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EXTENDED ABSTRACT

Derivation of River's Cross-Section Hydraulic Relationships Using Inverse Modeling

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Introduction

In this study, a methodology is presented in which hydraulic relationships including mathematical formulas for the variations of the flow area, the wetted perimeter and the flow top width with the depth are computed by inverse solution of the Saint-Venant equations. The main focus is on the comprehensiveness and applicability of the method in practical conditions. Also, one application of the presented method in the case of flood routing is presented.

In the context of river hydraulics, inverse modeling usually refers to the estimation of the Manning roughness coefficient via calibration process or identifying boundary conditions by measuring the flow properties inside the domain i.e. water level or flowrate records (Ding and Wang, 2005, Fread and Smith, 1978, Khatibi et al., 1997, Nguyen and Fenton, 2005). Inverse problems are often inherently ill-posed; and this leads to some difficulties in solving them in comparison with forward problems. Some essential issues must be considered in solving inverse problems including solution existence, solution uniqueness and solution stability (Hansen, 1998). The underlying idea of the present research is to identify the mathematical formulas of geometric-hydraulic relationships for river cross sections. In this case, the unknown parameters are determined in the functional form by inverse solution of the Saint-Venant equations. The proposed model is validated using hypothetical and real test cases; and in each case the actual and identified geometric-hydraulic relationships are compared. Additionally, application of the method is showed for the case of hydraulic flood routing in conditions where no information is available about river cross sections; and water level data records are used instead of river cross sections data.

Methodology

In science and engineering, it is frequently necessary to relate physical parameters characterizing a model to easily measurable data assuming that the fundamental physics of the underlying problem is adequately understood. This can be expressed as:

$$G(m) = d \tag{1}$$

where *m* is the model parameters vector, *d* is the data vector and *G* is the underlying physics operator. According to Equation (1), the forward problem is to find *d* using given *m* and the inverse problem is to calculate *m* using known *d* (Richard et al., 2004). There are two main approaches for solving the inverse problems including the direct numerical approach and the optimization based iterative approach (Gessese and Sellier, 2012). In this article, the optimization technique is used to solve the inverse problem.

The Forward Model

The governing equations for unsteady flow in one-dimensional open channel flows are the Saint-Venant equations; involving the continuity and the momentum equations. In this research, the well-known Preissmann scheme is used to solve the Saint-Venant equations (Wu, 2008).

The Inverse Model

In this study, the Sequential Quadratic Programing (SQP) method has been used to minimize the objective function. This method is frequently used for constrained nonlinear optimization problems and has a number of advantages over the other solutions

Results and Discussion

The proposed inverse model is validated using two test cases. The first test case is a hypothetical example and the second one is real.

Test Case 1 (Hypothetical River)

This test case is a 5000 m trapezoidal river in which the first half (0 to 2500 m) has the bottom width of 10 m and side slope of 1:1 and the second half (2500 to 5000 m) has the bottom width of 5 m and the same side slope. Figure (1) shows the comparison of the geometric-hydraulic relationships with the actual values for the first reach in Test Case 1.

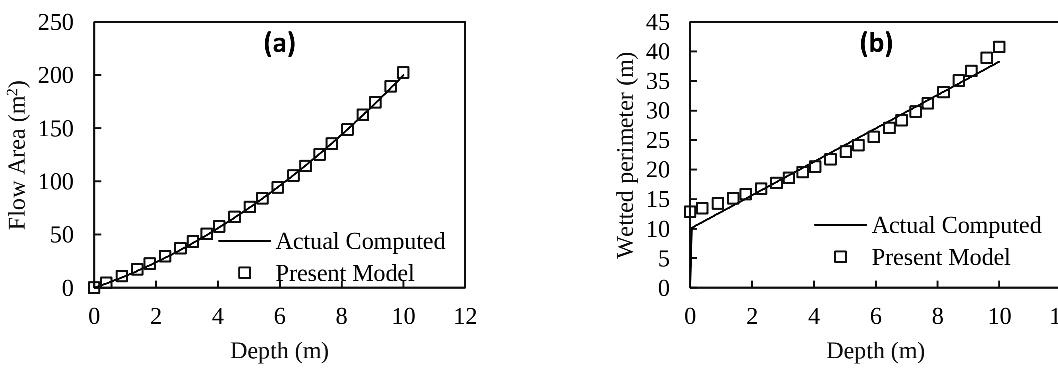

Fig. 1- Comparison of the geometric-hydraulic relationships. (a) Flow Area (b) Wetted perimeter

Test Case 2 (Kootenay River)

Hydraulic relationships of a reach of the Kootenay River have been identified by present model. This river has been selected to evaluate the ability of the presented inverse model in identifying the hydraulic relationships. Figure (2) shows the applicability of the present model in natural river without of river cross sections existence.

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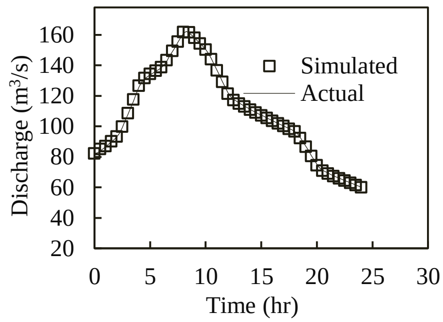

Fig. 2- Application of the presented method, flood routing in 1000 m from the beginning of the river

Conclusions

The key concept of this study is that, in spite of the irregularities in river cross sections, the relationships between the flow area and wetted perimeter variations with depth often follow from relatively smooth functions. These functions can be expressed in terms of exponential type functions with a reasonable accuracy. In fact, by a combination of numerical solution of the Saint-Venant equations and an optimization method, using water level data, the coefficients of the above-mentioned assumed function could be identified. The proposed inverse model only uses water level records as an input rather than both water level and discharge records. The main limitation is that the method is applicable in cross sections with sufficiently slowly varying parameters i.e. the sudden and abrupt change in geometric-hydraulic relationships should not exist.

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