Hydraulic analysis and ecological and physical study of hydraulic Alas-Singkil river Southeast Aceh, Indonesia

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Abstract. The problem of flooding that occurs around the Lawe Alas-Singkil, Aceh Province is the conservation function of the area from upstream to downstream needs serious attention. The area around the watershed is degraded due to several factors. This factor is closely related to illegal logging, exploitation of nature with mineral mining to the conversion of area functions. This study aims to identify the existing conditions of the riverbanks, how the relationship between community social activities and the banks of the Alas-Singkil River, and to study the physical conditions of the river from upstream to downstream. The study method in this research includes a literature study, hydrological conditions of the Alas-Singkil Watershed, field surveys, identification of existing conditions, and study of the ecology and physicality of the river. Survey the condition of flora and fauna in the study area and the economic and social activities of the community. The results of the study on the hydrological conditions of the Alas-Singkil watershed with an area of 10,090.13 km² and a river length of 316.26 km, in the upstream form of mountains and natural forests where deforestation has occurred due to forest conversion to cocoa plantations, planting of corn on the hills and so on, The maximum annual daily rainfall is high (151-300 mm), so the potential for flood disaster is even greater. In the rainy season, large amounts of water cause mountains or hills in Southeast Aceh to melt and become a flash flood disaster. Many of the rivers in the middle and downstream have turned into plantations and rice fields and some are still swamps. The condition of the river in the Alas-Singkil watershed generally occurs silting or sedimentation in the river body, the existing condition of the Alas-Singkil riverbank, where there are still many settlements on the riverbanks. The downstream Krueng Singkil is experiencing more frequent flooding, either due to the overflow of Krueng Singkil in the upstream part and the blocked river flow and rising tides. The frequency of inundation and flood disasters in Singkil City reaches 3 to 4 times each year with an inundation height of 0.5-3.0 meters. It is necessary to repair the riverbanks by using vegetation components found on the banks of the Alas-Singkil River and overcoming floods in the upstream and downstream rivers to protect the ecosystem and people living on the riverbanks. The solution that can be done is to restore the conservation function of the area around the Lawe Alas watershed. and built channel diversion flood from the Lae Soraya river in the village of Gelombang directly to the sea.

1. Introduction
The Alas-Singkil River has an important role for the people who live along the riverbanks. Residents who live on the banks of the river consider the river to be able to meet their needs and sustain their lives, both from the aspects of transportation and mobility, economic, social, cultural and political. From the concentration of the population and their interaction with the river, the river culture was
born. River culture is characterized by the presence of riverside settlements, floating markets, and jukung, as well as social interactions that occur in them. The people who come from the majority of traders make this culture egalitarian, cosmopolitan and open.

Based on Presidential Decree No. 12/2012 concerning the Designation of River Basins, Aceh has nine major river basins. One of them is the Alas-Singkil River area which covers an area of 10,090.13 km². It is along the riverbanks that the people of Singkil (Aceh Singkil-Subulussalam city since they started civilization, but now almost 80% of the local population has moved to areas some distance from the watershed due to natural disasters, especially to avoid flash floods and frequent overflow floods. The longest river in Aceh is also a historical witness about billions of cubic of good quality wood from the Singkil forest being assembled, pulled by tugboats through the estuary to the sea and finally shipped to various countries.

According to The National Disaster Management Agency the problem of flooding that occurs around the Lawe Alas watershed (Catchment area), Singkil, Aceh Province where the conservation function of the area from upstream to downstream needs serious attention. The area around the watershed is degraded due to several factors. This factor is closely related to illegal logging, exploitation of nature with mineral mining to the conversion of area functions. The solution that can be done is to restore the conservation function of the area around the Lawe Alas watershed.

Gayo Lues to Aceh Tenggara changes in vegetation, where the area is dominated by agriculture and plantations, and the Alas River undergoes physical changes, sedimentation occurs, so if the potential for a flood disaster can occur because the area's absorption capacity is reduced when the rain intensity reaches its highest point. Human activities (anthropogenic activities) in the Alas-Singkil River are very important factors in morphological, ecological, and hydraulic changes. These changes will disrupt the balance of the river in question and lead to unpredictable destabilization of the river. In the development of river functions, the concept of pure hydraulic development cannot be used because it does not consider ecological aspects and impacts that will occur after construction.

Efforts to restore the conservation function may experience resistance from residents who are comfortable with farming and gardening. Solutions with social impacts also need to be considered together. Restoring the conservation function needs to be accompanied by efforts of economic value; on the other hand, so that the ecological function is not neglected.

Vegetation has a very vital hydraulic function, namely as a component of flood resistance and erosion resistance of river beds and cliffs. Ecological and hydraulic factors support each other. During a flood, the vegetation along the river will function as a retention factor that will inhibit the speed of river flow to the downstream area. Because the speed of the water is slowed down, the water level will rise and inundate the riverbank areas where vegetation grows. This dynamic inundation of the riverbanks with natural duration is very much needed by the river flora and fauna for their survival.

The flood is affected by geomorphometric of watershed [2]. The relationship between hydrometeorology and social science is considered important to improve our ability to cope with flash flood [9]. In the context of risk management, the perception of flood risk from the local population is the first step towards achieving community and community resilience, so it is necessary to take watershed management measures as an effort to control flash floods [4].

Structural river management or river normalization aims to drain water as quickly as possible downstream, build a sheet pile, restore river width, increase river capacity by dredging sedimentation, protect the area around the river from flooding and optimal water utilization. The construction of physical structures such as embankments or cliff concreting and diversion channels and pumping water into the sea is expected to protect rivers from flooding, this is usually done downstream of the river. River management and flood prevention in a non-structural manner (naturalization) are usually carried out upstream of the river. The naturalization process is restoring the river to its natural condition and restoring the degraded river so that it will increase the flow capacity, add large rocks as natural reservoirs for the river and the ecological restoration process with trees, shrubs and flowers. This will restore the river's biodiversity, and create new open spaces along the river banks which are greened, but the constraints require more time and more open land.
The purpose of this study was to analyze the hydrological and ecological conditions, how the relationship between community social activities and the Alas-Singkil riverbank, as well as to examine the hydraulics of the river from upstream to downstream. The location can be seen in Figure 1.

![Map of the Lawe Alas-Singkil watershed.](image)

Eco-hydraulics have existed from the results of the integration of hydraulics and ecology in the management of aquatic ecosystem assessment [10]. Much history has demonstrated a hydraulic integration model with biological functional response to assess the ecology of regime flows in river systems [5]. According to [3] provide the best analysis of methods and concepts in ecohydraulic applications that form the basis of river restoration. According [6] explains very well how previous research on eco-hydraulics, the state of the art in the development of methodology, is very clearly illustrated from case studies.

According to [11] stated that the vegetation on the riverbanks affects the deposition process and prevents erosion. According [7], flood control is generally carried out with a purely hydraulic concept, namely increasing physical or structural development, for example making embankments, making river diversions, dredging riverbeds, making the slope of river cliff, and others. Realize that this is an incorrect step in the application of the eco-hydraulic concept. Flood control by physical development causes a decrease in river retention, an enlarging river slope, resulting in increased flow discharge, peak flow and decreased time to peak discharge which results in increased flood retention in the downstream area of the river.

According to [12], the bad result of structural development is that the watershed will lose the flora and fauna habitat around the river environment and change the characteristics of the river shape. This is included in pure hydraulics. With the development rate of environmental awareness and the discovery of the enormous negative impact of pure hydraulic engineering as mentioned above, a new interdisciplinary engineering pattern was developed by incorporating ecological considerations in every water problem solving. This interdisciplinary ecohydraulics approach is seen as a new approach pattern that can be accepted by both ecologists and hydro civil engineering people and has high sustainability. Figure 2 presents an illustration of pure hydraulic engineering of a river. The method of calculating the influence of vegetation in the riverbank area on water velocity and discharge is based on the Merten equation [8].
1. Coefficient of resistance

\[ \frac{1}{\sqrt{\lambda}} = -2.03 \log \left( 12.27 \frac{R}{K_s} \right) \]  

(1)

2. Roughness Value

\[ K_s = Cb + 1.5dp \]  

(2)

with:
- \( C \) = vegetation composition coefficient
- \( b \) = riverbank width (m)
- \( dp \) = vegetation diameter (m)

3. Vegetation composition coefficient

\[ C = 1.2 - 0.3(B/1000) + 0.06(B/1000)^{1.5} \]  

(3)

\[ B = \left[ \frac{\alpha_x}{d_p} - 1 \right]^2 \frac{\alpha_y}{d_p} \]  

(4)

with:
- \( B \) = vegetation parameter
- \( \alpha_x \) = transverse vegetation distance (m)
- \( \alpha_y \) = distance between vegetation in longitudinal direction (m)

4. Water velocity according to Darcy - Weisbach

\[ V = \left( \frac{1}{\lambda} 8gRI \right)^{0.5} \]  

(5)

with:
- \( \lambda \) = resistance coefficient
- \( g \) = gravity speed (m/s²)
- \( R \) = hydraulic radius (m)
- \( I \) = river slope

Calculation of the influence of the width of the riverbank on the water discharge for all three types of vegetation. The water discharge is calculated by the equation:

\[ Q = (A1 \times V1) + (A2 \times V2) + (A3 \times V3) \]  

(6)

where:
- \( A1, A2, A3 \) = cross-sectional area (m²)
- \( V1, V2, V3 \) = velocity of water (m/s)
- \( Q \) = discharge (m³/s)

Q1 and Q3 are the capacity of the riverbanks to accommodate water overflow from the riverbed, while Q2 shows the capacity of the river.

2. Data analysis

The first location of the study was in the area of Badar District, Kutacane City, Aceh Province, with the main research location being the upstream area of the Lawe Alas River. The research was conducted from September 2018 to November 2018. In the study, the method of calculating flood discharge used the Melchior method because it has a watershed area of more than 100 km².
The data required are river hydrometry data, daily rainfall data and topographic maps. River hydraulic data is obtained from measurements for 7 days in the field such as measuring river depth, river width. Rainfall data are analyzed using statistical parameters which can then be determined the appropriate distribution type between Normal, Normal Log, Gumbel and Pearson Log distributions. Then the distribution test was carried out with the Chi Square test. After that, the flood discharge was calculated using the Melchior Method.

The purpose of the eco-hydraulics analysis is to determine the eco-hydraulics plan, which is a riverbank design. The stages to be carried out in the eco-hydraulics analysis in this study are as follows:

1. To plan the width of the bank, from the measurement it is obtained that the left bank width is 50 m and the right bank is 20 m, so that in this study the width of the bank is 20 m;
2. Planning the diameter of the vegetation, which consists of 10 cm, 20 cm, 30 cm, 40 cm, and 50 cm;
3. Designing the distance between vegetation along the transverse and longitudinal direction of 1 m; 2 m; 3 m; 4 m; and 5 m.
4. Calculating the channel roughness using equation (2) based on various vegetation diameters;
5. Calculating the value of water velocity for various vegetation diameters using equation (5);
6. Calculating the flood discharge after the effect of vegetation planting; and
7. Comparing flood discharge before and after vegetation planting.

3. Result and discussion

3.1 Lawe Alas river

The research results obtained data from the Lawe Alas River. Watershed area = 312.05 km², river length = 89.7 km and river slope = 0.0245. The table of discharge and velocity measurements can be seen in Table 1.

| Tanggal     | Velocity (V) (m/s) | Discharge (Q) (m³/s) |
|-------------|-------------------|----------------------|
| 09-Nov 2018 | 0.76              | 514.36               |
| 10-Nov 2018 | 0.67              | 441.55               |
| 11-Nov 2018 | 0.61              | 388.13               |
| 12-Nov 2018 | 0.56              | 346.02               |
| 13-Nov 2018 | 0.50              | 297.70               |
| 14-Nov 2018 | 0.46              | 260.48               |
| 15-Nov 2018 | 0.43              | 236.75               |

Based on the Rating curve shows the maximum discharge that can be accommodated by the Lawe Alas river is 514.360 m³/s. Table 2 calculation the roughness parameters, drag coefficient, velocity and discharge for various vegetation diameters in the Lawe Alas river. Then, a graph of the relationship between the Diameter of the Vegetation and the Roughness and the Coefficient of inhibition can be seen in Figure 2. Based on Figure 2, it can be seen that the larger the diameter of the vegetation, the greater the roughness, and likewise the drag coefficient the greater the effect of the diameter of the vegetation is getting bigger. The graph of the relationship between vegetation diameter and velocity and discharge can be seen in Figure 3.

Based on Figure 3, it can be seen that the greater the diameter of the vegetation, the smaller the velocity, and likewise the discharge decreases the greater the diameter of the vegetation. For the design of the banks with a width of 20 m, a vegetation diameter of 10-50 cm, the discharge is 356.91 - 338.26 m³/s.

The discharge can be reduced by 32.5-36% from before the arrangement of the riverbank. The velocity value with 10 - 50 cm vegetation planting is 1.164 m/s - 1.104 m/s. The velocity obtained before the arrangement of the banks is 1.725 m/s, the velocity that can be reduced is 32.5-36 %.
Table 2. Calculation results of roughness parameters, drag coefficient, velocity and discharge for various vegetation diameters in the Lawe Alas river.

| Diameter | Horizontal Distance | Transverse Distance | Parameter | Coefficient | Roughness | Cross Section Area | Radius of Hydraulics (R) | Roughness Coefficient | Velocity (V) | Qeco-hydraulic (m³/s) |
|----------|---------------------|---------------------|-----------|-------------|-----------|--------------------|------------------------|-----------------------|--------------|---------------------|
| (m)      | (m)                 | (m)                 | (B)       | (C)         | (Ks)      | (m²)               | (m)                   | (m)                   | (m/s)        | (m³/s)              |
| 0        | 0                   | 0                   | 0         | 0           | 0         | 306.5              | 2.881                  | 0                     | 1.725        | 528.67              |
| 0.1      | 1                   | 1                   | 810       | 1.001       | 20.165    | 306.5              | 2.881                  | 4.085                  | 1.164        | 356.91              |
| 0.2      | 2                   | 2                   | 810       | 1.001       | 20.315    | 306.5              | 2.881                  | 4.195                  | 1.149        | 352.2               |
| 0.3      | 3                   | 3                   | 810       | 1.001       | 20.465    | 306.5              | 2.881                  | 4.308                  | 1.134        | 347.52              |
| 0.4      | 4                   | 4                   | 810       | 1.001       | 20.615    | 306.5              | 2.881                  | 4.426                  | 1.119        | 342.87              |
| 0.5      | 5                   | 5                   | 810       | 1.001       | 20.765    | 306.5              | 2.881                  | 4.547                  | 1.104        | 338.26              |

Figure 2. Graph of the relationship between diameter and roughness and the roughness coefficient.

Figure 3. Graph of the relationship of diameter of vegetation with velocity and discharge.

3.2 Lae Soraya river
The second research location is in the district of Rundeng, Subulussalam municipality, Aceh Province, with the main research location being the Lae Soraya River area. The research was conducted from February 2017 to June 2017. River hydraulic data was obtained from measurements for 7 days in the field such as measurements of river depth, river width, velocity, discharge and river water level, as shown in Table 3. Table 4 summarizes ecohydraulic analysis and the relationship between velocity and discharge.
Table 3. Results of measurement of discharge and velocity for 7 days in the Lae Soraya river.

| Date        | Flow Area (m²) | Velocity (V) (m/s) | Discharge (Q) (m³/s) |
|-------------|----------------|--------------------|-----------------------|
| 23-Mei 2017 | 826.73         | 0.909              | 751.45                |
| 24-Mei 2017 | 802.49         | 0.790              | 634.31                |
| 25-Mei 2017 | 780.67         | 0.739              | 577.24                |
| 26-Mei 2017 | 761.28         | 0.664              | 505.80                |
| 27-Mei 2017 | 741.90         | 0.602              | 446.72                |
| 28-Mei 2017 | 720.08         | 0.567              | 408.14                |
| 29-Mei 2017 | 698.27         | 0.517              | 360.77                |

Table 4. Ecohydraulic analysis and the relationship between velocity and discharge.

| Vegetation Diameter (m) | Roughness (Ks) | Velocity (V) (m/s) | Discharge (Q) (m³/s) |
|-------------------------|---------------|--------------------|-----------------------|
| 0                       | 0             | 1.672              | 1406.946              |
| 0.07                    | 68.483        | 0.915              | 792.690               |
| 0.10                    | 100.224       | 1.391              | 1293.484              |
| 0.15                    | 114.397       | 1.556              | 1467.417              |
| 0.20                    | 118.036       | 1.595              | 1508.593              |
| 0.25                    | 119.336       | 1.609              | 1522.999              |
| 0.50                    | 120.691       | 1.623              | 1522.999              |

The maximum discharge that can be accommodated by the Lae Soraya river, when the water level reaches 3.66 m, is 1090.734 m³/s. Furthermore, the calculation of the eco-hydraulics analysis with the Merten equation [8]. The relationship between vegetation on the riverbank effects on changes in flow velocity, which can be seen in Figure 4.

Figure 4. Relationship between vegetation diameter and velocity.

Figure 4 is a graph showing that the initial water velocity before the riverbank arrangement was 1.672 m/s, while in the presence of 0.07 m vegetation, the water velocity on the banks decreased to 0.952 m/s or the water velocity could be reduced by 43%. The velocity on a larger vegetation diameter results in a greater velocity, but at a lower value compared to conditions without vegetation. The smallest speed reduction with the arrangement of the banks is 2.57% on a vegetation diameter of 0.5 meters.
3.3 Hydrological analysis

3.3.1 DAS (Watershed). Based on Environmental Impact Analysis, data by the Aceh Transportation Service, in 2019, the hilly and mountainous topography has resulted in many rivers that have quite heavy flows. Hydrology in Southeast Aceh District is characterized by a long river, namely the Lawe Alas River and its tributaries (hundreds in number) which originate from many mountains, including Mount Leuser, Mount Kemiri, Mount Bendahara and Mount Perkison. Generally, the tributaries run water all year round.

The water catchment areas in Southeast Aceh Regency, including Mount Perkison and Mount Bendahara, are a source of drinking water for rivers flowing to the east coast. Apart from irrigation and transportation facilities, rivers are also used as drains for draining dirty water and rainwater.

The topographical conditions of the Sungai Gelombang and Singkil watersheds are classified as lowland areas (altitude 0-200 MDPL), with an area of the Waves and the Singkil River Basin each covering an area of 5752.68 km² with river lengths respectively 219.84 km and 316.28 km.

3.3.2 Surface water quality. Based on Environmental Impact Analysis, data by the Aceh Transportation Agency, in 2019, the results of the river water quality tests observed were Alas River, Soraya River and Singkil River, all of the parameters tested were below the established quality standards. Specifically, for the DO parameter, the value can be declared good if the values are below the quality standard, except at the points of Singkil and Sigrun Villages.

3.3.3 Groundwater quality. Based on the Environmental Impact Analysis, data by the Aceh Transportation Agency in 2019, the results of testing the quality of clean water for all the parameters tested were below the established quality standards, the quality standards used to compare the results of the measurement / analysis were the Clean Water Quality Standards PerMenKes No 416 / MenKes / Per / IX / 1990. Even so, overall clean water around the location of the activity is still good enough to be utilized, but we must pay more attention to the procedures for using clean water, especially if the water is used for consumption.

3.4 Ecological analysis

3.4.1. Vegetation. Based on data from the 2019 Transportation Service Environmental Impact Analysis, the vegetation cultivated at the Salim Pipit, Wave, Rundeng, Panji and Singkil locations is in the form of mixed gardens such as oil palm, coffee, cocoa, cloves and rubber, community garden plants such as bananas and cassava. The dominant commodities are areca nut and palm oil.

The natural forest vegetation in the study area includes Alstonia Scholaris, Terminalia sp, Bridelia Pustulata, MacaRnga sp, Delonix sp, Intsia Bijuga, Senna Alata, Duabanga Moluccana, Endiandra Maingayi, Litsea Grandis, Aglaia Forbessi.

Based on data from the Aceh Province Natural Resources Conservation Center, 2018, the protected vegetation types are found in the forests of Mount Leuser National Park, namely Rafflesia, Semar Bags, Carrion Flowers, Shoe Orchids and Umbrella Palm.

3.4.2. Animal. The types of mammals in the study area are wild boar, squirrel, squirrel, bat, rat, field rat and ground squirrel. There are also 13 bird species in the study area. Types of amphibians and reptiles include monitor lizards, rice field snakes, pythons, estuarine crocodiles as well as lizards and frogs.

3.4.3. Aquatic Biota. In general, the aquatic biota in the study area is grouped into plankton, benthos, and nekton. The study of marine biota is to determine the richness of marine biota species found in the area.
3.5 **Environmental, social, economic analysis**

The study of community perceptions in this study is focused on 3 things, namely the community's perception of the plan to improve river banks in an ecohydraulically manner, the community's perception of land acquisition and the community's perception of land management with vegetation. The number of respondents studied was 100 households consisting of 86 male and 14 female heads. Respondents' ages ranged from 20 to 69 years. The average number of dependents is 2 people per family, and two of them work. Judging from the education level, it is known that 18 people have not graduated from elementary school, 39 people have graduated from elementary school, 20 people have graduated from junior high school and 17 people have graduated from high school. The results of interviews with communities in the study locations indicated that there had never been any conflicts over land ownership or conflicts between ethnic groups and religions. Security and order were well maintained. Based on the results of a survey on community perceptions of land acquisition, 98% agreed and 2% disagreed with reasons of concern that the value of compensation was not what they wanted [1].

4. **Conclusion**

1. Flood Management in Lae Soraya River to Singkil, starting from the village of Gelombang a diversion channel must be made to drain some of the flow into the sea.
2. The government immediately looks for a location to move the slum settlements of residents who live along the river. Based on interviews with the community, they all wish to move as long as they are provided with a place by the local government because most of them are low income earners.
3. Flood management with eco-hydraulics, namely the arrangement of river banks with local vegetation in the upper reaches of the Lawe Alas River. $Q_{50} = 528,670 \text{ m}^3 / \text{s}$, the riverbanks $L=20 \text{ m}$, $D = 10-50 \text{ cm}$, the discharge is $356.91 - 338.26 \text{ m}^3 / \text{s}$. The discharge can be reduced by 32.5-36% from before the arrangement of the riverbank.
4. The value of velocity with vegetation planting 10 - 50 cm is 1.164 m/s - 1.104 m/s. The velocity obtained before the arrangement of the banks is 1.725 m/s, the velocity that can be reduced is 32.5-36%.
5. The results of research in the upper reaches of the Alas river, 50 cm diameter vegetation is best planted on the riverbanks with a width of 20 m. The results showed that all vegetation diameters could reduce river flow and velocity, so planting vegetation along the riverbanks was highly recommended to immediately reduce flood discharge downstream of the river.
6. The results of the study in the middle of the Lae Soraya river show that the maximum storage capacity of the Lae Soraya River is 1090.734 m$^3$/s. The appropriate eco-hydraulic design for 5-year to 10-year flood discharge is 100 m wide and the use of vegetation with a diameter of 7 cm to 10 cm with a spacing between vegetation is 100 cm.
7. This is a preliminary study conducted by the author in further analysis of the conditions in the Alas Singkil river area.

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