SEDIMENTATION ANALYSIS BASED ON RIVER HYDROLOGICAL DISCHARGE AT CIPUNAGARA ESTUARY, SUBANG, INDONESIA

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Abstract. Coastal area is very dynamic. The sedimentation in estuary causes coastal morphological changes. Sediment which is transported by the river flow tends to accumulate in the estuary. Sedimentation also occurs in Cipunagara, Subang and causes the accretion. Based on this phenomenon of sedimentation, the objective of the study is to calculate the hydrological discharge, calculate the sediment transport rate, and analyze the added area of sedimentation in the Cipunagara estuary. The method of calculation of hydrological discharge has been referred to SNI 2145-2016 while the analysis of sedimentation referred to Van Rijn's analytical equations. The frequency analysis of maximum daily rainfall in Cipunagara watershed was done to obtain the value of rainfall plan. The rainfall plan was then used to calculate flood discharge plan with using HSS Nakayasu method. The flood discharge plan with a 2-years return period was chosen to determine the flow rate at STA 1 in Cipunagara River. Furthermore, the flow rate and sediment characteristic at STA 1 is used as the parameter to determine the sediment transport rate at STA 1. The sediment transport rate from January to December is calculated to obtain the volumetric value of the transported sediment which then used for the added area of sedimentation analysis at STA 6 and STA 9 in Cipunagara estuary. In this study, the value of flood discharge plan from January to December was obtained as, 328.41 m³/s, 275.96 m³/s, 247.62 m³/s, 300.25 m³/s, 212.19 m³/s, 129.84 m³/s, 142.14 m³/s, 67.83 m³/s, 52.93 m³/s, 160.33 m³/s, 266.60 m³/s, and 299.44 m³/s. The added area of sedimentation over one year at STA 6 and STA 9 are 320.04 ha/year and 182.88 ha/year with scheme A and 337.33 ha/year and 203.36 ha/year with scheme B.

1. Introduction

The coastal area is very dynamic. Coastal morphological changes could be the growth and shrinking coastal areas. This phenomenon also occurs on the north coast of Subang Regency. According to Andi Gustiani Salim, et.al. (2016), within 24 years (1989-2013) there is accretion near to 1.7 km at Cipunagara estuary. Meanwhile, according to Achiari H., et.al. (2017), the total annual sediment flux in the Cipunagara River is 2,73.106 tons/year. Those researchers are estimated the Cipunagara River sediment transport just based on the rough observation and satellite image change interpretation.

The phenomena of accretion in Cipunagara estuary is related to sediment transportation, which is carried along Cipunagara River and settled at river mouth delta. This study is focused on the calculating of the sedimentation accumulation in Cipunagara estuary. The important of this study is to support the estuarine management for the area which some part has erosion problem that will be filled.
by this excess supply of this river sediment. The discharge of Cipunegara River is based on hydrological data calculation. The location of hydrological discharge calculation and the analysis of sedimentation accumulation can be seen on Figure 1 below.

![Figure 1. Location of Sedimentation Analysis based Google Earth](image)

2. Method

The hydrological discharge is calculated by conducting a frequency analysis on the maximum daily rainfall data which can lead to determine the rainfall plan and then the flood discharge calculation plan. Frequency analysis includes determination of statistical parameters, Smirnov–Kolmogorov test, Chi-Square test, and rainfall plan calculation.

The calculation of rainfall plan uses two methods which are Gumbel distribution on Equation 1 and Log Pearson III distribution on Equation 2, as follows:

\[ X_T = \bar{X} + k \cdot S_x \]  

(1)

where:
- \( X_T \) = rainfall plan with T-years return period (mm)
- \( \bar{X} \) = average maximum daily rainfall (mm)
- \( S_x \) = standard deviation (mm)
- \( k \) = reduction factor of Gumbel distribution (-)

\[ Y = \bar{Y} + K \cdot S_Y \]  

(2)

where:
- \( X \) = maximum daily rainfall (mm)
- \( Y \) = logarithmic value of X (mm)
- \( \bar{Y} \) = average maximum daily rainfall (mm)
- \( S_Y \) = standar deviation (mm)
- \( K \) = reduction factor of Log Pearson III (-)

The calculation of flood discharge plan uses Nakayasu method on Equation 3 as follows:
$Q_p = \frac{C \cdot A \cdot R_0}{3.6 \cdot (0.3T_p + T_{0.3})}$  \hspace{1cm} (3)

where:

\( Q_p \) = peak flood discharge (m$^3$/s)
\( C \) = flow coefficient (-)
\( A \) = catchment area (km$^2$)
\( R_0 \) = rainfall plan unit (mm)
\( T_p \) = the grace period from the beginning of rain to the peak of flood (hour)
\( T_{0.3} \) = the time required for decreasing, from peak discharge to 30% peak discharge (hours)

To determine the total of sediment transport rate, suspended sediment transport rate should be calculated first. The calculation of suspended sediment transport rate uses Van Rijn’s method on **Equation 4**, as follows:

$$q_1 = F \bar{u} h c_a$$  \hspace{1cm} (4)

where:

\( q_1 \) = suspended sediment transport rate (m$^2$/s)
\( \bar{u} \) = depth-averaged velocity (m/s)
\( h \) = water depth (m)
\( c_a \) = reference concentration (-)
\( F \) = shape factor (-)

Another Van Rijn’s method formulates **Equation 5** based on independent variables \( \bar{u}, \bar{u}_{cr}, h, \) and \( d_{50}, \) as follows:

$$q_2 = 0.012 \bar{u} h \left( \frac{\bar{u} - \bar{u}_{cr}}{[(s - 1) g d_{50}]^{0.5}} \right)^{2.4} \left( \frac{d_{50}}{h} \right)^{1.2} \left( \frac{1}{D_*} \right)^{0.6}$$  \hspace{1cm} (5)

where:

\( \bar{u} \) = depth-averaged velocity (m/s)
\( \bar{u}_{cr} \) = critical depth-averaged velocity (m/s)
\( h \) = water depth (m)
\( d_{50} \) = particle diameter (m)
\( D_* \) = particle parameter (-)

The calculation of volumetric sediment load uses **Equation 6** and to calculate the added area of sedimentation uses **Equation 7**, as follows:

$$V_{sed} = \frac{Q_t}{\rho_s} N$$  \hspace{1cm} (6)

where:

\( V_{sed} \) = volumetric sediment load (m$^3$)
\( Q_t \) = sediment transport rate (kg/s)
\( N \) = number seconds in month of i (s)
\( \rho_s \) = sediment density (kg/m$^3$)

$$A_{sed} = \frac{V_{sed}}{D}$$  \hspace{1cm} (7)

where:
\[ A_{sed} = \text{area of sedimentation (m}^2) \]
\[ V_{sed} = \text{volumetric sediment load (m}^3) \]
\[ D = \text{water depth (m)} \]

3. Result and Analysis

With the use of hydrological discharge calculation procedures, including the maximum daily rainfall data processing, frequency analysis, rainfall plan calculation, and flood discharge plan calculation of Nakayasu method, so that the result of flood discharge plan per month for 2-years-return period is presented in **Table 1**.

**Table 1. Hydrological Flood Discharge calculation per month for 2-Years Return Period**

| Month    | Flood Discharge Plan (m³/s) |
|----------|----------------------------|
| January  | 328,41                     |
| February | 275,96                     |
| March    | 247,62                     |
| April    | 300,25                     |
| May      | 212,19                     |
| June     | 129,84                     |
| July     | 142,14                     |
| August   | 67,83                      |
| September| 52,93                      |
| October  | 160,33                     |
| November | 296,60                     |
| December | 299,44                     |

By using the sediment transport rate procedures, including calculation of depth-averaged velocity and sediment size, so that the result of suspended sediment transport rate is presented in **Table 2**.

**Table 2 Result of Suspended Sediment Transport Rate calculation**

| Month   | Suspended Sediment Transport Rate (kg/s) | \( Q_1 \) | \( Q_2 \) | \( Q_{measurement} \) |
|---------|------------------------------------------|-----------|-----------|------------------------|
| January | 392120,28                                | 3317,50   | -         |                        |
| February| 238122,94                                | 1656,22   | -         |                        |
| March   | 152936,14                                | 1062,03   | -         |                        |
| April   | 274668,34                                | 2327,22   | 330,28    |                        |
| May     | 80850,67                                 | 552,88    | -         |                        |
| June    | 8851,50                                  | 53,68     | -         |                        |
| July    | 13638,14                                 | 86,08     | -         |                        |
| August  | 122,64                                   | 0,20      | -         |                        |
| September| 0                                       | 0         | -         |                        |
| October | 20870,87                                 | 155,24    | -         |                        |
| November| 186084,01                                | 1438,75   | -         |                        |
| December| 298535,99                                | 2299,45   | -         |                        |

Based on the calculation of the sediment transport rate in **Table 2**, \( Q_2 \) is selected for sedimentation analysis. The selection of \( Q_2 \) is based on the depth-averaged velocity parameter which is considered
dominant in determining the value of the sediment transport rate. The rate of sediment transport is converted into volumetric sediment load. The analysis of sedimentation area is calculated into 2 schemes, namely scheme A and scheme B based on depth profile as shown in Figure 2. The result of the addition of sedimentation area at the estuary of STA 6 is 320.04 ha/year in scheme A and 337.33 ha/year in scheme B, while the addition of sedimentation area at STA 9 estuary is 182.88 ha year in scheme A and 203.36 ha/year in scheme B.

Figure 2 Sketch of Scheme A and Scheme B for Sedimentation accumulation analysis

4. Conclusion and further works

The conclusion is the hydrological discharge per month with a 2-years return period has been successfully calculated, where the results can be seen in Table 1. The addition of sedimentation area at the estuary of STA 6 and STA 9 has been successfully obtained which is 320.04 ha/year and 182.88 ha/year for schemes A and 337.33 ha/year and 203.36 ha/year for scheme B.

As for the improvement for this research, it is necessary to measure the flow rate of stream flow and the direct flow velocity to calibrate the results of the calculated discharge and flow rate. It is also necessary to not neglect the interference from the sea in in sedimentation analysis, such as wave, tide, and current. It is recommended to model the sedimentation by using model software.

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