The uncertainties of gaugings

1 Uncertain gaugings as calibration data

For the analysis of a rating curve with BaRatin, you need to provide a set of gaugings representative of the stage-discharge relation for the study period. The validity of these gaugings must be checked (quality assurance) beforehand in order to avoid outliers, to ensure the continuity of their stage with respect to the staff gauge of the station, and to control and document measurement errors. It is especially important to consider:

- The measurement technique and gauging procedure;
- The date and hydraulic conditions at the time of the measurement, including: vegetation, flood, rating changes, etc.;
- The datum of the gauged stage, particularly when the staff gauge of reference has undergone changes or displacement, or if multiple staff gauges were used simultaneously.

BaRatin allows consideration of uncertainties on the gauged discharges and stages that are potentially different for each measurement. It is an interesting advantage when using more uncertain gaugings (e.g. surface velocity gaugings, historic gaugings that are poorly documented) or discharge estimates (e.g. post-flood survey and slope-area method) in stage ranges with few or no gaugings, because their contribution is weighted by their information content. It is important to specify realistic gauging uncertainty values, neither overestimated nor underestimated, as they impact both the fitting of the curve and the width of its uncertainty envelope.

A (strong) assumption of BaRatin is that the measurement errors are independent from a gauging to another gauging. This assumption is clearly violated if BaRatin receives some gaugings performed under repeatability conditions, typically with the same instrument at the same place on the same day in the same hydraulic conditions, etc. This can lead to an underestimation of the uncertainty of the rating curve. We must therefore avoid including repeated gauging (e.g. successive ADCP gaugings of a constant discharge), but either sub-sample them or average them together.

Attention: in BaRatinAGE, BaRatin's GUI, gauging uncertainty is expressed at a confidence level of 95% (or ±1.96 standard deviations assuming errors follow a normal distribution) and in relative terms (in %) for the gauged discharges and in metres for the gauged stages.

In the XY.BAD calculation file, the uncertainty is expressed as one standard deviation in absolute value (in m^3/s and m).

2 Uncertainties of gauged discharges

Uncertainty of the gauged discharge can be estimated from the available information on discharge measurements or calculated by methods of propagation of uncertainty. For velocity-area gaugings, uncertainty calculations can be done with the methods of the ISO748 or ISO1088 standard, or alternative methods: IVE (USGS), Q+ (French national hydrological services) or FLAURE (EDF) methods. All of these methods have limitations.

According to the technique used and the measurement conditions, the individual gauging uncertainty can be evaluated simply by means of simplified calculations. Inter-laboratory comparisons are also used to determine empirically the uncertainty of gauging technologies deployed in the measurement conditions of the experiments. This uncertainty is typically taken to be ±7% for streamflows gauged using a current meter with at least a dozen verticals correctly sampling the flow field, and ±5% for a gauging by ADCP achieved in good conditions (±10% in bad conditions).

The following table provides typical discharge uncertainty values (expanded to 95% level) for the main gauging techniques.

Conditions	Volumetry	Velocity-area methods				Tracer dilution	Hydraulic formulas
		ADCP	Current meter	Floats	Radar, LSPIV		
Optimal	±5%	±5%	±7%	±10%	±10%	±3%	±5%
Poor	±10%	±10%	±15%	±50%	±20%	±10%	±40%

Note. These typical uncertainty values are provided only as examples. Uncertainty analysis of discharge measurements in each case, at least by categories, is highly recommended.

3 Uncertainties of gauged stages

In addition to uncertainty in gauged discharges, BaRatin also allows taking into account the uncertainty of gauged stages. However, as a first approach and routinely, it is recommended to ignore it, by specifying it as zero for all the gaugings. Indeed, considering this uncertainty significantly increases the complexity and duration of the computations since the stage error of each gauging becomes an additional parameter to estimate, in addition to those of the rating curve and of the remnant uncertainty. And the results are generally very little different, unless the stage uncertainty of gaugings important for the rating calibration is high.

Unlike the discharge uncertainty, the stage uncertainty is never expressed in relative terms (in %) but always in metres. The main sources of error in the gauged stage include the reading of the staff gauge, the resolution, the waves, the deformation of the free surface near the gauge, the datum of the gauging when it was measured at another staff gauge, the time lag if the staff gauge reading is not made during the gauging operations, and importantly the variation in water level during the gauging operations, particularly in situations of flood rise or flood recession. The latter uncertainty component can be estimated simply as (95% expanded uncertainty):

$$U_{var}(h) = \frac{h_{max} - h_{min}}{\sqrt{3}}$$

where h_{max} and h_{min} are the maximum and minimum stages attained during the measurement. As these various sources of errors are assumed to be independent, the combined uncertainty is obtained by quadratic sum of elementary uncertainties.