | 94.44 | 103.66 | 112.57 |
| 29.00 | 49.98 | 65.67 | 75.74 | 85.60 | 87.72 | 96.28 | 104.56 |
| 30.00 | 45.99 | 60.44 | 69.71 | 78.78 | 80.73 | 88.61 | 96.22 |
| 31.00 | 42.33 | 55.63 | 64.15 | 72.50 | 74.29 | 81.55 | 88.56 |
| 32.00 | 38.96 | 51.19 | 59.04 | 66.72 | 68.37 | 75.05 | 81.50 |
| 33.00 | 35.85 | 47.11 | 54.34 | 61.40 | 62.93 | 69.07 | 75.01 |
| 34.00 | 33.00 | 43.36 | 50.01 | 56.51 | 57.91 | 63.56 | 69.03 |
| 35.00 | 30.37 | 39.90 | 46.02 | 52.01 | 53.30 | 58.50 | 63.53 |
| 36.00 | 27.95 | 36.72 | 42.35 | 47.86 | 49.05 | 53.84 | 58.47 |
| **Qmax** | **557.68** | **732.85** | **845.18** | **955.15** | **978.80** | **1074.35** | **1166.71** |

The results of the analysis from Table 9 can be seen in the recapitulation of the Flood Hydrograph from a return period of 2 years to 100 years. In the 2-year return period, the peak discharge was 557.68 m3/second, and the peak discharge in the 100-year period was 1166.71 m3/second, which occurred at hour 8..

**River Discharge Analysis in the Field**

To obtain river discharge in the field, direct measurements need to be carried out. Data obtained from the field describe the situation and the existing river discharge. Measurements were carried out at 2 points at the Bengkulu Water RBA located in Tanjung Jaya Village, Sungai Serut District, Bengkulu City.

**Table 10.** RBA Condition of Air Bengkulu on the Field

| Data of RBA Condition of Air Bengkulu in the Field | |
|---|---|
| Water surfase | Fixed (not up/down) |
| Condition when measuring | Bright |
| Location Condition | Basic Sand Material, mud |
| Measurement Methods | float |

River discharge is the wet cross-sectional area that has been obtained multiplied by the current velocity.

**Table 11.** Debit Measurement of Data 1 in the field

| No | t (sec) | Length (m) | h1(m) | h2 (m) | h3 (m) | L(m) | A (m²) | V (m/det) | Q (m³/s) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 26 | | | | | | | | |
| 2 | 25 | | | | | | | | |
| 3 | 32 | 15 | 0.77 | 0.4 | 0.46 | 31.7 | 17.224 | 0.532 | 9.162 |
| 4 | 26 | | | | | | | | |
| 5 | 32 | | | | | | | | |

**Table 12**. Debit Measurement of Data 2 in the field

| No | t (det) | length (m) | h1 (m) | h2 (m) | h3 (m) | L (m) | A (m²) | V (m/det) | Q (m³/s) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 58 | | | | | | | | |
| 2 | 81 | | | | | | | | |
| 3 | 63 | 10 | 1.12 | 1.85 | 1.41 | 46.8 | 68.328 | 0.149 | 10.198 |
| 4 | 68 | | | | | | | | |
| 5 | 65 | | | | | | | | |

Based on Table 11 and Table 12, field measurements of data 1 obtained 9.162 ($m^3$/s) and field measurements of data 2 obtained 10.198 ($m^3$/s), so the field flow discharge can be averaged at 9.68 ($m^3$/s)..

**Hydrolics Analysis**

Analysis of the channel dimensions in the analysis of 3 alternative cross-sectional shapes, namely circular, square and trapezoidal cross-sections and the design flood discharge used is a 25-year recurrence period of Q25 = 978.8 m3/sec. The following is an analysis of various cross-sectional shapes as follows.

**Dimensional Analysis of Circular Flood Canal Channels**

An alternative circular channel using iron material with a value of n = 0.013 and a channel slope of S = 0.001.

**Table 13.** Circle Design Data Parameters

| Description | Symbol | | SI Unit |
|---|---|---|---|
| Planned Debit | Q25 | 978.8 | $m^3$/s |
| Canal Base Slope | S | 0.001 | m/m |
| Manning's Roughness Value | n | 0.013 | |

**Dimensional Analysis of Square Flood Canal Channels**

Alternative square-shaped canal using concrete material with a value of n = 0.011 and a canal slope of S = 0.001

**Table 14.** Square Design Data Parameters

| Description | Symbol | | SI Unit |
|---|---|---|---|
| Planned Debit | Q25 | 978.8 | $m^3$/s |
| Canal Base Slope | S | 0.001 | m/m |
| Manning's Roughness Value | N | 0.011 | |
| Base Width | b | 25 | m |

**Findings**

Design dimensions of circular canal channels

$Q = A * V$

$$Q = \frac{1}{4}\pi D^2 \frac{1}{n}\left(\frac{A}{P}\right)^{\frac{2}{3}} S^{\frac{1}{2}}$$

$$D = (1290.986)^{\frac{1}{8/3}} = 14.676\ m$$

$$High\ maintenance = 25\%\ x\ 14.676\ m = 3.669\ m$$

$$D\ planning = 14.676 + 3.669 = 18.344\ m\ \approx 18.5\ m$$

$$A\ planning = \frac{1}{4}\pi D^2 = \frac{1}{4} \times 3.14 \times (18.5)^2 = 268.666\ m^2$$

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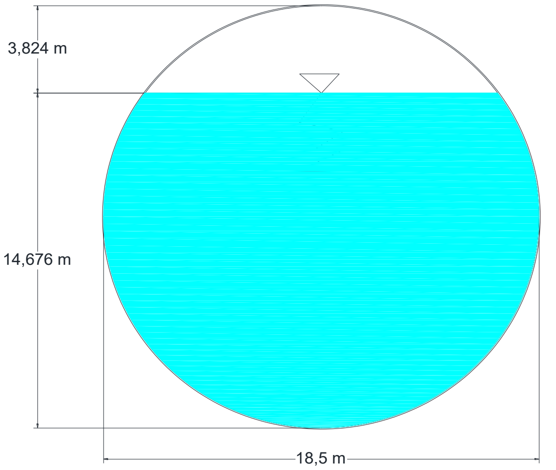


**Figure 2.** Dimensions of the Cross Section of a Circular Channel

The results of the calculation of the dimensions of the circular canal channel to channel the flood discharge with a 25-year return period in the Air Bengkulu watershed obtained a wet cross-section depth of 14.676 m and a guard height of 3.824 m with a cross-section diameter of 18.5 m, which is shown in Figure 2.

Design dimensions of square canal channel

$$Q = A * V$$

$$Q = (b\ x\ h) x\ \frac{1}{n}\ x\ (\frac{A}{P})^{\frac{2}{3}}\ x\ S^{1/2}$$

$$Q = b\ x\ h\ x\ \frac{1}{n}\ (\frac{b\ x\ h}{b + 2h})^{\frac{2}{3}} x\ S^{1/2}$$

$$978.8 = 25\ x\ h\ x\ \frac{1}{0.011}\ (\frac{25\ x\ h}{25 + 2h})^{\frac{2}{3}} x\ 0.001^{1/2}$$

(try the value (h))

The calculation is done by trial and error of water depth (h) and channel base width, b; where the boundary condition is high speed (Q Channel Canal > Q Flood 25-year return period). If the boundary condition is met, the calculation result is used as the design dimension., Q Channel Canal ≈ Q Flood 25-year return period, or slightly larger, the trail error calculation result shows that the channel height is 5.550 m, while the guard height is 1.3876 m, so the total channel depth is 6.939 m rounded to 7 m.

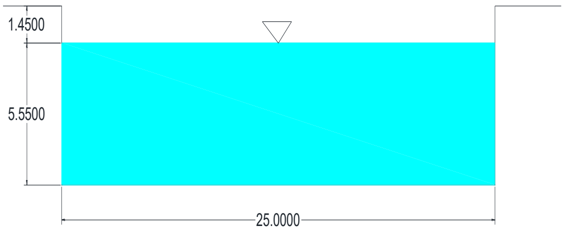


**Figure 3.** Dimensions of the Cross Section of a Square Flood Canal

Based on research by [6], a canal was planned to control flooding on the highway. Calculation of planned flood discharge using rational formula and the cross-sectional shape of the canal is rectangular with dimensions of 4.5 m × 2.2 m.

## Conclusions

The peak discharge of the planned flood is calculated using the Nakayasu Synthetic Unit Hydrograph method with the peak discharge of the Air Bengkulu River with a return period of 25 years of 955.15 m3/sec; The design planning for a circular flood canal obtained a cross-section diameter dimension of 18.5 m; with a water height of 14.68 m and a guard height of 3.82 m; while the design of a square flood canal with a base width dimension of 25 m; a water height of 5.55 m; and a guard height of 1.45 m; capable of accommodating the planned flood discharge with a return period of 25 years.

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## Author Contributions

Conceptualization, methodology, validation, M.B., M.R.P., and A.S.; formal analysis, M.B. and M.R.P.; investigation, A.S.; resources, A.S. and M.B.; data curation, M.B. and M.R.P.; writing—original draft preparation, M.R.P. and M.B., I.B.R. and A.S.; writing—review and editing, M.R.P. and M.B., I.B.R. and A.S.; visualization, A.S.; supervision,

M.B.; project administration and funding, M.R.P.

**Conflicts of Interest**

The authors declare that there is no conflict of interest in this research.

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