ChanGe: a MATLAB-based tool for calculation of channel hydrological parameters

Estimation of water discharge (Q), at a channel cross-section, for a given stage has wide application in (1) stream management for hydropower station, irrigation and domestic water supply, and navigation at modern time scale[1,2] and (2) river sciences for flood hydrology at historical to geological time scale[3–5]. Quantification of water discharge and channel geometry is important to maintain environmental flows for river ecology[6]. Calculation of water discharge in a conventional open-channel approach utilizes Manning or Chézy formulation using several hydraulic and morphometric parameters at a cross-section. It is difficult to estimate those parameters for a natural irregular channel geometry. In practice, sometimes a channel is idealized as a rectangular cross-section[7]. Otherwise, advanced computer programs allow to model the physics of flow dynamics of a reach, in three-dimension for known bulk properties such as cross-section area, hydraulic radius, reach slope and friction coefficient. However, this requires skill and the mentioned input parameters at a reach scale. Here, we introduce a relatively simple tool called ChanGe tool that requires minimum input on channel parameters that can be readily (1) extracted from digital elevation models (DEM) or toposheets using any geographical information system (GIS) software or (2) measured in the field using differential GPS or (robotic) total station.

First, we discuss the theoretical background of the ChanGe tool. Several equations are available to estimate bulk water discharge using simplified hydraulic parameters and the well-known and widely used is the Manning equation. It provides a quantitative relationship between channel geometry, slope and velocity. Manning equation scales average velocity by the following

$$V = \frac{k}{n} R_h^{2/3} S^{1/2} \qquad (1)$$

In this formulation, V is the average velocity (L/T), R_h the hydraulic radius (L), S the loss of hydraulic head or gradient of the channel along the flow (L/L), k a conversion factor between SI and English units (1 and 1.49 respectively) and n is the Gauckler–Manning coefficient. Generally, there is no unit assigned to the value of n, but the unit of n is ($T/L^{1/3}$).

The Manning equation is originally a correction to the Chézy equation $V = C(RS)^{1/2}$. The value of C used to vary within a reach which is not suitable for the calculation of average velocity in a reach. Therefore, Manning proposed a constant friction factor n which is constant for a reach. Experiments show that as the water discharge increases, the coefficient decreases due to the decrease of friction[8]. Hydrologic Engineering Center's and River Analysis System (HEC-RAS) model allows a discharge-dependent n, but most of the current studies idealize fixed n value. The instantaneous discharge is calculated as

$$Q = A \cdot V \qquad (2)$$

where A is the cross-section area (L^2). We have implemented the same theory to estimate water discharge and associated parameters (Table 1) from the cross-section data.

The ChanGe tool is a user-friendly, open-source MATLAB tool for calculation of discharge (eq. (2)). This tool requires input values of S and n to calculate V. And for the calculation of A, the user requires to present the input data in excel sheet format. The first column represents the distance along the cross-section and the second column represents the elevation (both in meter). For demonstration, we imported a hypothetical dataset to prepare a cross-section with a cursor (Figure 1 *a*). Next, the tool requires the user to click the cursor to select a point on the cross-section to mark the stage. We assumed the presence of palaeoflood deposit at elevation ~425 masl (meter above sea level). Palaeoflood deposits are depositional features that accumulate from suspension during major flood events in protected areas of reduced velocity near channel bank[9] and represents stage during the past flood events. Clicking the cursor at ~425 masl on P generated a straight line (water stage) intersecting the opposite bank at P' (Figure 1 *b*). Then, the tool requires the user to click the cursor as near as possible to P' on the cross-section. This produced a new figure demarcating the area of water flow within the cross-section (Figure 1 *c*). The area under the cross-section curve is estimated using the trapezoidal rule. Subsequently, area of water flow is calculated by subtracting the area under the curve from the area of the rectangle defined by the endpoints PP' (width) and stage above the river bed (height) at the cross-section. We assumed $S = 0.008$ (m/m), a typical slope of ~1 km channel reach upstream of the cross-section and $n = 0.03$ (for gravely river bed) from the standard table[10]. Finally, there is an option to display discharge and average flow depth on the figure (Figure 1 *d*). All the important parameters are saved in the MATLAB workspace that can be retrieved easily (Table 1).

We demonstrated use of this tool for the palaeohydrological study where we had palaeoflood deposits as a representative of the past stage of the river. There are numerous studies that reported palaeoflood events identified in channel stratigraphy[3–5,9]. However, such studies either used empirical relations or set up the HEC-RAS model for palaeohydrological analysis; while the former approach has too many assumptions involved, the latter is a cumbersome process. Whereas the ChanGe tool can be used efficiently in all such cases of palaeohydrological analysis to estimate palaeoflood discharge. Thus, using the ChanGe tool for discharge estimates for any desired stage of a river, a useful database can be generated for river management. For example, to maintain minimum e-flow (river stage favourable for the

Table 1. Summary of the estimated parameters from the hypothetical channel cross-section dataset

Parameters	Estimated values
Cross section area	21948.9 m^2
Wetted perimeter	803.7 m
Hydraulic radius	27.3 m
Average depth	28.1 m
Mean velocity	27 m/s
Water discharge	593451.4 m^3/s

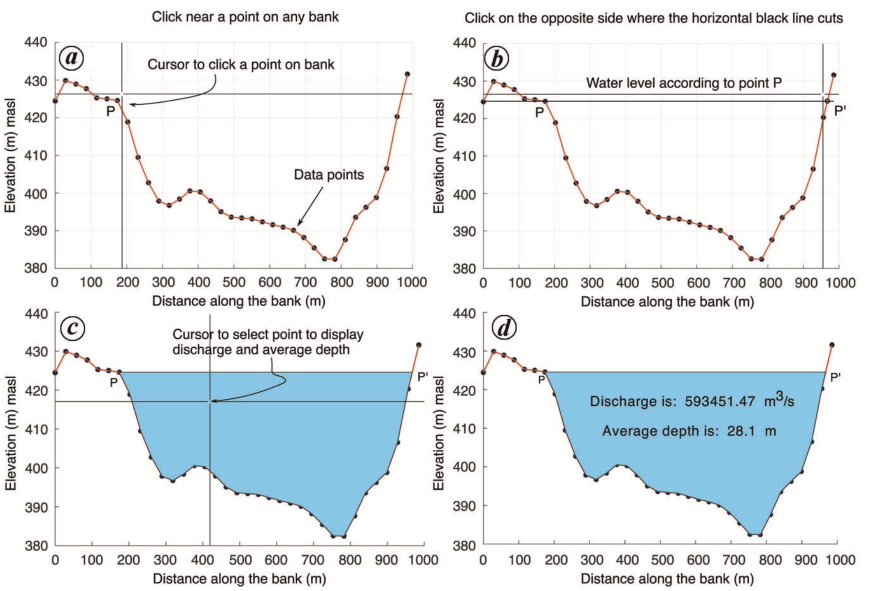

Figure 1. Channel cross-sections generated at different steps of the tool. ***a***, Cross-section profile generated after import of data; ***b***, With water stage after first click; ***c***, Water inundated shown by shaded region; ***d***, Final display with values of water discharge and average depth.

sustenance of river ecology) at any given cross-section, the ChanGe tool can be used to estimate the amount of discharge to be released from upstream[6]. Water resource management for irrigation canals or agricultural practice will be another potential sector where this tool can be utilized. Lastly, the estimation of flood inundation due to high magnitude floods can also be estimated with this tool.

We have presented a simple tool, ChanGe to estimate the discharge for any desired stage using the cross-section data from any natural river. Additionally, the tool provides channel geometry parameters such as hydraulic radius, average flow velocity and average depth. Results from a hypothetical cross-section show the usefulness of the MATLAB based tool in flood hydrology analysis. Moreover, the simple workflow approach with an intuitive graphical interface will help researchers to estimate hydrological and hydraulic parameters with ease. Although there are many sophisticated toolboxes available[11,12], ChanGe will provide simplistic means to the researchers and planners. Future work seeks to incorporate discharge-dependent roughness coefficient which will minimize the error in discharge estimation. Quantification of this error will be helpful for designing hydropower stations, irrigation and other management practices[1,2,6]. It is also noted that the flow-velocity is variable across the channel and with the depth[11]. Therefore, another future development could be the incorporation of variable flow velocity along the river cross-section as well as the depth-dependent distribution of flow velocity with physics-based laws.

1. Bakken, T. H. *et al.*, *Hydrol. Earth Syst. Sci.*, 2013, **17**, 3983–4000.
2. Shen, Y. *et al.*, *Agric. Water Manage.*, 2013, **128**, 55–64.
3. Kale, V. S. *et al.*, *Catena*, 2000, **40**(4), 337–358.
4. Wasson, R. J. *et al.*, *Quat. Sci. Rev.*, 2013, 77, 156–166.
5. Srivastava, P. *et al.*, *Geomorphology*, 2017, **284**, 17–30.
6. Tare, V. *et al.*, *J. Hydrol. Reg. Stud.*, 2017, **13**, 110–121.
7. Sichangi, A. W. *et al.*, *Remote Sensing*, 2018, **10**(9), 1385.
8. Ferguson, R., *Earth Surf. Proc. Landon*, 2010, **35**(15), 1873–1876.
9. Baker, V., *Spec. Publs Int. Ass. Sediment.*, 1983, **6**, 229–239.
10. Chow, V. T., *Open-Channel Hydraulics*, McGraw Hill, New York, 1959, p. 680.
11. Yang, Y. *et al.*, *J. Hydrol.*, 2019, **577**, 123930.
12. Straatsma, M. W. and Kleinhans, M. G., *Environ. Modell. Softw.*, 2018, **101**, 102–116.

ACKNOWLEDGEMENTS. We thank Professor Vikrant Jain, Head, Natural Science, Indian Institute of Technology Gandhinagar, for encouragement and logistic support. We also thank Dr Sonam and Dr Ramendra Sahoo for discussions and useful suggestions. The constructive comments from anonymous reviewer helped improve the manuscript substantially.

Received 29 February 2020; revised accepted 7 August 2020

SHANTAMOY GUHA[1]
AJIT SINGH[1,*]
RAHUL KUMAR KAUSHAL[1,2]

[1]*Earth Sciences Discipline,*
Indian Institute of Technology,
Gandhinagar 382 355, India
[2]*Physical Research Laboratory,*
Navrangpura,
Ahmedabad 380 009, India
**For correspondence.*
e-mail: ajit268@gmail.com

Invasive hawthorn spider mite, *Amphitetranychus viennensis* (Zacher) (Acari: Tetranychidae) from India

The spider mites (Acari: Tetranychidae) are the most economically important group of mites which cause considerable loss of yield on different crops[1–3]. Till date, 1321 valid spider mite species are known on 3917 species of plants with 16,221 host records[3]. The Indian spider mites fauna is also rich with 122 species and nearly 10% of total species of the world. Among these, more than 12 species are reported as most economically important on different agro-horticultural crops[3,4].

Hawthorn spider mite, *Amphitetranychus viennensis* (Zacher, 1920)[5] (family