Normalization of Way Ruhu River in Hative Kecil, Galala and Aster Villages in Sirimau District, Ambon City

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Abstract—Way Ruhu River is one of the watersheds in Sirimau District, Ambon City. The limited handling of the city government and the awareness of the local community to expand residential areas in the Way Ruhu watershed resulted in floods and landslides that brought sedimentation and garbage, which caused shallowness that occurred on the riverbed, thereby overflowing river water into the residential area of Hative Kecil, Galala, and Aster. To overcome this problem, an intensive study and periodic handling of sedimentation and garbage on the riverbed is required by periodically backfilling the Way Ruhu river area. Therefore, the analysis of sedimentation and garbage in the Way Ruhu river area is felt to be done by special handlers to deal with the overflows of water that occur every rainy season in the villages of Hative Kecil, Galala and Aster. This study aims to overcome the water overflow caused by the accumulation of sedimentation on the riverbed so that there is no flooding, by backfilling the riverbed. The results of the analysis of this study indicate that most of the Way Ruhu river area has been damaged by water-fed land which has been turned into residential land which has resulted in flooding and landslides in the Way Ruhu watershed area. The sedimentation rate that occurs in the Way Ruhu river watershed averages every year of: 3,599 m³/day or 1,313,635 m³/year. So that the sedimentation that is carried out of the river is as much: 32,386 m³/day atau 11,954,078 m³/year.

Keywords—Watershed, Sedimentation, River Normalization.

I. INTRODUCTION

Climate change is a global phenomenon, experiencing an increase as a result of human activities such as the use of fossil fuels and changes in land use. One of the global climate changes is the increasing frequency and incidence of climate extremes such as storms, floods, and drought.

The development of Ambon City from year to year with a sufficiently increasing population so that the problem of settlements is the main problem of the city government to overcome the existence of flooding that occurs in every river and settlement, especially the Way Ruhu river area, so that from observations in the area it must be a concern by the local community and the city government. Observing the results of observations, most of the Way Ruhu river area has been damaged by water-fed land which has been turned into residential land which has resulted in flooding and landslides in the Way Ruhu Watershed area.

Way Ruhu is one of the watersheds in Sirimau District, Ambon City. The limited handling of the city government and the awareness of the local community to expand the residential area in the Way Ruhu watershed resulted in floods and landslides that brought sedimentation and garbage made shallowness that occurred on the riverbed, thus overflowing the Way Ruhu river water resulting in flooding in the residential area of Hative Kecil, Galala and Aster.

To overcome this problem, it is necessary to periodically study and handle intensive sedimentation and garbage and the characteristics of the river bed by periodically backfilling the Way Ruhu river area. Therefore, the analysis of sedimentation and garbage in the Way Ruhu river is felt to be done by special handlers to deal with the water overflows that occur every rainy season in the villages of Hative Kecil, Galala and Aster, from problems that occur in fact in the study area, the authors raise the title: "Normalization of Way Ruhu River in Hative Kecil, Galala and Aster Village in Sirimau District, Ambon City".
The purpose of this research is to overcome water overflow so that there is no flooding in the villages of Hative Kecil, Galala and Aster by backfilling the riverbed of Way Ruhu.

II. LITERATURE REVIEW

2.1. General purpose

Flood control is a relative term, because it is not economical to provide protection against the largest possible flood. Since the beginning of human civilization, flooding is a natural occurrence that is well documented after describing a series of past floods. Hoye and Langbein (1955) concluded that the concept of flood control is generally understood. Nature will let go of all the burdens it carries. Year-round floods cause immeasurable damage and terrible loss of life. Climatologists believe that the current flood rains are caused by a combination of meteorological and hydrological conditions that will only occur once a million years. Reservoir,

2.2. Hydrology

Meteorology is part of a broader hydrological science, which includes observing the occurrence of water in the atmosphere and water on the ground and below the earth's surface. One presentation of the hydrological cycle as shown in Figure 1 which shows the formation of rain (in the form of rain, snow, drizzle or hail)

Rain usually occurs in many forms and can change shape during the process. The form of rain in the form of falling water droplets can be classified as drizzle or rain. Drizzle consists of rain with a grain size of <0.5 mm. While larger raindrops are scattered in the air, droplets >5 mm in diameter are generally unstable. Part of the rain will evaporate partially or completely before it reaches the ground surface. Rain on the soil can be captured by vegetation, infiltrated into the soil to evaporate or become surface runoff. Evaporation can come from the soil surface, free water surface, or from plant leaves through the process of transpiration. Some of the rain will move on the ground as runoff, some of it will enter the soil used by plants, can become a deep supply of groundwater,

2.3. Surface Water Runoff

Runoff is the portion of rainfall that flows towards a channel, lake, river or sea as surface or underground flow. Runoff will only occur when the rate of rain exceeds the infiltration rate into the soil. After the infiltration rate is met, water begins to fill small or large depressions on the soil surface. After the basin is filled, runoff begins. So a rain in a short time may not produce runoff, while rain with the same intensity for a long time will produce runoff, in other words, rainwater that falls to the ground will flow to the ground if the soil infiltration capacity is less than the intensity of rain. The destructive force of water flowing on the ground is greater in proportion to the steeper and longer the slope. Plants that live above the soil surface will increase the ability of the soil to absorb water and reduce the destructive force of falling raindrops, the dispersion power, and the carrying capacity of surface runoff. The rate and volume of runoff from a catchment area is influenced by the distribution of rainfall in the area, however heavy rainfall in a particular part of the catchment area can produce more runoff than moderate rainfall above the catchment. The amount of water that constitutes this layer is highly dependent on the amount of rainwater per unit time (intensity), soil conditions (especially the slope), soil type, and the presence or absence of previous rain. and surface runoff. The rate and volume of runoff from a catchment area is influenced by the distribution of rainfall in the area, however heavy rainfall in a particular part of the catchment area can produce more runoff than moderate rainfall above the catchment. The amount of water that constitutes this layer is highly dependent on the amount of rainwater per unit time (intensity), soil conditions (especially the slope), soil type, and the presence or absence of previous rain. and surface runoff. The rate and volume of runoff from a catchment area is influenced by the distribution of rainfall in the area, however heavy rainfall in a particular part of the catchment area can produce more runoff than moderate rainfall above the catchment. The amount of water that constitutes this layer is highly dependent on the amount of rainwater per unit time (intensity), soil conditions (especially the slope), soil type, and the presence or absence of previous rain. and surface runoff. The rate and volume of runoff from a catchment area is influenced by the distribution of rainfall in the area, however heavy rainfall in a particular part of the catchment area can produce more runoff than moderate rainfall above the catchment. The amount of water that constitutes this layer is highly dependent on the amount of rainwater per unit time (intensity), soil conditions (especially the slope), soil type, and the presence or absence of previous rain.

For the magnitude of the surface flow coefficient value can be seen in Table 1 as follows:

![Fig. 1: Hydrological Cycle](image-url)
### Table 1: Flow Coefficients for the Rational Method

| Land description / surface character | Flow coefficient, C |
|-------------------------------------|---------------------|
| Business                            |                     |
| Urban                               | 0.70 - 0.95         |
| Fringe                              | 0.50 - 0.70         |
| Housing                             | 0.30 - 0.50         |
| Single house                         |                     |
| Multiunit, separate                 | 0.40 - 0.60         |
| Multiunit, incorporated              | 0.60 - 0.75         |
| Village                             | 0.25 - 0.40         |
| Apartment                           | 0.50 - 0.70         |
| Industry                            |                     |
| Light                               | 0.50 - 0.80         |
| Weight                              | 0.60 - 0.90         |
| Pavement                            |                     |
| Asphalt and concrete                | 0.70 - 0.95         |
| Bricks, paving                      | 0.50 - 0.70         |
| Roof                                | 0.75 - 0.95         |
| Yard, sandy soil                    |                     |
| Flat, 2%                            | 0.05 - 0.10         |
| Average, 2-7%                       | 0.10 - 0.15         |
| Steep, 7%                           | 0.15 - 0.20         |
| Yard, heavy soil                    |                     |
| Flat, 2%                            | 0.13 - 0.17         |
| Average, 2-7%                       | 0.18 - 0.22         |
| Steep, 7%                           | 0.25 - 0.35         |
| Railroad yard                       | 0.10 - 0.35         |
| Playground                          | 0.20 - 0.35         |
| Garden, cemetery                    | 0.10 - 0.25         |
| Forest                              |                     |
| Flat, 0-5%                          | 0.10 - 0.40         |
| Wavy, 5-10%                         | 0.25 - 0.50         |
| Hilly, 10-30%                       | 0.30 - 0.60         |

(Source: McGuen, 1989 in Suripin, 2004)

2.4. Soil Structure

Soil structure is defined as the mutually binding arrangement of soil particles, the bonding of soil particles aims as the soil aggregate that forms itself, this aggregate (Soil Survey Staff, 1975). Slopes can be grouped as shown in Table 2 below.

### Table 2: Slope Classification

| Symbols | Slope Class | Land Shape |
|---------|-------------|------------|
| L₀      | 0 - 3       | Flat       |
| L₁3     | 0 - 8       | Slight sloping / wavy |
| L₂8     | 1 - 12      | Somewhat climbing |
| L₃5     | 15 - 30     | Hilly      |
| L₄5     | 30 - 45     | Very steep |
| L₅5     | 45 - 60     | Steep      |
| L₆5     | > 65        | Very steep |

(Source: Asdak, 2002)

The effectiveness of the soil as a means of removing water depends largely on the size and resistance of the channel in the soil. The physical properties of the soil change the infiltration capacity and how large the particles can be separated and transported. Soil properties that explain how easily soil particles can be eroded are their separation and transportability. The properties that renew erosion include soil structure, texture, organic matter, and chemical and biological properties of soil.

2.5. Vegetation and Land Use

Vegetation is one part of the land system that provides benefits for the survival of creatures, especially humans. The existence of vegetation varies from place to place, because it is influenced by different land conditions. Vegetation plays an important role in maintaining soil sustainability because it can inhibit surface runoff and erosion, including: (1) interception of rain by plant canopy; (2) reduce surface runoff speed and water-destroying force; (3) the influence of roots and biological activities related to vegetative activities and their influence on the stability of the structure and soil porosity; and (4) transmiration which results in reduced groundwater content. Thick ground cover vegetation such as grass or jungle will eliminate the influence of rain and topography on erosion.

Land use (Land use) according to Aryad (1989; 207) can be interpreted as any form of human intervention (intervention) on land in order to meet their needs. Land use is a dynamic process. Therefore, information on land use becomes out-of-date relatively quickly when compared with geological, geomorphological and soil information.
Land use can be grouped into two major groups, namely agricultural land use and non-agricultural land use.

2.6. Erosion

Erosion is the event of removing or transporting material in the form of a solution or suspension from the original site by flowing water (runoff flow), erosion is the loss or erosion of soil or parts of land in one place that are transported by water and wind to another place (Arsyad, 1989).

The damage experienced to the soil where erosion occurs takes the form of a deterioration of the physical and chemical properties of the soil such as loss of nutrients and organic matter, poor infiltration, the ability of the soil to retain water, reduced stability of soil structure which ultimately leads to worsening plant growth. (Arsyad, 1989)

The classification of the level of soil damage by erosion according to (Arsyad) is presented in Table 3.

| Table 3: Classification of Soil Damage and Erosion Levels |
|--------------------------------------------------------|
| Symbol | Erosion Rate | Information |
|--------|--------------|-------------|
| E0     | No erosion   | Fixed soil layer |
| e1     | Light        | Less than 25% of the top layer is lost |
| e2     | Moderate     | 25-27% of topsoil is lost |
| e3     | It's a bit heavy | More than 75% of the topsoil up |
| e4     | Weight       | More than 25% of that layer is gone |
| e5     | Very heavy   | Same with trench erosion |

(Source: Asyad, 1989)

2.7. Land Erosion Factors

The factors that influence the amount of erosion in a watershed include:
- Rain Erosion
- Soil sensitivity to rain
- Drought and slope length and tillage factors are closely related to soil cover or vegetation
- Rain Erosion (REI)
- Soil Erodibility (K)
- Slope (LS)

The slope factor can be calculated based on the empirical formula developed by Wischmeies, namely:

- For the slope (S) <20%, take:
  \[ \text{LS} = \text{Lo} \times 0.0138 + 0.00965 \times S + 0.00138 \times S^2 \]  \( \text{(1)} \)
- For a slope (S) > 20%, is taken:
  \[ \text{LS}^{0.614} \]  \( \text{(2)} \)

Where:
- \( \text{Lo} \) = Length of flow over the ground
- \( S \) = Slope / slope

Factors on Plant Types and Soil Processing (CP)

This CP factor has a huge effect on sediment production and the amount of erosion in an area. The size of the CP value can be adjusted based on soil processing activities and by planting certain types of plants on the land

- Erosion Rate

The estimated magnitude of the permissible erosion rate for a watershed is approximated by the following formula (Achlil, 1982):

\[ A = 4 + 1.226 \times (10 \times D - K^2) \]  \( \text{(3)} \)

Where:
- \( A \) = Permissible rate of erosion (tonnes / ha)
- \( K \) = soil erodibility factor
- \( D \) = depth of soil layer, (m)

Table 4: Classification of Erosion Hazards

| Erosion Rate ton/ha/ year | Classification |
|---------------------------|----------------|
| 0.0 - 12.5                | Very small     |
| 12.5 - 17.5               | Small          |
| 17.5 - 25.0               | Medium         |
| 25.0 - 30.0               | Weight         |
| > 30.0                    | Very Heavy     |

2.8. Stream Erosion

In the analysis of river channel erosion, the stability of the grains on the river bed and the volume of sediment transport will be reviewed.

In a gloomy river channel, in general, sediment transport seen from the way it moves can be divided into two, namely:
- Suspended load where the sediment particles move floating in the water and carried along with the flow
- Bed load, which moves from the particles not far from the river bed and moves, shifts, rolls and jumps individually.
If there is a change in the river either artificially or naturally, the riverbed will change accordingly. Over time an adequate relationship will re-form between the hydraulic properties of the irrigation and the sediment that flows downward and eventually a stable channel will be formed.

Therefore, in making a review / planning of a river, the cross section must be selected not only based on the flood discharge but also taking into account the condition of the river repair work.

The stable condition of the channel means the conditions along the channel where there is no streak and deposition. This means that the amount of sediment flowing in each cross section of the river must be kept stable.

2.9. Riverbed Stability Calculations

From the results of research on riverbed stability analysis, some basic equations can be used as follows:

- Fiber force and critical shear speed according to the Two Boys:
  \[ T_o = \text{fiber force (ton/m}^2) \]  
  \[ U^* = V \left( \frac{\text{Ton}}{\text{fw}} \right) \]  
  Where:
  \[ T_o = \text{fiber force (ton/m}^2) \]

2.10. Rainfall Intensity Analysis

To find out the intensity of rainfall, it is analyzed using the Gumbel method with the formula:

\[ X_t = X + K \cdot S_x \]  
Where:
\[ X_t = \text{The amount expected to occur t year (mm)} \]
\[ t = \text{Return period in this case t = 10 years} \]
\[ X = \text{Average daily rain during observation (mm)} \]
\[ Y_t = \text{The relationship between times and the reduction factor (Y_t and n)} \]
\[ S_n = \text{Reduced standard deposit (relationship between Yn and n)} \]
\[ S_x = \text{Standard deviation} \]

The value of \( S_n, Y_n, \) and \( Y_{Tr} \) can be seen in Table 5; 6; 7 as follows:

Table 5: Reduced mean (Yn)

| N  | 0   | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     |
|----|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 10 | 0.4952 | 0.4996 | 0.5035 | 0.5070 | 0.5100 | 0.5128 | 0.5157 | 0.5181 | 0.5202 | 0.5220 |
| 20 | 0.5236 | 0.5252 | 0.5268 | 0.5283 | 0.5296 | 0.5309 | 0.5320 | 0.5332 | 0.5343 | 0.5353 |
| 30 | 0.5362 | 0.5371 | 0.5380 | 0.5388 | 0.5396 | 0.5403 | 0.5410 | 0.5418 | 0.5424 | 0.5436 |
| 40 | 0.5436 | 0.5442 | 0.5448 | 0.5453 | 0.5458 | 0.5463 | 0.5468 | 0.5473 | 0.5477 | 0.5481 |
| 50 | 0.5485 | 0.5489 | 0.5493 | 0.5497 | 0.5501 | 0.5504 | 0.5508 | 0.5511 | 0.5515 | 0.5518 |
| 60 | 0.5521 | 0.5524 | 0.5527 | 0.5530 | 0.5533 | 0.5535 | 0.5538 | 0.5540 | 0.5543 | 0.5545 |
| 70 | 0.5548 | 0.5550 | 0.5552 | 0.5555 | 0.5557 | 0.5559 | 0.5561 | 0.5563 | 0.5565 | 0.5567 |
| 80 | 0.5569 | 0.5570 | 0.5572 | 0.5574 | 0.5576 | 0.5578 | 0.5580 | 0.5581 | 0.5583 | 0.5585 |
| 90 | 0.5586 | 0.5587 | 0.5589 | 0.5591 | 0.5592 | 0.5593 | 0.5595 | 0.5596 | 0.5598 | 0.5599 |
| 100| 0.5600 | 0.5602 | 0.5603 | 0.5604 | 0.5606 | 0.5607 | 0.5608 | 0.5609 | 0.5610 | 0.5611 |

(source, Suripin, 2004)
Table 6: Reduced standard deviation (Sn)

| N   | 0    | 1   | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    |
|-----|------|-----|------|------|------|------|------|------|------|------|
| 10  | 0.9496 | 0.9676 | 0.9833 | 0.9971 | 10.095 | 10.206 | 10.316 | 10.411 | 10.493 | 10.565 |
| 20  | 10.628 | 10.696 | 10.754 | 10.811 | 10.864 | 10.915 | 10.961 | 11.004 | 11.047 | 11.080 |
| 30  | 11.124 | 11.159 | 11.193 | 11.226 | 11.255 | 11.285 | 11.313 | 11.339 | 11.363 | 11.388 |
| 40  | 11.413 | 11.436 | 11.458 | 11.480 | 11.499 | 11.519 | 11.538 | 11.557 | 11.574 | 11.590 |
| 50  | 11.607 | 11.623 | 11.638 | 11.658 | 11.667 | 11.681 | 11.696 | 11.708 | 11.721 | 11.734 |
| 60  | 11.747 | 11.759 | 11.770 | 11.782 | 11.793 | 11.803 | 11.814 | 11.824 | 11.834 | 11.844 |
| 70  | 11.854 | 11.863 | 11.873 | 11.881 | 11.890 | 11.898 | 11.906 | 11.915 | 11.923 | 11.930 |
| 80  | 11.938 | 11.945 | 11.953 | 11.959 | 11.967 | 11.973 | 11.980 | 11.987 | 11.994 | 12.001 |
| 90  | 12.007 | 12.013 | 12.020 | 12.026 | 12.032 | 12.038 | 12.044 | 12.049 | 12.055 | 12.060 |
| 100 | 12.065 | 12.069 | 12.073 | 12.077 | 12.081 | 12.084 | 12.087 | 12.090 | 12.093 | 12.096 |

(Source: Suripin, 2004)

Table 7: Reduced Variate (YTr)

| Reset Period Tr (year) | Reduced Variate YTr |
|------------------------|---------------------|
| 2                      | 0.3668              |
| 5                      | 15.004              |
| 10                     | 22.510              |
| 20                     | 29.709              |
| 25                     | 31.993              |
| 50                     | 39.028              |
| 75                     | 43.117              |

| Reset Period Tr (year) | Reduced Variate YTr |
|------------------------|---------------------|
| 100                    | 46.012              |
| 200                    | 52.969              |
| 250                    | 55.206              |
| 500                    | 62.149              |
| 1000                   | 69.087              |
| 5000                   | 85.188              |
| 10000                  | 92.121              |

(Source: Suripin, 2004)

2.11. Calculation of Flood Plan

Design flood is a large annual flow rate caused by rain with a certain return period.

Calculation of the flood discharge plan using the Der Weduwen Method:

Formula: \[ Q = \alpha \cdot \beta \cdot q_n \cdot A \] .............................................. (7)

Where:
- \( Q \) = Discharge (m³/sec)
- \( \alpha \) = Flow coefficient (run off coefficient)
- \( \beta \) = Reduction coefficient
- \( q_n \) = Maximum rain (mm)
- \( A \) = Area of flow

1. The run off coefficient is the ratio between run off and rain: \( \alpha = 1 - 4.1 / (\beta \cdot q_n + 7) \) ...................... (8)

2. Concentration Time (t):
   \( t = 0.25 \cdot L \cdot A - 0.126.1 - 0.26 \) ................................. (9)

3. Redux Coefficient (\( \beta \))
   This figure is used to get the average rainfall from the maximum rainfall.
   \[ \beta = \frac{120 + t + 1.1}{120 + A} \] ............................................... (10)

Where:
- \( \beta \) = Reduction coefficient
- \( t \) = Concentration time (hours)
- \( A \) = Area of watershed (km²)

4. The relationship between \( q \) and \( R \):
   \[ q_n = \frac{Rn}{240} + \frac{67.65}{t+4.45} \] ...............................(11)

2.12. Analysis River Discharge
This analysis was carried out to determine the river discharge that occurred in the Way Ruhu river using the following formula:

River Water Flow Discharge (DLAS) uses the general equation DLSA (Chow), namely;

\[ Q = V \cdot A \] ............................................. (12)

Where :

- \( Q \) = River flow rate (m\(^3\) / sec)
- \( V \) = River water layer velocity (m / sec)
- \( A \) = Wet cross-sectional area of river water layer (m\(^2\))

2.13. Analysis Average Sediment Discharge

To calculate the annual average sediment discharge, the planned annual return time discharge using the DER WIDUWEN method is used as follows:

\[ Q = a \cdot \beta \cdot g \cdot A \] ............................................. (13)

Where :

- \( Q \) = Return flood discharge (m\(^3\) / sec)
- \( A \) = Area of flow area (Km\(^2\))
- \( S \) = slope of the river bed
- \( \tau \) = Kosentime constellation (hour)
- \( \beta \) = Reduction coefficient
- \( g \) = Intensity of rain yang is calculated (m\(^3\) / km\(^2\) / sec)

2.14. Sedimentation Rate

Sedimentation rate prediction is done using the equation:

\[ Q_s = Q \cdot S \] ............................................. (14)

Where :

- \( Q_s \) = River water sediment discharge (gram / second)
- \( Q \) = River flow rate (m\(^3\) / sec)
- \( C_s \) = Weight of filter paper (mg)
- \( V \) = Sediment concentration (mg / liter)

2.15. Sedimentation Transport

Many methods for estimating the capacity for sediment transport have been developed based on the hydraulic shear rate, flow velocity and sediment properties.

\[ V = P \cdot Q \] ............................................. (15)

Where :

- \( V \) = volume of sedimentation (m\(^3\))
- \( P \) = length of river (m)
- \( Q \) = amount of sedimentation (m\(^2\))

The process of erosion between grooves is used in several computer models to estimate erosion, including CREAMS (Kniel, 1980).

III. METHODOLOGY

3.1. Analysis Technique

In general, the sedimentation rate analysis of this study can be seen in the following diagram:

![Research Flowchart](image)

3.2. Location and Time

The location or object of the analysis was taken based on the sediment transport plan that occurred in the Way Ruhu River (NegeriGalala), in the last 10 years the rainfall data at the Ambon Pattimura Airport Meteorological Station.
3.3. Materials and Analysis Tools

The materials needed in conducting this analysis are a permit and data, both in the form of analysis data and planning data from the object being analyzed, and so on. Meanwhile, the tools used are digital cameras, heavy equipment to support the implementation, meters and other supporting tools.

3.4. Analysis Variable

The analysis variables required in the analysis of sedimentation transport on the Way Ruhu River are specified based on the following problem formulations:

1) Map of the Way Ruhu River
2) Research Location Map

3.5. Data Collection Technique

The data collection stages from the sedimentation transport analysis are as follows:

1) Preparation phase
2) Data Collection Stage
3) Problem Formulation Stage
4) Problem Analysis Stage
5) Implementation of Activities

IV. ANALYSIS AND DISCUSSION

4.1. The Mechanism of Erosion

So erosion can occur at least in one step, namely dispersion by granules or runoff. The erosion stages include:

1. Raindrops collide with the ground;
2. Splash the ground by raindrops with soil.
3. Destruction of a lump of soil by raindrops;
4. Transport of splashed particles / soil mass dispersed by runoff during rain.

To find out the relationship between erosion and hydrology, we must study the effects of land and vegetation management in the upper watershed areas, including its effects on erosion, water quality, flooding and climate in the upstream and downstream areas. And the influencing factors in this calculation are rain erosivity, slope slope, soil sensitivity to erosion, and river length. And soil management factors are closely related to land cover or vegetation.

4.2. Hydrological Data Analysis

To find out how much erosion has occurred in the Way Ruhu watershed, it is necessary to know the planned flood discharge which will be used to calculate the amount of erosion rate that occurs in the Way Ruhu Watershed.

Rainfall data required is maximum daily rainfall data with a minimum number of observations of 10 years. Rainfall data for this analysis were taken from the Pattimura - Ambon Meteorological Station.

4.3. Rainfall Calculation

Rainfall calculation analysis, selected the Pattimura Airport Meteorological Station Observation Post - Ambon.

Table 8: Data of Way Ruhu River Maximum Daily Rainfall 2003 - 2012

| No. | Observation Year | Rainfall (mm) |
|-----|------------------|--------------|
| 1   | 2003             | 94.47        |
| 2   | 2004             | 135.65       |
| 3   | 2005             | 237.82       |
| 4   | 2006             | 262.05       |
| 5   | 2007             | 284.66       |
| 6   | 2008             | 476.31       |
| 7   | 2009             | 167.32       |
| 8   | 2010             | 325.68       |
| 9   | 2011             | 384.17       |
| 10  | 2012             | 420.09       |

(Source: Pattimura-Ambon Airport Meteorological Station)

a) Calculation of Algebraic Average Rainfall

\[ R = \frac{1}{n} (R^1 + R^2 + R^3 + \ldots + R^n) \] (16)

b) Calculation of Standard Deviation, Coefficient of Variation and Coefficient of Skewness

1. \[ \Sigma \text{Year (}n\text{)} = 10 \]
2. On average, \( R_r \)
\[ R_r = \sum_{i=1}^{n} R_i / n = 2788.29 \]
\[ = 278.82 \]

3. Standard Deviation, Std
\[ \text{Std} = \sqrt{\frac{\sum_{i=1}^{n} (R - R_r)^2}{n-1}} = \sqrt{3411.03 / 9} = 19.46 \]

4. Coefficient of Variation, Cv
\[ \text{Cv} = \frac{\text{Std}}{R_r} = \frac{19.46}{278.82} = 0.07 \]

5. Skewness Coefficient, Cs
\[ \text{Cs} = \frac{n \sum (R - r)^3}{(n-1)(n-2)(\text{Std})^3} = \frac{10 \times 7047794.66}{(9)(8)(19.46)^3} = 132.82 \]

Table 9: Rainfall Recapitulation

| Year | R     | R - Rr | (R - Rr)^2 | (R - Rr)^3 |
|------|-------|--------|------------|------------|
| 2003 | 94.47 | -184.35| -33984.92  | -6265.12   |
| 2004 | 135.65| -143.17| -20497.64  | -2934648.34|
| 2005 | 237.82| -41     | -1681     | -68921     |
| 2006 | 262.05| -16.77  | -281.23    | -4716.27   |
| 2007 | 284.66| 5.84    | 34.10      | 199.17     |
| 2008 | 476.31| 197.49  | 39002.3    | 7356848.77 |
| 2009 | 167.32| -111.5  | -12432.25  | -1386195.87|
| 2010 | 325.68| 46.86   | 2195.84    | 102897.98  |
| 2011 | 384.17| 105.35  | 11098.62   | 169239.88  |
| 2012 | 420.09| 141.27  | 19957.21   | 2819355.46 |
| \(\Sigma\) | 2788.29| 3411.03| 7047794.66 |

(Source: Analysis Results)

4.4. Calculation of Flood Plan

Design flood is a large annual flow rate caused by rain with a certain return period.

To calculate the planned flood discharge, the Der Weduwen method can be used:

- Calculation of flood discharge plans using the Haspers Method:
  
  The formula \( Q = \alpha \cdot \beta \cdot qn \cdot A \)
  
  Where:
  
  \( Q \) = Debit
  \( \alpha \) = Flow coefficient (run off coefficient)
  \( \beta \) = Reduction coefficient
  \( qn \) = Maximum rain (mm)
  \( A \) = Area of flow = 0.0216 km²

1) Calculation of the length of rain (hours)
\[ t = 0.25 \cdot L \cdot A - 0.126.1-0.26 \]

Where:

\( t \) = Concentration time (hours)
\( L \) = Length of river (km)
\( I \) = Slope of 0.01
\( A \) = Area of watershed (km²)

\[ t = 0.25 \cdot 9.10 \cdot 0.0216 - 0.126.1 \]
\[ = 0.25 \cdot 9.10 \cdot 0.0216 - 0.01-0.26 \]
\[ = 12 \text{ hours} \]

2) \( \beta = \frac{120 + t + A}{120 + A} \)

Where:

\( \beta \) = Reduction coefficient
\( t \) = Concentration time (hours)
\( A \) = Area of watershed (km²)

\[ \beta = \frac{120 + 12 \cdot 0.0216}{120 + 0.0216} = 1.02 \]

3) Calculation of rainfall area (m³ / sec. km²) with a return period
\[ qn = \frac{Rn}{240} + \frac{67.65}{t+1.45} \]

Where:

\( Rn \) = Maximum daily rainfall (mm / day) with return period (n) years. = 278.8 mm / day
\( t \) = Time (hour)

\[ qn = \frac{278.8}{240} + \frac{67.65}{t+1.45} = 6.2 \text{ m}^3 / \text{sec.km}^2 \]

4) The run off coefficient is the ratio between run off and rain:
\[ \alpha = 1 - 4.1 / (\beta \cdot qn + 7) \]

Where:
\[ \beta = \text{Reduction coefficient} \]
\[ q_n = \text{area of rainfall (m}^3/\text{sec.km}^2) \]
\[ \alpha = 1 - 4.1 / (1.02 6.2 + 7) \]
\[ = 0.7 \]

5) Flood discharge calculation

\[ Q = \alpha \cdot \beta \cdot q_n \cdot A \]

Where:

- \( Q \) = Discharge (m\(^3\)/s)
- \( \alpha \) = Flow coefficient = 0.7
- \( \beta \) = Reduction coefficient = 1.02
- \( q_n \) = Maximum rain (mm) = 6.2 m\(^3\)/sec.km
- \( A \) = Area of flow = 0.0216 km\(^2\)

\[ Q = 0.7 \cdot 1.02 \cdot 6.2 \cdot 0.0216 = 0.0956 \text{ m}^3/\text{sec} \]

4.5. Slope (Ls)

As an example of calculating the slope, the Way Ruhu Watershed was chosen.

Known:

- River length, \( L \) = 9.10 km
- Watershed area = 0.0216 km\(^2\)
- Drainage Density, \( d \) = \( 9.10 / 0.0216 \) = 421.29 km\(^2\)

4.6. Calculation of potential and actual land erosion on the Way Ruhu river

From the data it is known:

1. For land slopes of 0 - 3%, value of \( K \) = 0.120
2. For land slopes of 3 - 8%, value of \( K \) = 0.120
3. For land slopes of 8 - 15%, value of \( K \) = 0.260
4. For land slopes of 15 - 40%, value of \( K \) = 0.230
5. For land slopes> 40%, value of \( K \) = 0.210

4.7. Calculation of Average Slope

(for average slope \( S = 4\% \))

\[ D = 1, 35. \ d + 0, 26. \ S + 2, 80 \]
\[ = 1, 35. \ 421.29 + 0, 26. \ 4 + 2. \ 80 \]
\[ = 572,581 \]

\[ L_o = \frac{1}{2 \cdot D} \]
\[ = \frac{1}{2 \cdot 572,581} \]
\[ = 0.0017 \text{ km} \]

\[ L_s = \left( \frac{L_o}{22.1} \right)^{0.6} \left( \frac{S}{9} \right)^{1.4} \]

(for average slope \( S = 20\% \))

\[ D = 1, 35. \ d + 0, 26. \ S + 2, 80 \]
\[ = 1, 35. \ 421.29 + 0, 26. \ 20 + 2. \ 80 = 576,741 \]

\[ L_o = \frac{1}{2 \cdot D} \]
\[ = \frac{1}{2 \cdot 576,741} \]
\[ = 0.0017 \text{ km} \]

\[ L_s = \left( \frac{L_o}{22.1} \right)^{0.6} \left( \frac{S}{9} \right)^{1.4} \]

(for average slope \( S = 35\% \))

\[ D = 1, 35. \ d + 0, 26. \ S + 2, 80 \]
\[ = 1, 35. \ 421.29 + 0, 26. \ 30 + 2. \ 80 = 579,341 \]

\[ L_o = \frac{1}{2 \cdot D} \]
\[ = \frac{1}{2 \cdot 579,341} \]
\[ = 0.0017 \text{ km} \]

\[ L_s = \left( \frac{L_o}{22.1} \right)^{0.6} \left( \frac{S}{9} \right)^{1.4} \]

(for average slope \( S = 40\% \))

\[ D = 1, 35. \ d + 0, 26. \ S + 2, 80 \]
\[ = 1, 35. \ 421.29 + 0, 26. \ 40 + 2. \ 80 = 581,941 \]

\[ L_o = \frac{1}{2 \cdot D} \]
\[ = \frac{1}{2 \cdot 581,941} \]
\[ = 0.0017 \text{ km} \]

\[ L_s = \left( \frac{L_o}{22.1} \right)^{0.6} \left( \frac{S}{9} \right)^{1.4} \]
Table 10: Calculation of Slope Slope (Ls)

| No. | Long River | Large Watershed | Drainage Density (d) | Slope Land% | Slope is average | D | Lo (m) | Ls |
|-----|------------|-----------------|----------------------|-------------|----------------|----|--------|----|
| 9,10 | Way Ruhu Watershed | 0.0216 | 421.29 | 0 - 3 | 4.00 | 572,581 | 285.79 | 1,259 |
| 9,10 | Way Ruhu Watershed | 0.0216 | 421.29 | 3 - 8 | 11.50 | 574,531 | 287,265 | 5,211 |
| 9,10 | Way Ruhu Watershed | 0.0216 | 421.29 | 8 - 15 | 20.00 | 576,741 | 288,370 | 14,283 |
| 9,10 | Way Ruhu Watershed | 0.0216 | 421.29 | 15 - 40 | 35.00 | 579,341 | 289,670 | 31,351 |
| 9,10 | Way Ruhu Watershed | 0.0216 | 421.29 | > 40 | 40.00 | 581,941 | 290,970 | 37,898 |

(Source: Analysis Results)

Thus:

1. For land slope 0 - 30%
   Formula: \( A = 4 + 1.226 (10 \times D - K^2) \)
   \( A = 4 + 1.226 (10 \times 572,581 - 0.120^2) \)
   \( = 7250,191 \) ton / ha / year

2. For land slope 3 - 8%
   \( A = 4 + 1.226 (10 \times 574,531 - 0.120^2) \)
   \( = 7274,878 \) ton / ha / year

3. For land slope 8 - 15%
   \( A = 4 + 1.226 (10 \times 576,741 - 0.260^2) \)
   \( = 7300,147 \) ton / ha / year

4. For land slope 15 - 40%
   \( A = 4 + 1.226 (10 \times 579,341 - 0.230^2) \)
   \( = 7335,633 \) ton / ha / year

5. For slopes > 40%
   \( A = 4 + 1.226 (10 \times 581,941 - 0.210^2) \)
   \( = 7368,575 \) ton / ha / year

The average allowable rate of erosion rates for the Way Ruhu river basin are:

\[ \bar{A} = \frac{1A + 2A + 3A + 4A + 5A}{5} \]

\[ \bar{A} = \frac{7250,191 + 7274,878 + 7300,147 + 7335,633 + 7368,575}{5} \]

\[ \bar{A} = 7305,884 \) ton / ha / year

Table 11: Calculation of Erosion Rate

| Watershed Name | Slope Land (%) | Thickness Humus (D)(M) | Erodibility (K) | Erosion Rate (A) ton / ha / year | A Average (ton / ha / hr) |
|----------------|----------------|------------------------|-----------------|----------------------------------|--------------------------|
| Way Ruhu       | 0 - 3          | 3.00                   | 0.120           | 7250,191                         | 7,305,884                |
|                | 3 - 8          | 3.00                   | 0.120           | 7274,878                         |                          |
|                | 8 - 15         | 3.00                   | 0.260           | 7300,147                         |                          |
|                | 15 - 40        | 3.00                   | 0.230           | 7335,633                         |                          |
|                | > 40           | 3.00                   | 0.210           | 7368,575                         |                          |

(Source: Analysis Results)

The calculation of erosion can be seen in Table 11. Based on the calculation results, it can be seen that the rate of erosion in the Way Ruhu watershed is classified as very heavy, so it needs immediate treatment.

4.8. Annual Average Sediment Discharge Calculation

To calculate the annual average sediment discharge, the annual discharge plan for the return period using the Der Widuwen method is used as follows

\[ Q = \alpha \beta^t q \]

Where:

\[ A = \text{Flow area (km}^2) = 0.0216 \text{ km}^2 \]
\[ t = \text{Concentration time (hours)} = 4.65 \text{ hours} \]
\[ \beta = \text{The reduction coefficient} = 1.26 \]
\[ q = \text{The calculated rainfall intensity (m}^3 / \text{km}^2 / \text{sec}) = 314,130 \text{ m}^3 / \text{km}^2 \text{ / second} \]
α = Flow coefficient = 0.421

Thus, the annual average sediment discharge can be calculated as follows:

\[
Q = 0.421 \times 1.26 \times 314,130 \times 0.0216 \\
= 3,559 \text{ m}^3 / \text{day} \\
Q \text{ year} = 365 \times 3,599 = 1,313,635 \text{ m}^3 / \text{year}
\]

4.9. Sedimentation Transport
River length : 9100 m
Lots of sedimentation : 3,599 m³ / day

\[
\text{Sedimentation Transport (V)} = P \times Q \\
\text{Sedimentation Transport / day} = 9100 \text{ m} \times 3,559 \text{ m}^3 / \text{day} \\
= 32,386 \text{ m}^3 / \text{day} \\
\text{Sedimentation Transport / yr} = 9100 \text{ m} \times 1,313,635 \text{ m}^3 / \text{yr} \\
= 11,954,078 \text{ m}^3 / \text{year}
\]

V. CONCLUSIONS AND SUGGESTION

5.1. Conclusion

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

The sedimentation rate that occurs in the Way Ruhu river basin annually is: 3,599 m³ / day or 1,313,635 m³ / year.

So that the sedimentation that is carried out of the river is as much: 32,386 m³ / day or 11,954,078 m³ / year

5.2. Suggestion

In this study, several suggestions are presented as follows:

1. For the Government of Galala Village and Hative Kecil Village and the communities of the two villages to be able to participate and work together to maintain environmental sustainability by replanting shade trees, providing formative counseling so that the people around the Watershed area realize their responsibility to keep maintaining and protecting existing forests from damage.

2. For people who live around the watershed, they should maintain and preserve a clean culture by not throwing garbage into the river.

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