Evaluation of Non uniform bed load transport rate for steep slope gravel bed river

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Abstract - *The erosion and deposition activity in river results in altering the sediment movement within the channel and hence affect the carrying capacity of river. Bed load transport has been the subject of extensive research since the pioneering work of Du Boys (1879). Many researchers have computed the bed load transport of uniform sediment to a fair degree of accuracy. However, natural river sediments are generally non uniform particularly in gravel bed river, and the bed load) movement in case of such sediments is quite complex. Sediment transplant formulas for coarse sediments and steep slopes have been considered traditionally to be bed load equations (Smart 1984).So the present study aims to analyses the predictability of transport functions of Smart (1984) which consider the non-uniformity of sediment size as well as the effect of high slope using field data set. Various statistical parameter like discrepancy ratio, Root mean square error, Mean normalized error are calculated to test the predictability of Smart bed load transport function.*

Key Words: Non uniform bed load transport, coarse sediment, steep slope, Mean Normalized error, Discrepancy Ratio.

1. INTRODUCTION

Bed-load transport has been the subject of extensive research since the pioneering work of Du Boys (Garde and Ranga Raju, 1985) and others. With the present state of knowledge, it is possible to compute the bed-load transport rate of uniform sediments with a fair degree of accuracy. However, computation of the bed-load transport rate in the case of non-uniform sediment which is typical of natural sediments—is quite complex because of the presence of particles of various sizes and their interactions. The pioneering research to fractionally calculate the non-uniform bed-material load transport rate is attributed to Einstein (1950).The effect of the presence of one size of particle on the transport rate of another size in the case of a non-uniform sediment is supposed to be taken care of through several correction factors introduced by Einstein (1950). Subsequent to the publication of his paper, many checks on Einstein's methods, using data for non-uniform sediments, have shown that agreement between the measured and computed total bed-transport rate is not satisfactory. Ashida and Michiue (1971), Parker et al. (1982), Parker, G. (1990a), Mittal et al. (1990), Bridge and Bennett (1992), Wilcock, P.R. and Mcardell, B.W. (1993) ,Patel and Ranga Raju (1996), and Fang and Yu (1998), Wu et.al (2000) proposed several methods for calculating the fractional transport rate of non-uniform bed-load. Hsu and Holly (1992) also proposed a method to predict the gradation of non-uniform bed-load by considering the probability and availability of moving sediment. . Misri et al. (1984) emphasized the limitations of Einstein's (1950) method. Meyer-Peter and Muller (1948), Bagnold (1966), Hayashi,et.al (1980) ,Proffitt and Sutherland (1983) Van Rijn (1984 a), Samaga et al (1986 a), Swamee and Ojha (1991), and Samaga et al. (1986) proposed methods to account for the non-uniformity of sediment in the calculation of bed-load transport rates . However, conventional transport equations typically overestimate bed load volumes in steep mountain streams by up to three orders of magnitude. This may be due to calibration of developed formulae with data from flume experiments or low gradient streams, with channel bed and transport characteristics that differ from those in steep mountain streams or for gravel bed stream of high slope. Sediment transported are highly influenced when flow under gravity with nonzero component acting parallel to the surface on which sediment is being transported and this situation is commonly occurring in river. Smart (1984) developed equation for predicting bed load rate for non-uniform sediment considering the effect of high slope. Due to the limitation of river data for evaluating fractional bed load computation, effort has been made in this study to predict non uniform bed load transport for higher slope. Smart (1984) non uniform bed load transport function is selected to test the predictability for gravel bed river with high slope.

2. METHODOLOGY AND DATA COLLECTION

For the present study, predictability of Smart (1984) non uniform bed load transport function is analysed using wide range of river data. Formulation of the selected function is summarized as below.

Smart (1984): The method of Smart (1984) is based on Meyer-Peter Mueller (1948) bed load discharge equation for natural stream. The effect of non-uniformity in sediment grain size was then investigated for sediment mixtures with $\frac{d_{90}}{d_{30}}$ values up to 8.5, and developed the following equation:

$$\Phi = 4\left[\left(\frac{d_{90}}{d_{30}}\right)^{0.2} S^{0.6}\ C\theta^{0.5}(\theta-\theta_{cr})\right] \qquad (1)$$

Where θ = dimensionless shear stress

θ_{cr} = the critical dimensionless shear stress introduced by Shields (1936)

C=flow resistance factor (conductivity) $= V/(g\ H\ S)^{0.5}$,

V = mean flow velocity, d_{90} and d_{30} are the grain diameters for which, respectively, 90% and 30% of the weight of a non-uniform sediment sample are finer. S= channel slope, (dimensionless quantity)

Data collected for the present study:

For the present studies, experimental data set of Recking, A.(2010) for following river are used and the range of hydraulic parameters are given in Table 1.

1. Blue river below Green Mountain Reserv data
2. Chultinana River below canyon near Talkeetna, Alaska Data
3. Muddy creek near Pinedale data
4. Lower South Fork of Williams Fork near Leal data.

Table -1: Range of hydraulic data for the collected River Data Recking, A.(2010)

Data sets	Blue river	Chultinana River	Muddy Creek	Lower South Fork of Williams Fork
Slope (m/m)	0.0026	0.00039-0.0026	0.0012	0.016
Discharge (m^3/s)	18-46.1	212- 7104	0.18-1.51	1.05-7.05
Flow depth (m)	0.68-1	1.7-3.6	0.16-0.52	0.34-0.56
Avg. velocity (m/s)	0.81-1.3	1.2-2.7	0.25-0.76	0.39-1.4
D_{16} (m)	0.004	0.002	0.0004	0.01
D_{50} (m)	0.058	0.0008	0.0008	0.072
D_{84} (m)	0.22	0.052	0.002	0.224
D_{90} (m)	0.258	0.062	0.0028	0.28

3. DATA ANALYSIS

Smart (1984) bed load predictor is tested for four natural rivers collected from Recking, A.(2010) data sets. Limitations, deficiencies and drawback of the selected transport formulae will be analysed by the following process. The discrepancy ratio (ratio of calculated value to measured value) for each set of data is considered for comparison of performance. Various statically parameters like root mean square error and percentage error (mean normalized error). Inequality coefficient were also calculated to test the predictability.

To examine the accuracy of the model, the computed bed load transport rate using the selected four river data viz; Blue River data ,Chultinana river data ,Muddy creek data and Lower South Fork of Williams Fork near Leal data are plotted in Fig 1, 2, 3 and 4. The solid line represents the line of equal or perfect agreement.

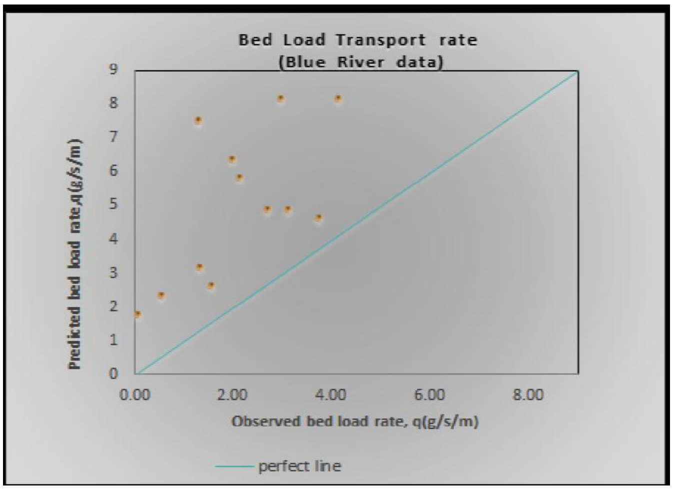

Chart -1: q using blue river data is plotted against q predicted

From the Chart 1, Smart (1984) bed load transport function over predicts for blue river data and needs further analysis.

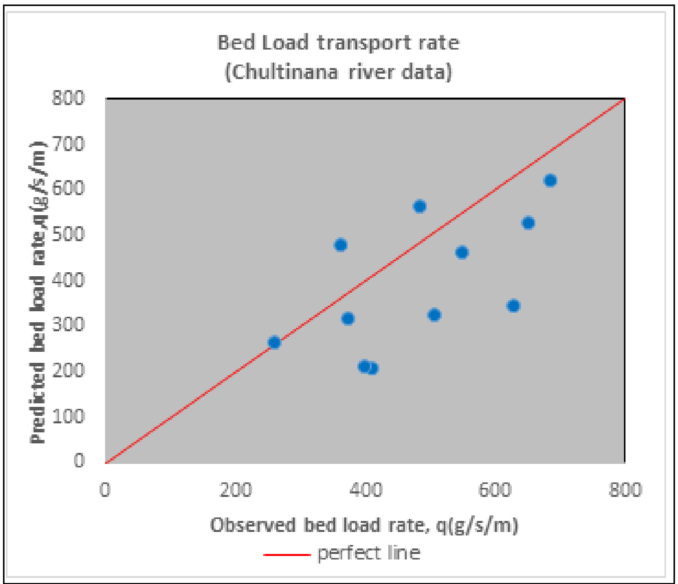

Chart -2: q using Chultinana River data is plotted against q predicted.

The above model of bed load transport rate under predicts as well as over predict giving half equal value.

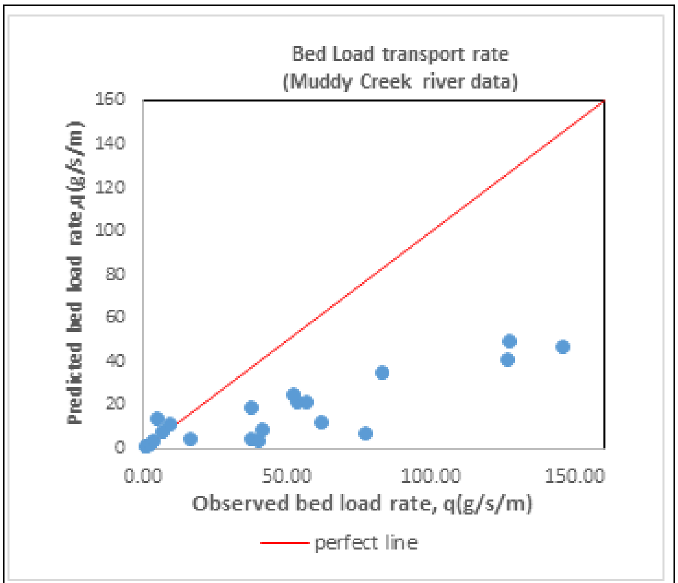

Chart -3: q using Muddy Creek River data is plotted against q predicted.

The above Chart 3 shows the prediction of bed load rate under predict and scatter to large value from the line of equality and some values are over predict and near to the line of equality.

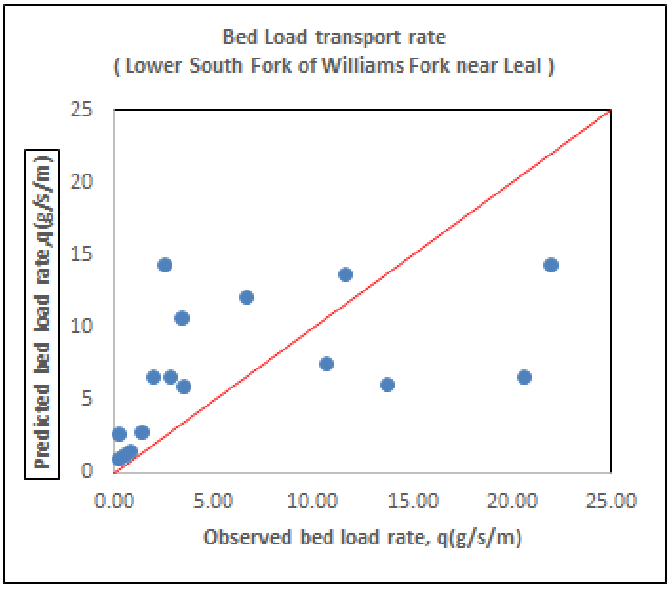

Chart -4: q using Lower South Fork of Williams Fork near Leal river data is plotted against q predicted.

From the above Fig 4, it is observed that the prediction of bed load rate under predict as well as over predict and scatter to large extent from the line of equality.

Sr. No.	Reckin g, A. (2010)	Root Mean Square Error(RMSE)	Discre pancy Ratio(predic ted/m easure)	Inequalit y Co-Efficient (U)	MNE (%)
1	Blue river	3.3	2.36	0.42233	29.86
2	Chulti nana River	148.01 7	0.72	0.15186 2	-12.29
3	Muddy Creek	55.98	0.35	0.50	-24.73
4	Lower South Fork of Willia ms Fork	5.3	1.13	0.3	230.65

3. CONCLUSIONS

Following findings can be summarized from the analysis of computed and observed bed load transport rate.

1. The formula proposed by Smart bed load transport function over predicts for Blue River below Green Mountain R. data as well as for Lower South Fork of Williams Fork near Leal data.

2. Smart (1984) bed load transport functions under predict for Chultinana River below canyon near Talkeetna, Alaska data and for Muddy Creek near Pinedale River data.
3. It is also observed that Smart (1984) bed load functions predicts to nearly double time the observed value for Blue River Data giving mean normalized error of 29.86 %.
4. Evaluation revealed that Smart (1984) transport function predicts well for Chultinana River data. with minimum discrepancy from the observed value giving discrepancy ratio near equal to 1 and mean normalized error of -12.6 % where the sediment size are large and for high flow transport.
5. Smart (1984) bed load functions poorly predict Lower South Fork of Williams Fork near Leal River data.
6. Overall consistency in the prediction is not observed for the present selected range of hydraulic river data.

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