INTRODUCTION

This module, "Module for flow discharge and sediment load relation in a river", was developed as a tool to estimate bed material load (or sediment load) for specified channel slope, channel width, grain size, and channel friction. The resulting plot shows the relation between bed material load and water discharge. In the river engineering, sediment is typically classified into two groups: bed material and wash load. Bed material is relatively coarse, and it composes the channel bed. Bed material can be transported by rotating or saltation near the channel bed, and by being suspended up in the water column. Wash load, on the other hand, is relatively fine and it is always being suspended up in the water column, and almost never deposits in the channel. Thus, predicting bed material load (both near bed and in the water column) is important for engineering measures. Here, the module is developed to predict the bed material load, which does not include wash load.

DEFENITIONS

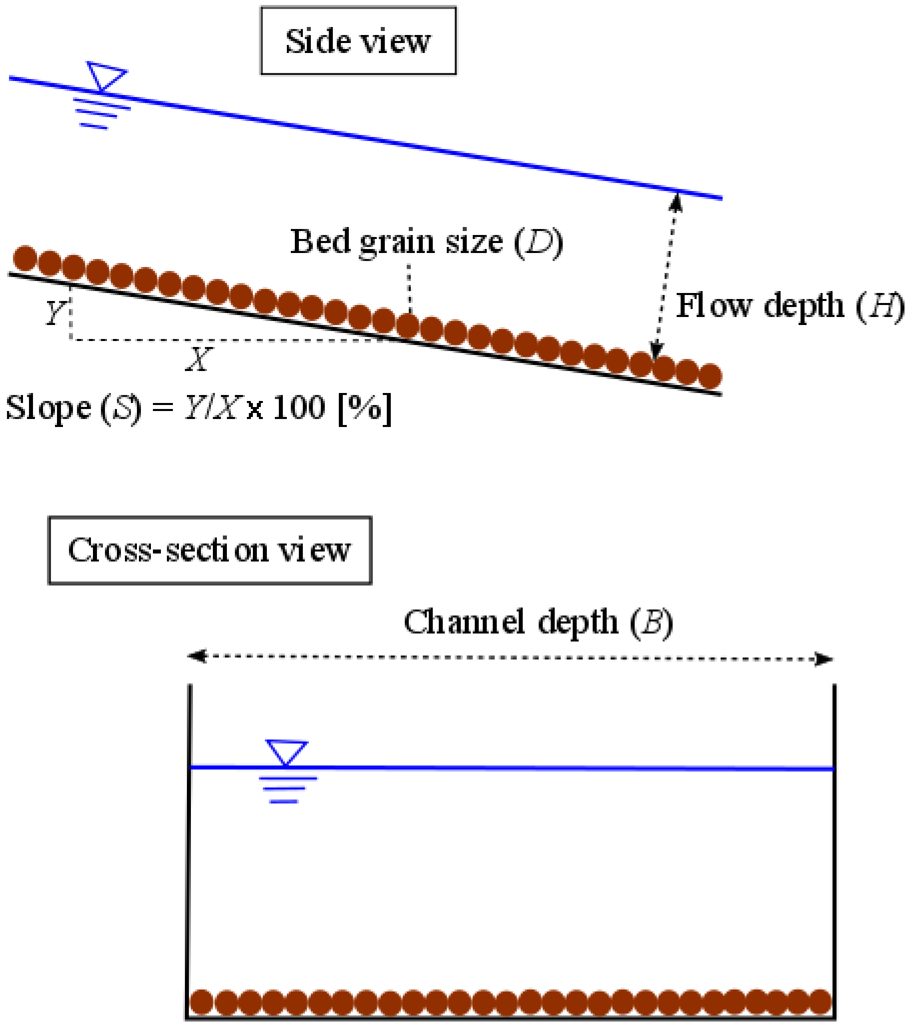
Notations

In this document, symbols are defined as follows.

Notation	**Definition**	**Unit**
B	Channel width	m
C_f	Channel friction coefficient	--
D	Characteristic bed surface grain size	mm
g	Gravitational acceleration	m/s^2
H	Flow depth	m
Q_t	Bed material load	m^3/s (tons/day)
Q_w	Flow diacharge	m^3/s
R	Submerged specific density of sediment	--
R_h	Hydraulic radius	m
S	Channel bed slope	--
U	Flow velocity	m/s
ρ_s	Density of sediment	kg/m^3
ρ_w	Density of water	kg/m^3
τ_b	Bed shear stress	Pa
τ_b^*	Dimensionless bed shear stress (Shields number)	--

River channel geometry

Conceptual diagram of a river that is under consideration is shown below.



THEORY

First, we assume that flow does not change in time and space. The flow discharge Q_w in channel is given as a function of flow velocity U, flow depth H and channel width B as follows:

$$Q_w = UHB \tag{1.1}$$

Flow velocity U is typically calculated using following relation:

$$U = \sqrt{\frac{gR_h S}{C_f}} \tag{1.2}$$

Here, R_h is hydraulic radius, which is defined as a ration of cross-sectional area to the wetted perimeter of the channel (the portion of channel that is wet by flow):

$$R_h = \frac{HB}{2H + B} \tag{1.3}$$

This means that the greater hydraulic radius, the larger volume of water the channel can carry. When the channel is wide, and the flow is shallow, the hydraulic radius can be approximated as the flow depth ($R_h = H$ for condition $B >> H$). Whereas when the channel is relatively narrow, the effect of side walls can be important, adding the resistance to the flow (wall effect). The wall effect can reduce the bed shear stress (Eq. (1.4) shown below). However, most of natural river has much wider channel compared to the flow depth. Thus, as far as natural river is concerned, it is commonly accepted to use flow depth as approximate of the hydraulic radius.

Bed shear stress τ_b, which is typically used to determine the magnitude of sediment transport, is computed as follows:

$$\tau_b = \rho_w g R_h S \tag{1.4}$$

It means that higher hydraulic radius and steeper channel slope yield higher bed shear stress. In order to compute sediment transport rate, the bed shear stress is usually normalized using bed grain size D and submerged specific gravity of bed sediment R as follows:

$$\tau^* = \frac{\tau_b}{\rho_w g R D} = \frac{R_h S}{R D} \tag{1.5}$$

Here τ^* is normalized bed shear stress, so called Shields number. Submerged specific gravity of sediment is a relative density of sediment ρ_s to water density ρ_w:

$$R = \frac{\rho_s - \rho_w}{\rho_w} \tag{1.6}$$

Typically, R = 1.65 is used, assuming that sediment is quartz.

Among many proposed relations for the estimation of sediment load, here we use the one proposed by Engelund and Hansen (1967). It has a very simple form yet it has been recognized to perform well for many rivers and also flume experiments. The sediment load (total load) Q_t is finally estimated as follows:

$$Q_t = \frac{0.05}{C_f} \left(\tau^*\right)^{2.5} \sqrt{g R D^3} B \tag{1.7}$$

The result is given in volume per second (m^3/s). The unit conversion to mass per day (tons/day) can be done by multiplying 60×60×24×(R+1) to the result obtained by Eq. (1.7).

REFERENCES

Engelund, F. and Hansen, E. A monograph on sediment transport in alluvial streams. Tekniskforlag Skelbrekgade 4 Copenhagen V, Denmark. (1967).