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Rating curve uncertainty assessment using hydraulic modelling

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Traditional methods for estimating stage–discharge rating curves and their uncertainties need numerous calibration gaugings. Years of data collection efforts are often needed to gauge the stage–discharge relation across the flow range to establish a reliable rating curve. In particular, high-flow discharge estimation is often highly uncertain since these flows rarely occur and are practically difficult to gauge. Therefore, the portion of the rating curve representing most extreme flows typically needs to be extrapolated.
Hydraulic modelling can be used to derive rating curves based on only a few calibration gaugings and can therefore potentially be a good alternative for quickly estimating rating curves. In particular, they have potential to improve high flow discharge estimation as they are based on hydraulic theory rather than extrapolation techniques. However, rating curve estimation with hydraulic models is also associated with multiple sources of uncertainty that have not yet been comprehensively assessed. These uncertainties need to be accounted for and estimated to evaluate the full potential of hydraulic rating-curve modelling.
We developed the Rating curve Uncertainty estimation using Hydraulic Modelling (RUHM) framework to investigate and estimate these uncertainties. The framework combines a one dimensional hydraulic model and Bayesian inference to incorporate information from both hydraulic knowledge (bed slope, roughness, topography and vegetation) and the (uncertain) calibration gauging data. The framework was applied at the Röån River catchment in Sweden. We investigated the number of gaugings needed to reliably calibrate the model, the sensitivity of the results to the prior hydraulic information quality (water-surface slope measurements and roughness), and the effect of the vegetation survey data on the high flow discharge estimation.
We found that the rating curve uncertainty could be estimated reliably with only a few gauging and water-slope measurements, and that the uncertainty was insensitive to the number of gaugings as long as they covered low and medium flows. We found that at least one (uncertain) water-surface slope measurement was needed, and that precise information about the roughness parameter was not needed. The impact of the vegetation survey data on the high flow discharge estimation was investigated to assess its importance for extrapolation at extreme flows. Our results at this site show that hydraulic rating curve uncertainty estimation is a promising tool for quickly estimating rating curves and their uncertainties. It can be particularly useful at previously ungauged sites or at established sites that have experienced major temporal changes to the stage–discharge relation.