Analysis of Flood Discharges on Way Samal River in Moluccas Province

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Abstract—Way Samal river is one of the rivers in district of Central Maluku which is intended for agricultural activities. But when its rainy season, there are many problem caused by overflowing of river Way Samal. So, we need to find the right solution to overcome this problem. In general the best solution is technical engineering, by planning the building control and normalization of the river. It needs to be analyzed how much flood discharge that occurs in the Way Samal river flow. In this study a flood discharge planning analysis was conducted using annual maximum rainfall. This rainfall is analyzed for rainfall plans by using probability distributions Gumbel, Normal, Log-Normal, and Log-Pearson Type III. Furthermore, the distribution is tested for compatibility by using Chi-Square test and Kolmogorof Smirnov Test. After that based on the match test results, the design flood discharged was calculated by using the synthesis hydrograph method of Snyder and Nakayasu. Then these two synthesis methods are compared and select the closest to trend based on the linear average approach.

Keywords—Rainfall, probability distribution, synthesis hydrograph.

I. INTRODUCTION
The river has an important role in improving the welfare of the Indonesian people in the areas it supports, in terms of irrigation and other uses. However, not in accordance with climatological characteristics, topography and the quality of the soil environment and vegetation of the catchment area, it can bring disaster [1].

One of them is Sungai Way Samal which is located in the central Maluku district administration. In the rainy season, the flow on the Samal River is very superior in other places in the Regency. Central Maluku.

2.2 Rainfall Design Analysis
Rainfall analysis plan, using the probability distribution method [1]:

1. Gumbel Probability Distribution

\[ X_T = X_{rt} + S \times K \]

with:

- \( X_{rt} \) = rain or discharge plan with a return period (T)
- \( X_{rt} \) = average of rain or discharge.
- \( S \) = standard deviation from rain or discharge data.
- \( K \) = gumbel reduction factor.

2. Normal Probability Distribution

\[ X_T = X_{rt} + S \times K_T \]

With :

- \( X_{rt} \) = rain or discharge plan with a return period (T)
- \( X_{rt} \) = average of rain or discharge.
- \( S \) = standard deviation from rain or discharge data.
- \( K_T \) = frequency factor, depends on return period (T)

3. Log Normal Probability Distribution

\[ \log X_T = (\log X_{rt}) + K_T \times (S \log X) \]

With :

- \( X_{rt} \) = rain logarithmic value or discharge with return period (T).
- \( X_{rt} \) = Average of Log \( X_T \)
S Log X = standard deviation of Log Xr :

S Log X = \sqrt{\frac{\sum_{i=1}^{n}(Log X_i - \bar{Log X})^2}{n-1}}

Kr = frequency factor, depends on return period (T)

4. Log Pearson Type III Probability Distribution

Log X_T = (Log X_{data}) + K_T x (S.Log X)

With:

Log X_T = rain logarithmic value or discharge with return period (T).

Log X_{data} = Average of Log X_T

K_T = Standard variable, the amount depends on the coefficient of precision (Cs or G)

2.3 Conformity Test

1. Chi Square Test

The chi-square test is intended to determine whether the opportunity distribution equation that has been chosen can represent the distribution of the statistical samples of the analyzed data. Taking this test decision uses the parameter χ², therefore it is called the Chi-Square test [2].

The parameter χ² can be calculated by the equation:

\[ \chi^2 = \sum \frac{(O_i - E_i)^2}{E_i} \]

with:

\( \chi^2 \) = calculated of chi-square parameters
n = number of sub-groups
O_i = number of observations in sub-group i
E_i = number of theoretical values in the i-th subgroup

Certain degrees of trust (α)= 5%

Dk = K – (p + 1)
K = 1 + 3,3 Log n

with:

Dk = independent variables
P = number of parameters, =2
K = number of distribution class
N = number of data

Furthermore, the probability distribution used to determine the planned rainfall is a probability distribution which has the smallest maximum deviation and is smaller than the critical deviation, or formulated as follows:

\[ \chi^2 < \chi^2_{cr} \]

With:

\( \chi^2 \) = Calculated chi-square parameter
\( \chi^2_{cr} \) = Critical chi-square parameter

2. Smirnov-Kolmogorov Test

The Smirnov – Kolmogorov suitability test, often also called a non parametric test, is because the test does not use a certain distribution function. The testing procedure is as follows:

X_1 \rightarrow P(X_1)
X_2 \rightarrow P(X_2)
X_m \rightarrow P(X_m)
X_n \rightarrow P(X_n)

Determine the value of each theoretical opportunity from the description of the data (distribution equation):

X_1 \rightarrow P'(X_1)
X_2 \rightarrow P'(X_2)
X_m \rightarrow P'(X_m)
X_n \rightarrow P'(X_n)

Determine whether \( \Delta P_i < \Delta P \) is critical, to find out whether the distribution is rejected or accepted.

2.4. Flood design-discharge analysis

2.4.1. Snyder Unit Hydrograph

Calculation step of Snyder Unit Hydrograph [3]:

Determine log-time:

T_p = 1.1 - 1.4(L.Lg)0.3 (hour)

Keterangan :

T_p = Log time and center of rainfall are effective during tr to peak Hydrograph Unit in hours
L = Distance from station to the upper limit of the drainage area in km
Lg = Distance from station to specific weight of the drainage area in km.

Effective rain time :

T_p1 = tp + 0.25(tr - te)

Rise to peak :

T_p = tp + tr

Peak discharge (1/second), for effective rainfall at 1 km² :

qp = \frac{275 Cp}{tp}
Peak discharge for effective 1 inci (25.4 mm) rain in an area of \( A \) km\(^2\):

\[ Q_p = \frac{25.4 A}{1000} \] (m\(^3\)/s)

### 2.4.2. Nakayasu Unit Hydrograph

Calculation of design flood discharge using Nakayasu method. The general equation of Nakayasu synthetic unit hydrograph is as follows [4]:

\[ \begin{align*}
Q_p &= \frac{C A R_0}{3.6 (0.3 T_p + T_{0.3})} \\
T_p &= t_g + 0.8 t_r \quad (L < 15 \text{ km}) \\
t_g &= 0.21 \times L^{0.7} \quad (L < 15 \text{ km}) \\
T_{0.3} &= \alpha x t_g \\
\end{align*} \]

with:
- \( Q_p \) = peak flood discharge (m\(^3\)/second)
- \( C \) = runoff coefficient
- \( R_0 \) = rain unit (mm)
- \( T_p \) = time period from the start of the rain to the peak of the flood (hour)
- \( T_{0.3} \) = the time required for a decrease in discharge (m\(^3\)/second)
- \( A \) = watersheds area (km\(^2\))
- \( t_g \) = time of concentration (hour)
- \( t_r \) = rain unit, used 1 hour
- \( \alpha \) = hydrograph parameters, between 1.5 - 3.5
- \( L \) = river length (m)

### III. RESULT AND DISCUSSION

#### 3.1. Rainfall Design Analysis

To calculating rainfall design, we use probability distribution namely Gumbel probability distribution, Normal probability distribution, Log Normal probability distribution, Log Pearson III probability distribution. The result can be seen on table 1-4.

**Table 1. Result of Gumbel Distribution Rainfall design**

| Return Period (Year) | Gumbel  |
|----------------------|---------|
| 2                    | 170.63  |
| 5                    | 351.97  |
| 10                   | 466.01  |
| 25                   | 598.99  |
| 50                   | 716.97  |
| 100                  | 823.06  |
| 500                  | 1068.44 |
| 1000                 | 1173.61 |

**Fig. 3. Nakayasu Unit Hydrograph**
Table 2. Result of Normal Distribution Rainfall design

| Return Period (Year) | Normal     |
|----------------------|------------|
| 2                    | 199.30     |
| 5                    | 320.52     |
| 10                   | 384.02     |
| 25                   | 445.83     |
| 50                   | 495.14     |
| 100                  | 535.55     |
| 500                  | 614.92     |
| 1000                 | 645.22     |

Table 3. Result of Log-Normal Distribution Rainfall design

| Return Period (Year) | Log Normal |
|----------------------|------------|
| 2                    | 166.25     |
| 5                    | 278.32     |
| 10                   | 364.55     |
| 25                   | 474.10     |
| 50                   | 584.65     |
| 100                  | 694.22     |
| 500                  | 972.80     |
| 1000                 | 1106.55    |

Table 4. Result of Log-Pearson III Distribution Rainfall design

| Return Period (Year) | Log Pearson Type III |
|----------------------|----------------------|
| 2                    | 158.45               |
| 5                    | 273.28               |
| 10                   | 373.91               |
| 25                   | 533.79               |
| 50                   | 680.32               |
| 100                  | 853.21               |
| 500                  | 1660.61              |
| 1000                 | 2194.26              |

3.2. Conformity Test

After calculating the design rainfall, the next step is to test the suitability of the result. Using the Chi-square and Smirnov-Kolmogorov test method. (the result can be seen on tables 5 and tables 6)

Table 5. Result of Chi Square Test

| Probability Distribution | Chi-Square | X² Calculate | X² cr  | Result   |
|--------------------------|------------|--------------|--------|----------|
| Gumbel                   | 2.167      | 3.841        | Accepted |
| Normal                   | 5.667      | 3.841        | Rejected|
| Log Normal               | 2.333      | 3.841        | Accepted|
| Log Pearson Type III     | 2.667      | 3.841        | Accepted|
Table 6. Result Smirnov-Kolmogorof Test

| Probability Distribution | Smirnov Kolmogorof | ΔP Maximum | ΔP critical | Result |
|--------------------------|---------------------|------------|-------------|-------|
| Gumbel                   | 0.921               | 0.41       | Rejected    |
| Normal                   | 0.187               | 0.41       | Accepted    |
| Log Normal               | 0.102               | 0.41       | Accepted    |
| Log Pearson Type III     | 0.102               | 0.41       | Accepted    |

In Table 5 and 6, there are two distributions received, namely normal log distribution and type II log pearson distribution.

Because the calculation of the chi-square test in the normal log distribution has $x^2$ calculated smaller than the other methods, the normal log distribution is chosen.

3.3. Design Discharges Analysis

To estimate the design flood discharge, a hydrological analysis can be carried out using the Nakayasu Hydrograph Unit method, Snyder. Analysis of flood discharge was carried out at the return period of 2 years, 5 years, 10 years, 25 years, 50 years, 100 years, 500 years and 1000 years. This flood discharge is used in hydraulic analysis and water building planning.

Table 7. Result of Snyder Synthetic Unit Hydrograph and Nakayasu Synthetic Unit Hydrograph

| Return Period (Year) | Design Rainfall (mm) | Flood Discharges (m³/second) |
|----------------------|----------------------|------------------------------|
|                      | Snyder               | Nakayasu                    |
| 2                    | 166.25               | 447.79                       | 307.15                       |
| 5                    | 278.32               | 749.66                       | 514.22                       |
| 10                   | 364.55               | 981.94                       | 673.55                       |
| 25                   | 474.10               | 1277.02                      | 875.95                       |
| 50                   | 584.65               | 1574.80                      | 1080.20                      |
| 100                  | 694.22               | 1869.91                      | 1282.63                      |
| 500                  | 972.80               | 2620.28                      | 1797.34                      |
| 1000                 | 1106.55              | 2980.54                      | 2044.45                      |

Fig. 4. Way Samal Discharges Curves Analysis
Furthermore, from the recapitulation of the calculation of Snyder and Nakayasu Synthetic Unit Hydrograph, a comparison with graphical assistance was made to the mean with a linear approach. The results of these comparisons can be seen from Figure 4. From the results of the comparison, it can be seen that the Snyder method is the closest, the design flood discharge chosen is the flood discharge design calculated by Snyder Synthetic Unit Hydrograph.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1. Conclusions

1. In calculating the design rainfall, the distribution chosen based on the compatibility test is the Log Normal distribution, because it has the following suitability values:
   
   - Chi-Square Test
     \[ (X^2_{\text{calculated}} < X^2_{\text{cr}}) \]
     \[ (2.333 < 3.841) \rightarrow \text{accepted} \]
   
   - Smirnov-Kolmogorov Test
     \[ \Delta_{\text{max}} < \Delta_{\text{cr}} \]
     \[ (0.102 < 0.41) \rightarrow \text{accepted} \]

2. For the calculation of the design flood discharge, by comparing the two methods of the Hydrograph Synthesis Unit, then the selected design flood discharge is the design flood discharge using Snyder Synthetic Unit Hydrograph.

V. REFERENCES

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