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How to avoid unreliable formulas for time of concentration in ungauged basins

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Estimating design flood hydrographs in ungauged basins requires the determination of hydrological response parameters. These parameters are derived from relationships that often lack a solid foundation in the specific physical characteristics of the basin. Among the parameters subject to greater uncertainty, the characteristic time of the IUH function certainly stands out. Indirect methods for estimating this parameter involve the use of empirical or analytical formulas and, in the engineering practice, the use of one or more formulas is often justified on heuristic grounds, lacking solid scientific considerations to guide the choice towards the most appropriate formulation.

Here, we propose a methodological approach to provide support in choosing a robust formulation for estimating basin flood response time. We have selected 35 formulas from the literature, all containing parameters related to the basin's length and slope. After verifying the real meaning of the input parameters and units required by the formulations in the original articles where they were published, the structure of the formulas considered has been analyzed in dimensional terms, using a reasoning scheme consistent with the hydraulic relations of resistance formulas. In this way, 17 hydraulically consistent formulas have been identified.

At this stage, we point out the advantage of comparing the formulas in terms of equivalent average flow velocity rather than in terms of observed travel times. Starting from the celerities obtained as the ratio between the length of the basin's drainage path and the response times provided by each formula and using the morphology of the river network of 135 basins in northwestern Italy, we compared the variability of estimated mean travel velocities. In line with literature observations, which highlight a slight increase in mean velocities with basin size, some formulas are deemed physically inconsistent, while 5 of them were identified as hydraulically robust and consistent with empirical observations. These formulas are Chow (1962), NERC (1975), SCS (1954), McEnroe and Zhao (1999), and Watt and Chow (1985).

The results obtained analytically identify the relationships between the exponents of length and slope in each formula and those governing empirical relationships between lengths and slopes of main river reaches in the basins. These relationships allow us to identify the range of values for the exponents of length and slope in the formulas for the characteristic time for which velocity estimates increase with the basin area. Based on these relationships, it is also possible to provide

a guideline for the calibration of new formulations.