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Peak flow estimation by means of synchronous water level measurements

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Peak flow measurement is fundamental for the validation of all the rainfall-runoff hydrological models, as well as of all the shallow water propagation models in fixed and movable beds.

Most of the flow rate estimations are actually carried out by recording the water levels in single sections of the river and assuming a monotonic relationship between the water depth and the flow rate, called depth-discharge relation. The depth-discharge relation is assumed known and constant for large time periods, without any assessment of the changes occurring in the shape of the river section and in the bottom bed vegetation.

Flow rate can also be estimated by integrating velocity profiles along the rivers section. Velocity profiles are usually obtained using Acoustic Doppler Current Profilers in full contact with the water. This causes serious inconveniences for measuring extreme hydrological events, because of the solid transport and the strong turbulence associated with the stream current.

In reality, the critical hyetographs associated to given time return periods are, according to the climatic conditions of several European countries, associated to quite unsteady flow rate and water depths hydrographs, such that a relatively precise estimation of the celerity associated to the wave propagating in the lower part of a basin is possible.

In the most simple case of strongly kinematic flow in prismatic channel, it is first shown that the momentum and continuity equation can be written in the form:

$$h_{\max} = \left(\frac{q_{\max} n}{\sqrt{i}} \right)^{3/5}$$

$c_{\max} = \frac{dq_{\max}}{dh_{\max}} = \frac{5}{3} \left(q_{\max} \right)^{2/5} \left(\frac{\sqrt{i}}{n} \right)^{3/5}$ (1),

where q_{max} and h$_{max}$ are the peak flow and the corresponding water depth, $i$is the channel slope and n is the Manning coefficient. This allows to compute both the maximum flow rate and the Manning coefficient for given maximum water depth and corresponding celerity. To measure the maximum water depth celerity at least two synchronous measurements in different sections are required. A lower limit of the distance between the two sections is given by the accuracy required to the celerity measurement and an upper limit is given by the spatial variability of the flow rate occurring between the two sections, due to the river lateral inflow.

A sensitivity analysis is carried out to show that, in the case of large rectangular section, the sensitivity of the system (1) solution with respect to the data error is small and the relative error in the peak flow estimation is lower than the input relative error of both the maximum water depth and the corresponding celerity.

Experimental set up in a Sicilian river, where surface velocity will be measured by means of a radar sensor and compared with the computed average values in the two sections, is finally outlined.