SAFL St. Anthony Falls Laboratory

UNIVERSITY OF MINNESOTA

Summer Undergraduate Research

Mechanics of Complex Materials

Determining the Critical Discharge for Sediment Transport in Beds of Different Grain Sizes

Ramsey Coronado, University of Arizona; Peter Wilcock, Chuck Podolak, Johns Hopkins University; Jeff Marr, Karen Campbell, Diana Dalbotten, National Center for Earth-surface Dynamics

Introduction

Sediment moves along a stream in several ways, and the need for evaluating numerically the rate that will cause sediment to move is very necessary in characterizing how flow ultimately affects the stream. The shear stress relates the tangential force that an object has when it moves along some surface, or the force to overcome the tension between a parallel surface and a face of an object. The idea is to describe the conditions that will cause the sediment to move, so when the flow is strong enough during the year, one can determine the conditions prior to the removal of the sediment from behind the dam. Determining the critical discharge will deal with relating the Shields number with the force to overcome the stress. Shields numbers can be used as the values that relate the motion of the particles along the bed to some critical value that will initiate some movement.

Objectives

The experiment will revolve around determining this critical flow rate for all the facies that are identified along certain cross-sections at the reaches of study.

• Then relating these values to the monitoring process throughout the year to get a better sense of the full impacts of the dam removal on the shear stress of the bed material.

• The goal is to create a "Pre-Condition," prior to the release of the Marmot Dam, to get a sense of the topography, physical aspects, sediment beds, velocity of stream, vegetation, etc. to better determine what the impacts of the dam removal are going to be on the characteristics of the river.

Fig. 1 Cross-sections taken at Reach B1 by Dave Evans

Abstract

The Marmot Dam in Sandy, Oregon, located on the Sandy River, is a dam that is being removed, and was the setting for a quantitative and qualitative analysis of the preconditions of a river system prior to dam removal. The area of focus was determining the critical shear stress required to cause sediment along a riverbed and the surface of a river bar with materials of different grain sizes to move. The method for evaluating the different grain sizes was with the use of the pebble count technique as described by Wolman. Then with the software WinXSPRO and several sediment transport equations, the critical discharge was determined. The results obtained were different critical flow rates at different cross-sections that will cause the sediment to move. Identifying these values will help to better determine how an increased flow after the dam removal will affect the sediment transfer rates and deposition.

Table 1: Roughness Approximations and Critical Discharge for the Facies

Reach	Cross Section Number	Facies*	Roughness (n)	Critical Discharge (Q) cfs
B1	1	cobble and sand facies	0.032	2204491.46
		boulder, cobble, and gravel	0.032	1051184.728
B1	2	boulder and sand facies	0.033	944.317724
		cobble and gravel facies	0.032	85981.75569
B1	3	cobble and sand	0.038	18269.36317
B2	1	cobble and boulder	0.043	958.8971548
B2	2	boulder and cobble	0.045	3825.571453

Methodology

Facies Mapping

The first part of determining the critical discharge that will cause sediment to move will be to go down the river and identify the certain areas of study; these regions, in Geology, are referred to as facies. Along the river, there are grains (pebbles) of different sizes that characterize a certain region, and the characterization of these grains is used as a means to describe the physical topography and bed composition of a certain reach.

Pebble Counting

The pebble count is a method of measurement that is used to determine the grain sizes for a certain area. The pebble count method will involve picking up 100 random stones from a certain area with some parameters along one of the facies. Several people will go to these defined areas and randomly pick up 100 stones, and then with the use of a gravelometer measure the intermediate axis of the stone.

Cross Section Analysis and Surveying

For the calculations, the depth of the water, the cross-section data, and the slope of the bed will be measured with surveying techniques; surveying will also done on the surface of the bars to get the current topography of certain areas, and within the channel to get the topography along the bed of the river. The methods that will be used to get the survey data will be with a total station, RTK GPS Surveying System, and the depth sounder.

Mathematical Calculations

The data analysis will involve the use of the determined variables, known variables, and approximated variables to compute the critical discharge that will cause the sediment to move along the bed. From the Grain Size Distribution, the bed sand content, and the median grain size will be determined. Then with the use of the depth-slope product, the continuity equation, Manning's flow resistance equation, the two fraction incipient motion criteria, and Shield's parameter equation the critical discharge will be determined.

Figure 2: Equations used in determining critical discharge

depth-slope product (momentum for steady uniform flow)	$\tau_0 = \rho g R S$
continuity	$Q = UA$
two fraction incipient motion criteria	$\tau^*_c = f(F_s)$
Manning's flow resistance eq.	$U = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$
Sheilds parameter def	$\tau^* = \frac{\tau_0}{(s-1)\rho g D}$

Conclusions and Future Work

The results that were yielded represent a critical flow rate that will cause the sediment to move along the bed, or the surface of the various facies. The critical discharge is directly related to the bed sand content, and through simple evaluation of fundamental hydraulic equations a critical discharge can be related to the sand content. These values can be used as a means of better monitoring the effects of the flow in the channel on the sediment, and if movement does occur it can be better attributed to the main factors of influence, natural flow conditions versus the dam removal. The research done will provide some basis for establishing some standard methods of measuring the quantitative impacts of dam removal on the shear stress.

The research done was the basis for an ongoing effort for creating a better model to predict how dam removals will ultimately influence the characteristics of a river. The precedent has been set to develop better methods of predicting the long-term and short-term changes from dam removals. Research and monitoring at the Sandy River will continue for several years, and the data determined will be used as a basis for comparison as changes occur.

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