Experimental Study on Velocity Profiles Due to Ecological Barriers

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Abstract: Streams are very complex system. In stream restoration projects, the existence of ecological structures should be considered as an important variable in the project. A lot of previous research focused on ecological aspects only, therefore the main purpose of this paper is to examine the velocity profile due to ecological barriers in downstream area of weir. A laboratory study to investigate the effect of ecological barriers in terms of velocity profile in 8 m length x 40 cm width a rectangular channel is presented. The study consists of an extensive set of rectangular flume experiments for flows with certain The results show that the average velocity (v=0.35 m/sec) was occurred for without ecological barriers condition. By comparing the scenarios, this study showed that ecological barriers (dl = 25 cm) has the highest velocity (v = 0.41m/s), meanwhile scenario 5 (v=0.36 m/s) has the nearest velocity with the scenario 1 (v=0.35 m/s). It indicated that the existence of ecological barriers had given the higher velocities in streams. The distance length between ecological barriers showed that the farther the distance length used the lower the formed velocity profiles.

1 INTRODUCTION

Streams are a very complex system (Stanford, Zavaleta, & Millard-Ball, 2018). Not only are the hydraulic properties complex, but so are the implications of those properties. Many experts such as stream engineers, geomorphologists, civil engineers and ecologists may share a similar opinion, especially when identifying the variable and complex stream that includes ecological aspects, can take place over time and across stream areas (Magilligan, Nislow, Kynard, & Hackman, 2016; Rinaldi, Gurnell, Del Tánago, Bussettini, & Hendriks, 2016; Tallar & Suen, 2015). In stream restoration projects, the presence of ecological structures should be seen as an important variable in the project. Much earlier research has focused on environmental issues (Chang, 2008; Rosgen & Silvey, 1996; Tallar & Suen, 2017). Therefore, the main aim of this paper is to study the velocity profile due to ecological barriers in the area downstream of the stream.

The scopes of this study consisted of the research was conducted in open channel with steady condition; the sediment used was classified as poorly graded sand; the type and diameter of the material are gravel with a diameter of 2cm and covered with wire mesh; and permeability is neglected because the sediment/soil condition is already saturated. The contribution of this study is to describe the existence of ecological structures should be considered as an important variable in the stream restoration projects.

2 METHODS

A laboratory study is presented to investigate the effect of ecological barriers on the velocity profile in a rectangular channel 8 m long x 40 cm wide. The study consists of an extensive series of experiments with rectangular channels for currents with a certain slope and a gravel bed.

The design of the ecological barriers can be seen in Figure 1. The distance length (dl) of each ecological barrier was set at 25 cm. 50 cm; 75 cm; and 100 cm. The study used the BACI (Before After Impact Control) method for established scenarios (Table 1).

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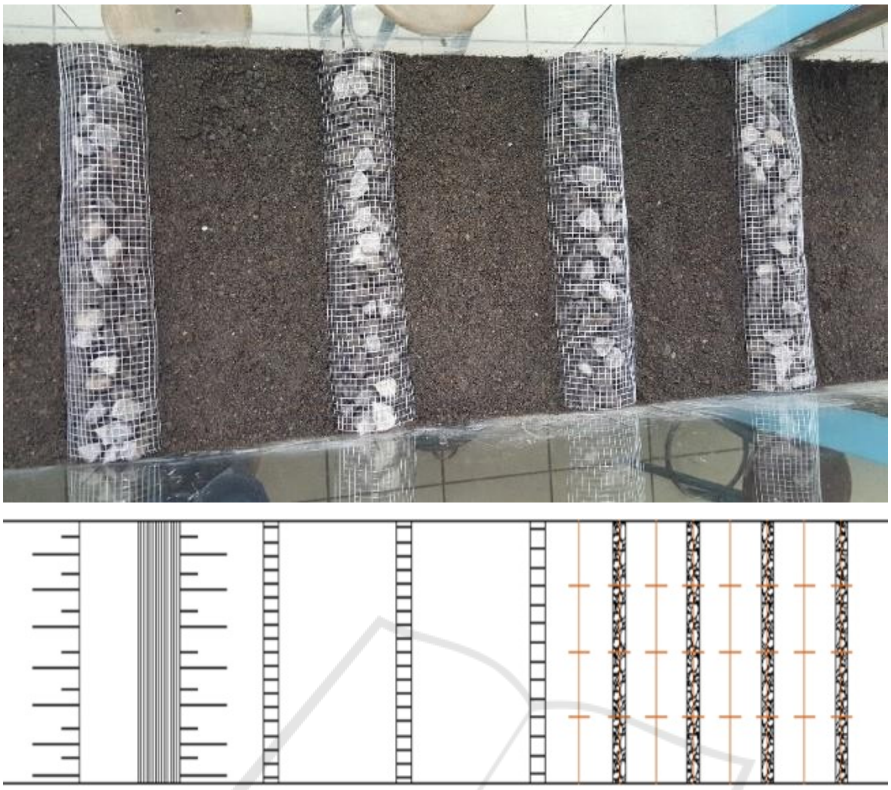

Figure 1: Design of ecological barriers.

In this study, Q = 0.02 m3 / s was used when the constant discharge flows into the channel. Different scenarios were also run with different limitations. The limitations of the study consisted of the flowing discharge and the slope of channel.

Table 1: Scenarios of the study.

Scenario	Description
1	Without ecological barriers
2	Ecological barriers (d_l = 25 cm)
3	Ecological barriers (d_l = 50 cm)
4	Ecological barriers (d_l = 75 cm)
5	Ecological barriers (d_l = 100 cm)

2.1 Method for Sieve Analysis

The sieve analysis is carried out by set up the weighed aggregate into a set of pre-arranged sieves. Particle size determinations on large samples of sediments are necessary to ensure that sediments perform as intended for their specified use. A sieve analysis or gradation test determines the distribution of sediment particles by size within a given sample. This information can then be used to determine study requirements. Data can also be used to understand the characteristics and classification of sediment. This study used cumulative method. As each retained fraction is added, divide the cumulative mass by the total mass of the sample and multiply by 100 to calculate percent retained. Subtract the cumulative percent retained on a given sieve from 100 to calculate percent passing.

2.2 Method for Flow Velocity Analysis

Flow velocity is simply the continual movement of water in channels each open and closed. This flow velocity is constricted connected with discharge, which defined as the rate of flow or the volume of water that passes through a channel cross section in a specific period of time. Discharge can be reported as total volume or as a rate such as cubic feet per second (ft^3 /s or cfs) or cubic meters per second (m^3/s). The terms flow velocity and discharge are often used interchangeably, but they will be used only as defined here.

Discharge data are very important to estimate the characteristics of channel such as rivers or streams. The aim of drawing the discharge rating curve is to work out the most discharge from a channel and to get an outlined discharge in experimental study. A rating curve may be a graph of discharge versus stage for a given purpose on a stream or open channel.

3 RESULTS AND DISCUSSION

3.1 Sieve Analysis Results

The sieve analysis has been performed to determine the grain size curve distribution of the sediment then to obtain the uniformity coefficient (Cu) and gradient coefficient (Cc). The first process of sieve analysis is set up the weighed aggregate into a set of sieve numbers inserted into the vibrating device for 10 minutes. Initial aggregate weight is 1000gr. The results of sieve analysis can be seen on Table 2 and Figure 2.

Table 2: Sieve analysis results.

Sieve Number	d (mm)	*Soil Retained* (%)	*Cumulative Soil Retained* (%)	*Soil Passing* (%)
#4	4.75	7.1	7.1	92.9
#10	2.00	17.7	24.8	75.2
#20	0.85	24.2	49.0	51.0
#50	0.30	22.6	71.6	28.4
#100	0.15	20.3	91.9	8.1
#200	0.075	7.1	99.0	1.0
Pan	-	0.5	99.5	0.0

The retained percentage and D_{10}, D_{30}, D_{60} has been used for sediment classification. From the graph, it shows that the relationship between grain size and percent finer so that Cu= 6.94 and Cc=0.484. By using Soil Classification Chart, it is classified that sediment is categorized in Poorly Graded Sand.

3.2 Flow Velocity Analysis Results

The completed analysis of flow rate velocity is taken by several positions both x and y direction. Several positions were in cross section area with the width distance between ecological barriers. The average flow velocity was measured by taking 3 depth positions which represented upper, middle, and lower area. Time duration for each point was 30 seconds. The results can be seen on Figure 3 and Table 3.

Table 3: Average flow velocity analysis results.

Scenario	Colour line	Average flow velocity (m/s)
1	Green	0.35
2	Purple	0.41
3	Red	0.39
4	Yellow	0.38
5	Blue	0.36

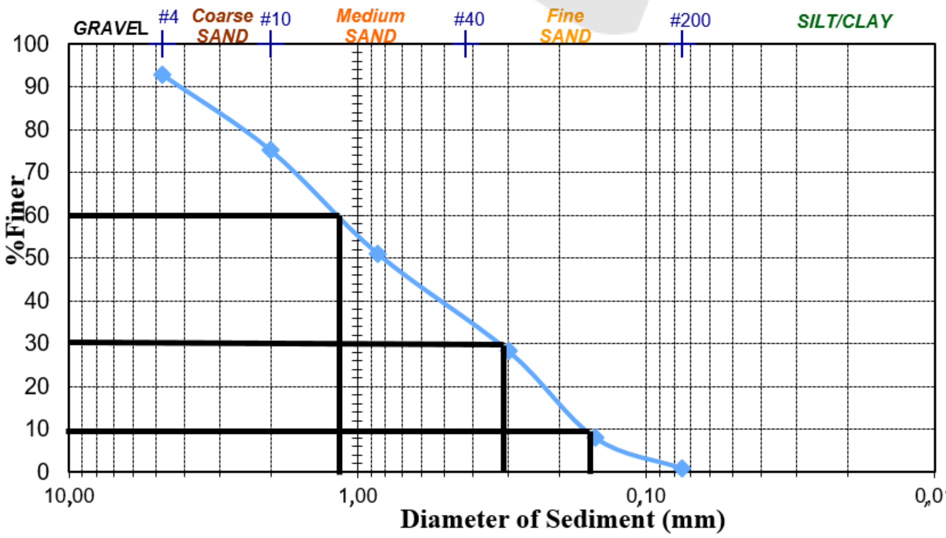

Figure 2: Sieve analysis results.

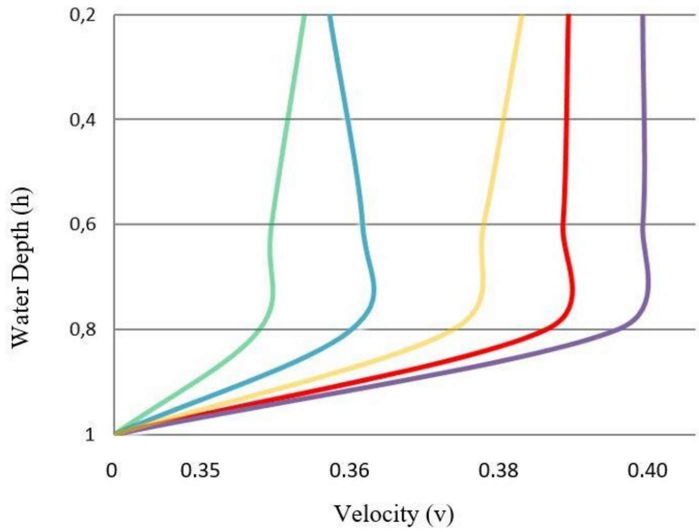

Figure 3: Velocity profiles for five scenarios (Note: Colours describe scenario 1-5).

3.3 Discussion

Basically, ecological barriers provide the necessary environmental conditions for aquatic organisms related to the flow velocity. The spatial and temporal condition determine the boundary of targeted area study. In context of velocity profile, the flow velocity is highest near the water surface an lowest near the channel bed. The drag forces exerted on water near the watercourse bed usually account for the decrease in flow velocity.

According to sieve analysis results, the used sediment was classified by poorly graded sand. It can be assumed that the roughness of sediment is higher than well graded sand. Meanwhile, flow velocity profiles outcomes are strongly associated with the roughness of sediment. On a stable channel, the final result of velocity will be faster but in a channel with ecological barriers, it can cause a decrease in flow velocity. The highest flow velocity is in channel with ecological barriers condition with distance length 25 cm (scenario 2) and the lowest velocity is in the channel without ecological barriers (scenario 1).

The influence of flow velocity profile is also influenced by other factors such as the placement and position of ecological barriers in a channel and the distance between ecological barriers. Different flow rates also will affect the flow velocity profiles. The other related parameters considered in this study are Froude and Reynold Number.

Froude number is the ratio of flow velocity to the characteristic velocity of water waves in the channel, whilst the Reynold Number deals with the relationship between frictional and inertial force. The higher the velocity, the higher the Reynold Number. It can be assumed that the existence of ecological barriers can increase the Reynold Number.

4 CONCLUSIONS

The results show that the average velocity (v=0.35 m/sec) was occurred for without ecological barriers condition. By comparing the scenarios, this study showed that ecological barriers (dl = 25 cm) has the highest velocity (v = 0.41m/s), meanwhile scenario 5 (v=0.36 m/s) has the nearest velocity with the scenario 1 (v=0.35 m/s). It indicated that the existence of ecological barriers had given the higher velocities in streams. The distance length between ecological barriers showed that the farther the distance length used the lower the formed velocity profiles. A conceptual framework for implementation of ecological barriers requires an understanding of three major aspects (geomorphology, hydraulics, and ecology). Moreover, it is necessary to investigate the effect of other variables such as ecological barriers dimension, variation of structure models and other related variables in the further research.

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