Revision Note

The authors thank the reviewer for the suggestions and comments on how to strengthen the paper. Our specific responses to the comments are as follows:

Anonymous Referee #1

1) Comments to author:

The paper in itself is OK, but lacks clearness and remains too speculative. Vague words like "believe", "supposed" and "seem" indicate this.

Response

We will remove unclearness throughout the paper by providing more scientifically based approach and rationale of doing so.

2) Comments to author:

The governing equation should be added to facilitate interpretation.

Response

We will add it.

3) Comments to author:

Measurement accuracy should be provided together with its consequences for the final results. The same holds for the reference of the USGS and Fread's methods. As the true discharge is not known, comparisons can only be valid if the measurement errors are taken into account.

Response

Thank you. We will estimate the total uncertainty associated with discharge measurements when using the continuous slope area method. This estimation will be based on standard uncertainty analysis method such as ASME PTC-19.1 (2013) and GUM (1993), and will primarily account for the uncertainties associated with measured water surface slopes and Manning's roughness coefficients. In addition, an accuracy of discharges from USGS records is known to be within 5-10% (Hirsch and Costa, 2004) and an average RMS error for Fread's method is known to be approximately 4% (Fread, 1975).

Reference

ASME PTC19.1, "Measurement Uncertainty", American Society of Mechanical Engineers, New York, USA, 2013.

GUM., 1993. Guide to the Expression of Uncertainty in Measurement. ISBN 92-67-10188-9. BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, International Organization for Standardization, Geneva, Switzerland.

Hirsch, R.M. and Costa, J.E., 2004. US stream flow measurement and data dissemination improve. Eos, 85(20), pp.197-203.

Fread, D.L., 1975. Computation of stage-discharge relationships affected by unsteady flow. JAWRA Journal of the American Water Resources Association, 11(2), pp.213-228.

4) Comments to author:

Given the aspect ratio of the channel, not only bed roughness but also bank roughness/irregularities should be accounted for and thus addressed. Given the accessibility of the river reach characterisations of bed and bank roughness should not be a problem. Why is this information not used here? Are inferred roughness values realistic? With some information on the sediment composition, estimates regarding dynamic bed roughness can easily be made e.g. vanRijn, JHE 1984.

Response

Thank you very much for this great comment. We totally agree with the concerns and issues raised by the reviewer. Conventional practices of estimating Manning's roughness coefficients are based on a) computation from experimental equations; b) selection from the published n-value table; c) comparison with photographs of channels for which n values have been computed. Since the second and third methodologies (i.e., b) and c)) are subjective and the accuracy largely depends on a hydrologist's experience, there have been a lot of efforts to estimate *n* values based on experimental equations (i.e., more objective approach, c)). As exemplified by the reviewer, we will review experimental equations that can account for bank roughness/ irregularities due to vegetated bank conditions as well as other flow retarding factors including particle diameters, cross-sectional irregularities, and variations in channel size. The review of those equations would include for example the methodologies proposed by Bray (1979), Jarrett (1984), and Sauer (1990), and the performance of those equations that can be applicable to Clear Creek conditions will be demonstrated.

However, it is also important to note that those experimental equations neglected the effect of flow unsteadiness while the *n* value is outcomes from a combination of those individual flow retarding factors, including flow unsteadiness. Coon (1998) demonstrated that the *n* value can reflect energy losses, such as those resulting from unsteady flow, extreme turbulence, and transport of suspended material and debris, that are difficult or impossible to isolate and quantify. Due to its difficulty, the effect of unsteadiness on the estimation of Manning's roughness coefficients has typically been neglected. For example, USGS crest-stage gages are used only to measure water surface slopes at peak stages (i.e., steady discharges) for each flood event (instead of measuring whole water surface slopes during rising and falling stages). Recorded water surface slopes at different peak stages specific for each flood event can account for the effect of non-uniformity of channel conditions, but cannot account for the effects of unsteadiness. Coon (1988) even considered that measured water surface slopes obtained during rising and falling stages of a flood flow are erroneous slopes.

Given that we are now capable of measuring unsteady slopes using a pair of transducers in a continuous manner, the *n* value may be accurately estimated if field unsteady discharge data obtained during rising and falling stages (i.e., calibration data) is available. This data can be used to create stage-*n* rating under various seasonal conditions (i.e., growing season vs non-growing season). This stage-*n* rating may represent two distinct curves that reflect dynamic changes of vegetation conditions during flood wave propagation. For example, the *n* value becomes smaller on the falling stage as vegetation is already inclined toward a flow direction due to the forces exerted by a flow during the rising stage (Smith, 2010). While this is the new method of estimating the *n* value for this proposed study, the initial manuscript suggested that the value *n* be estimated using assumed steady slopes by simply averaging two unsteady slopes. This assumption comes from the fact that the value of steady water surface slopes remains between the values of two unsteady slopes at the same stage because pressure gradient term (the largest contribution factor for changing discharges) in 1D Saint-Venant equation plays a role of adding or subtracting values from the steady water surface slopes, resulting in hysteresis in stage-discharge rating curves.

As we acknowledge the reviewer's comment that this approximation lacks experimental and theoretical supports, we will change the manuscript by eliminating this approach, and introducing the suggested use of stage-*n* ratings (i.e., the use of field calibration data from USGS records along with the measured geometric data, the measured water surface slopes, and Manning's equation). While the accuracy of this approach will largely depend on the availability of calibration data, it is scientifically well based approach.

Reference

Bray, D.I., 1979, Estimating average velocity in gravel-bed rivers: American Society of Civil Engineers, Journal of the Hydraulics Division, v. 105, no. HY9, p. 1103-1122.

Coon, W.F., 1998. Estimation of roughness coefficients for natural stream channels with vegetated banks (Vol. 2441). US Geological Survey.

Jarrett, R.D., andPetsch, H.E., Jr., 1985, Computer program NCALC user's manual verification of Manning's roughness coefficient in channels: U.S. Geological Survey Water-Resources Investigations Report 85-4317, 27 p.

Sauer, U.S. Geological Survey, written communication, 1990 as reported in Coon, W.F., 1998. Estimation of roughness coefficients for natural stream channels with vegetated banks (Vol. 2441). US Geological Survey.

Smith, C. F., Cordova, J. T., and Wiele, S. M.: The continuous slope-area method for computing event hydrographs, US Geological Survey2328-0328, 2010.

5) Comments to author:

Was there any vegetation in the domain under study? How much effect would it have?

Response

We identified that the channel bank was covered with thick vegetation while the channel bed was composed primarily of clay. The effect of vegetation will be examined by a) the review of existing experimental equations and b) the use of field unsteady flow data from USGS records measured at different periods of time, while quantification of those effects may be limited for this study due to a small set of available data.

6) Comments to author:

What is the rationale behind averaging the measured "unsteady slopes" knowing that the flow is subject to non-linear friction?

Due to limited availability of measured discharge data, the simple averaging method is assumed in the original manuscript while we acknowledge the fact that the flow is subject to non-linear friction. As we demonstrated in response to comments #4, we will eliminate this approach in the revised manuscript and propose the method that can estimate the *n* value for unsteady flow conditions by creating stage-*n* ratings. Manning's *n* values are often selected from tables, but can be back calculated from field discharge measurements obtained during unsteady flow conditions. Once stage-*n* ratings are established along with measured (unsteady) water surface slopes, unsteady flow discharges can be calculated in continuous and accurate manners.