RAPPORT

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Uncertainty of current meter measurement: Analysis of NVE's database

Usikkerhet i vannføringsmålinger målt med flygel:

Analyse av målingene i filarkivet

Alexandre Christophe Hauet

NVE Rapport 25/2020

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Usikkerhet i vannføringsmålinger målt med flygel: Analyse av målingene i filarkivet

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Sammendrag:

Denne rapporten beskriver usikkerheten til vannføringsmålinger gjort med flygel for omtrent 750 målinger i NVEs filarkiv. Dette blir gjort ved å bruke metoden Fleure beskrevet i kapittel 3 i «Uncertainty of discharge measurement methods - A literature review» (Rapport 27/2020, ISBN: 978-82-410-2048-3) Halvparten av målingene har en usikkerhet på mindre enn 6% og halvparten har usikkerhet mellom 5% og 9%. Hovedkildene til usikkerhet er usikkerhet i areal og i horisontal hastighetsfordeling pga. for få vertikaler. Andre store bidrag er usikkerhet i vertikal hastighetsfordeling for grunne elver hvor man kun måler ett hastighetspunkt og målinger der vannhastigheten er svært lav.

This report describes the uncertainty of water flow measurements made with a flygel (mechanical currentmeter) for approximately 750 measurements in NVE's file archive. This is done using the method Fleure described in chapter 3 in «Uncertainty of discharge measurement methods - A literature review» (Rapport 27/2020, ISBN: 978-82-410-2048-3). Half of the measurements have an uncertainty of less than 6% and half have an uncertainty between 5% and 9%. The main sources of uncertainty are uncertainty in area and in horizontal speed distribution due to too few verticals. Other major contributions are uncertainty in the vertical speed distribution for shallow rivers where only one speed point is measured and measurements where the water speed is very low.

Emneord:

Vannføring, vannføringsmåling, salt, fortynning, saltfortynning, saltmåling, nøyaktighet, usikkerhet, usikkerhetsberegning, måleusikkerhet, feilkilder, kvalitet

Discharge, discharge measurement, salt, dilution, salt dilution, salt measurement, accuracy, uncertainty, uncertainty calculation, measurement uncertainty, sources of error, quality

Forord

Denne rapporten er en av flere rapporter om usikkerhet i vannføringsmålinger skrevet av Alexandre Christophe Hauet, PhD, for hydrometriseksjonen på NVE. Hydrometri - Teknikk og feltdrift HHT, Hydrologisk avdeling, NVE.

Hauet jobbet i ett år for HHT, NVE, fra august 2019 til august 2020, finansiert av FoU-midler i prosjektet 80501 «Nye metoder for måling av vannføring og sedimenttransport». Usikkerhetsberegning var en viktig del av dette prosjektet.

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Report

Uncertainty of current meter measurement: Analysis of NVE's database

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1 Database and cleaning

The current meter measurements used in this study were extracted from the NVE's discharge measurements folder[1]. The .Vng files exported by Vinge software were used. We selected only the measurement realized with 5 verticals or more. It consists in 749 measurements, ranging from $1L/s$ to 11 m^3/s, with one measurement reaching 260 m^3/s. The mean and median discharges are 2,137 m^3/s and 0,596 m^3/s respectively, as illustrated in figure 1.

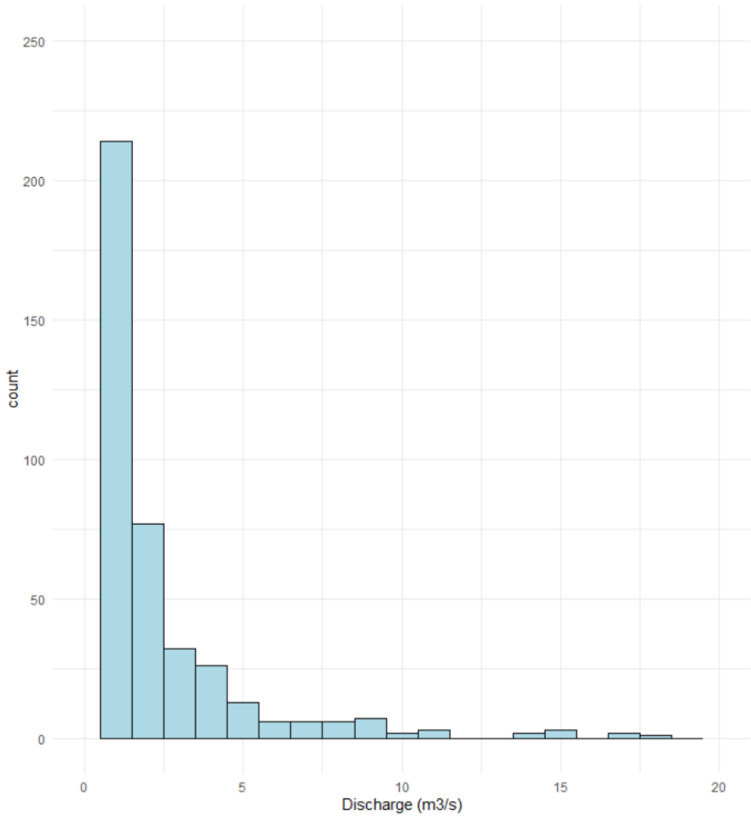

Figure 1: Bar-plot of the distribution of the discharges for the gaugings used in that study (the measurement of 260 m^3/s is not shown)

50% of the gaugings have discharges ranging 0,183m^3/s to 1,59m^3/s, and 90% ranging 0,0356m^3/s to 7,4m^3/s, as shown in table 1.

As illustrated in figure 2, the measurements were realized with a number of verticals ranging 5 to 35, with a median value of 17 verticals. 90% of the measurements have 10 to 26 verticals. The measurements have an averaged number of velocity points per verticals ranging 1 to 3, with most of the gaugings realised with 1 and 2 points per vertical.

[1] //nve.no/fil/h/HH/Vannføringsmålinger

Statistic	Mean	5%	25%	50%	75%	95%
Discharge (m^3/s)	2,137	0,0356	0,183	0,596	1,59	7,4

Table 1: Statistics of the discharges for the gaugings used in that study

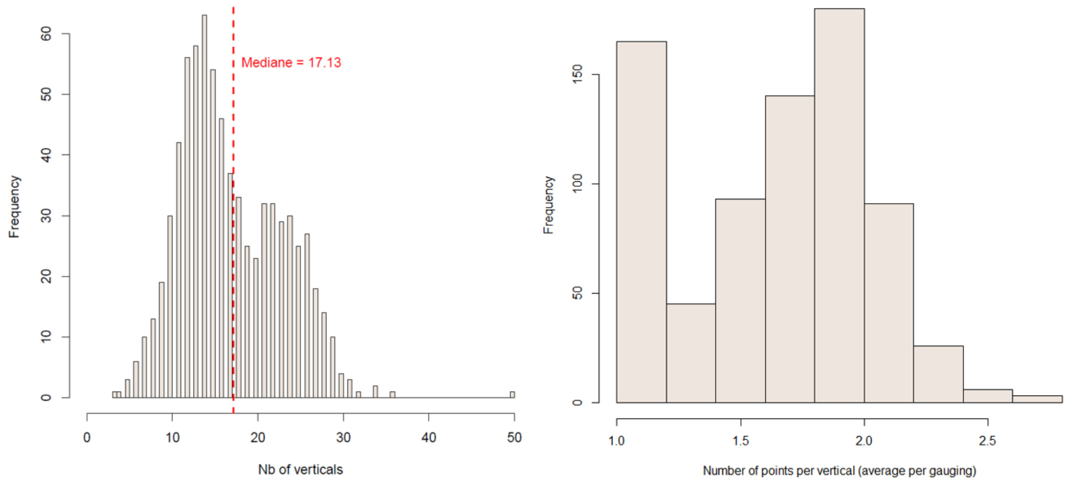

Figure 2: Bar-plots of the distribution of the number of verticals (left) and the averaged number of points per vertical (right)

2 Uncertainty analysis

In a literature review realized by NVE, it was shown that the most advanced method for computing the uncertainty of current-meter measurements is the Flaure method (Despax et al. 2016). This method consider the following error sources:

- Systematic error represents the residual error with the true discharge value if the measurement was done in perfect ideal condition. It is fixed at 2% and can not be reduced.
- Width and Depth error are related to the measurement of the width and the depth. They are computed using the Iso 748 standard and are generally low.
- Depth averaged velocity error is related to the number of points per vertical used to computed the depth averaged velocity.
- Point velocity error is related to the measurement of a single point velocity and is mostly linked to the magnitude of the velocity (the slowest, the highest the error) and to the exposure time.
- Bathymetric profile error is related to the complexity of the cross-section bathymetry. The more complex it is (bumps, high gradients of slope), the more important is the error.
- Lateral velocity profile error is related to the complexity of the velocity lateral distribution over the cross-section.
- Edge discharge error is related to the extrapolation of the discharge close to the edges.

2.1 Total expanded uncertainty

Over the 749 measurements studied, the total expanded uncertainty, at the 95% confidence level, ranges from 2,7 to 39%, with a mean and median values of 7,5% and 6,3% respectively. As illustrated in figure 3, the most represented uncertainty values are 5 to 7%. The statistics of the expended uncertainty are given in table 2

Statistic	Mean	5%	25%	50%	75%	95%
Expanded uncertainty (%)	7,5	3,6	4,7	6,3	9,15	15,6

Table 2: Statistics of the expended uncertainty for the gaugings used in that study

Figure 4 shows that there is a link between the total uncertainty and the number of vertical of the measurement, but a wide spreading can be observed, meaning that a measurement

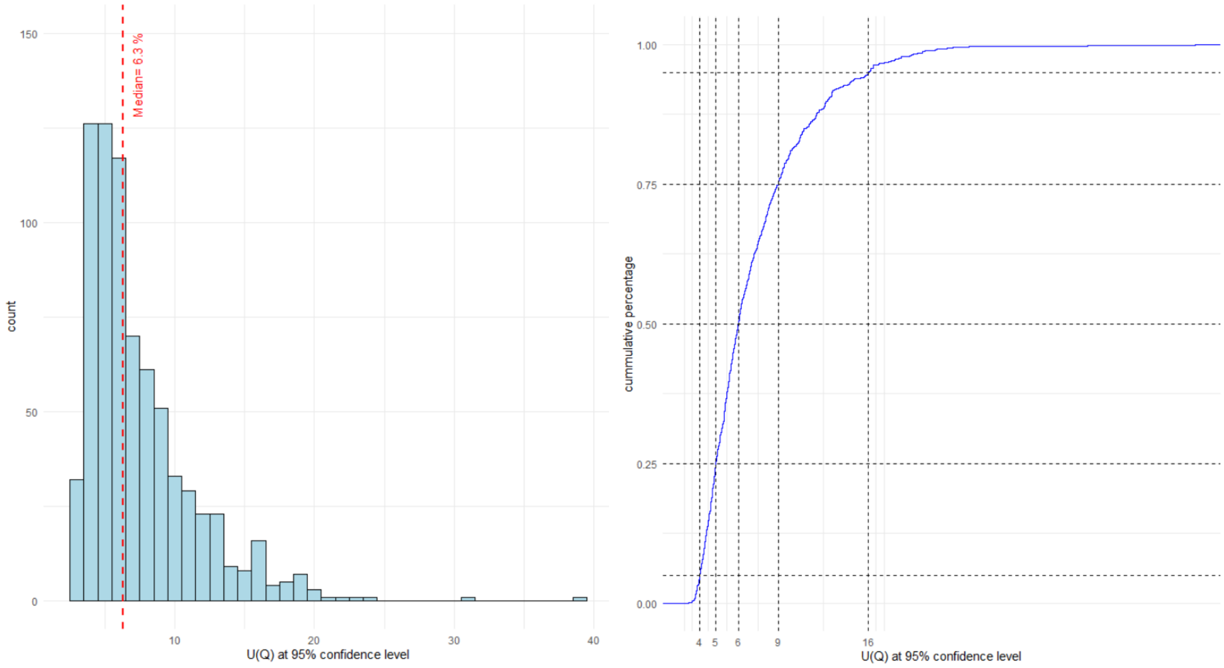

Figure 3: Distribution (left) and cumulative distribution (right) of the total expanded uncertainty

with few verticals can have a relatively small uncertainty if the measurement conditions are good (simple bathymetry and velocity distribution).

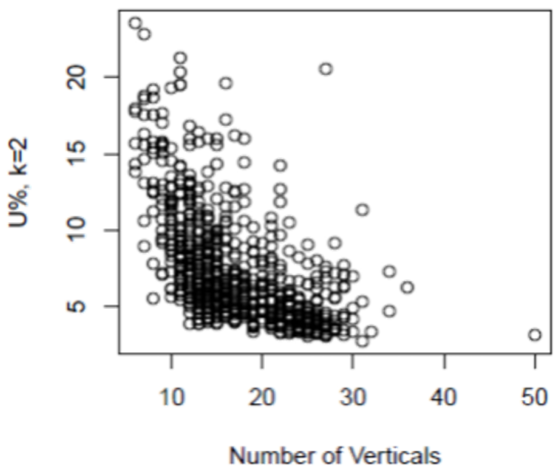

Figure 4: Relationship between the Flaure uncertainty and the number of verticals of the measurements

2.2 Uncertainty budget

Figure 5 shows the global budget of uncertainty for all the gaugings studied. Error sources due to the number of verticals (bathymetric profile and lateral velocity profile) are the most important, as they represent abut 26% and 15%, respectively, of the total uncertainty in median. They can reach very important relative parts in the total budget. The depth averaged velocity error source can also be important in the total budget, with a median value of 17%. The spreading is lower than for the the bathymetric and velocity lateral profiles. Point velocity error can be relatively high for measurement with slow velocities, with a median value of 10% and maximum relative part reaching about 50%.

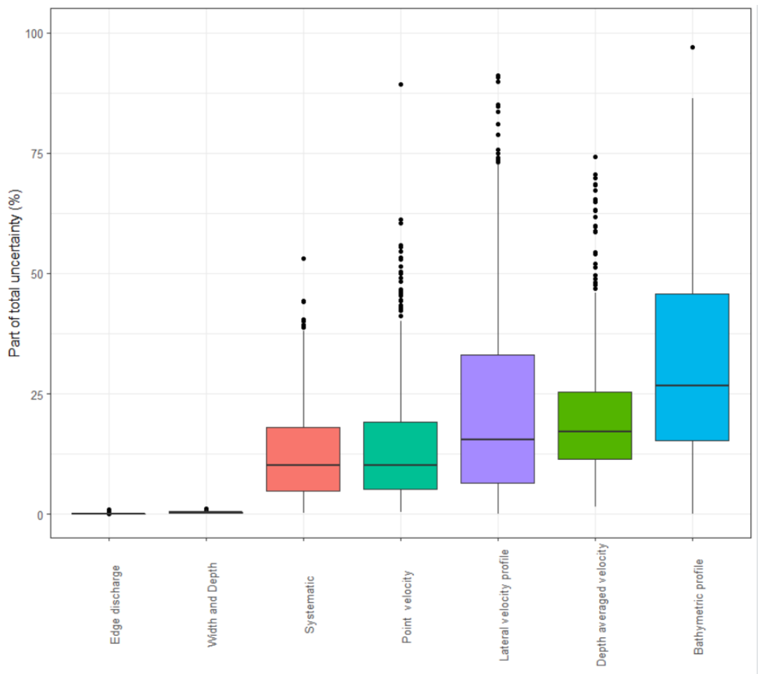

Figure 5: Global budget of uncertainty for the gaugings used in that study

3 Examples of measurements

3.1 Low uncertainty measurement

Figure 6 shows a measurement with a very low uncertainty. The total expended uncertainty is low, about 3%, and the main error source is the systematic error, that is fixed and can not be reduced. It's not possible to reduce the uncertainty of this measurement, the best has been done !

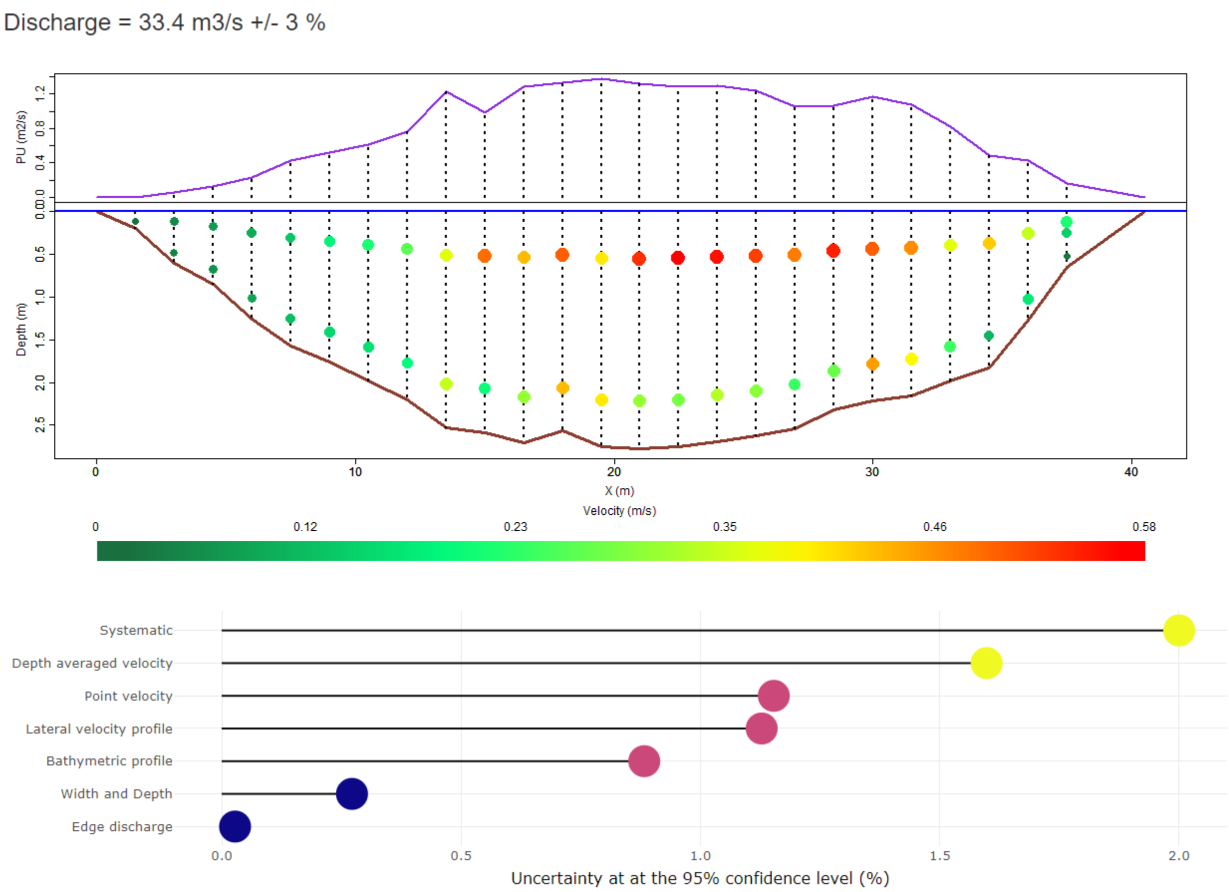

Figure 6: Measurement with low uncertainty

3.2 Measurement with a complex lateral velocity distribution

Figure 7 illustrate a cross-section with a lateral velocity profile showing high gradients. The total uncertainty is high, about 16%, and the main error source is the lateral velocity profile. One should have choose an other cross-section with a smoother velocity distribution, or, if this section was the only possible solution, one should have make more verticals to reduce the uncertainty.

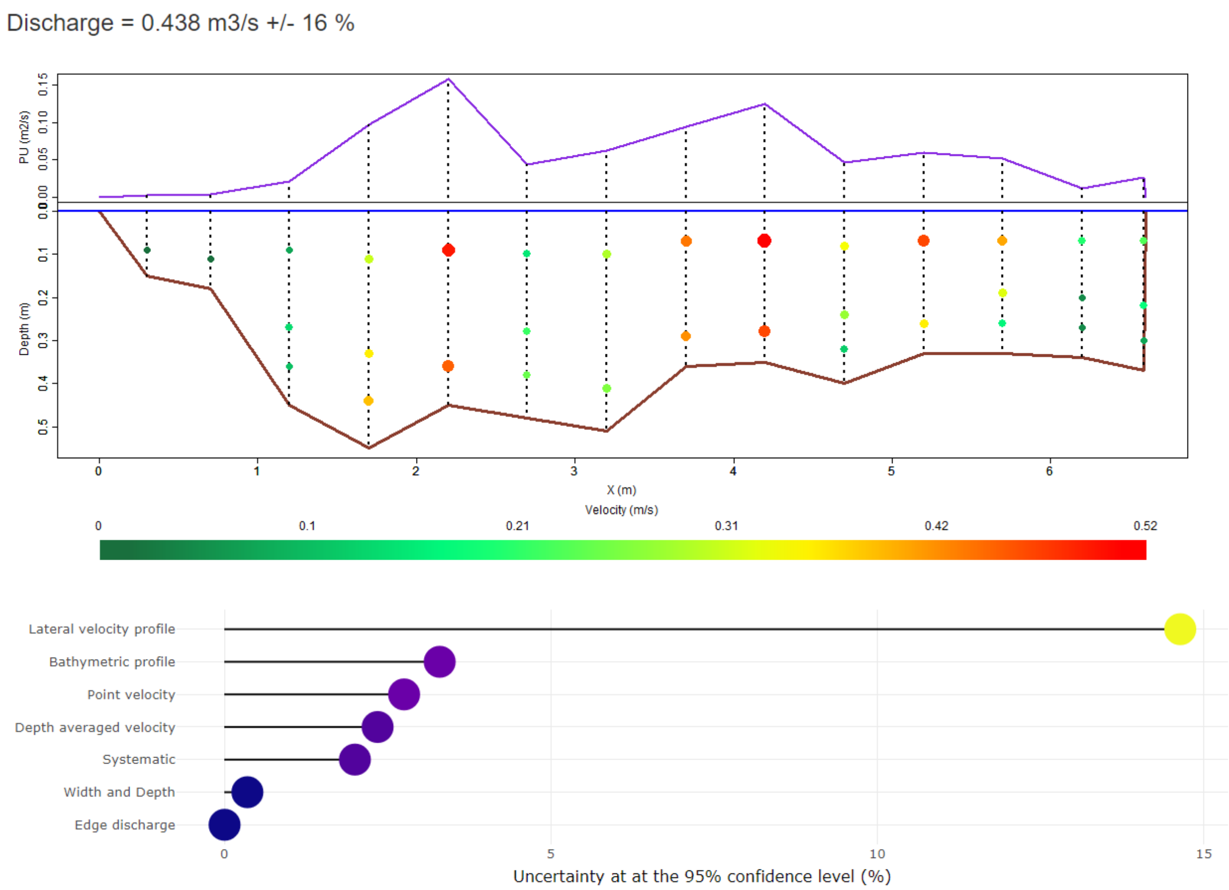

Figure 7: Measurement with a complex bathymetry and lateral velocity distribution

3.3 Measurement with 1 point per vertical

Figure 8 shows a measurement with a quite flat bottom. One single point of velocity was measured per vertical. The total uncertainty is quite low, about 4%, but the main error source is the computation of the depth averaged velocity. To reduce the uncertainty, one should do more points per vertical.

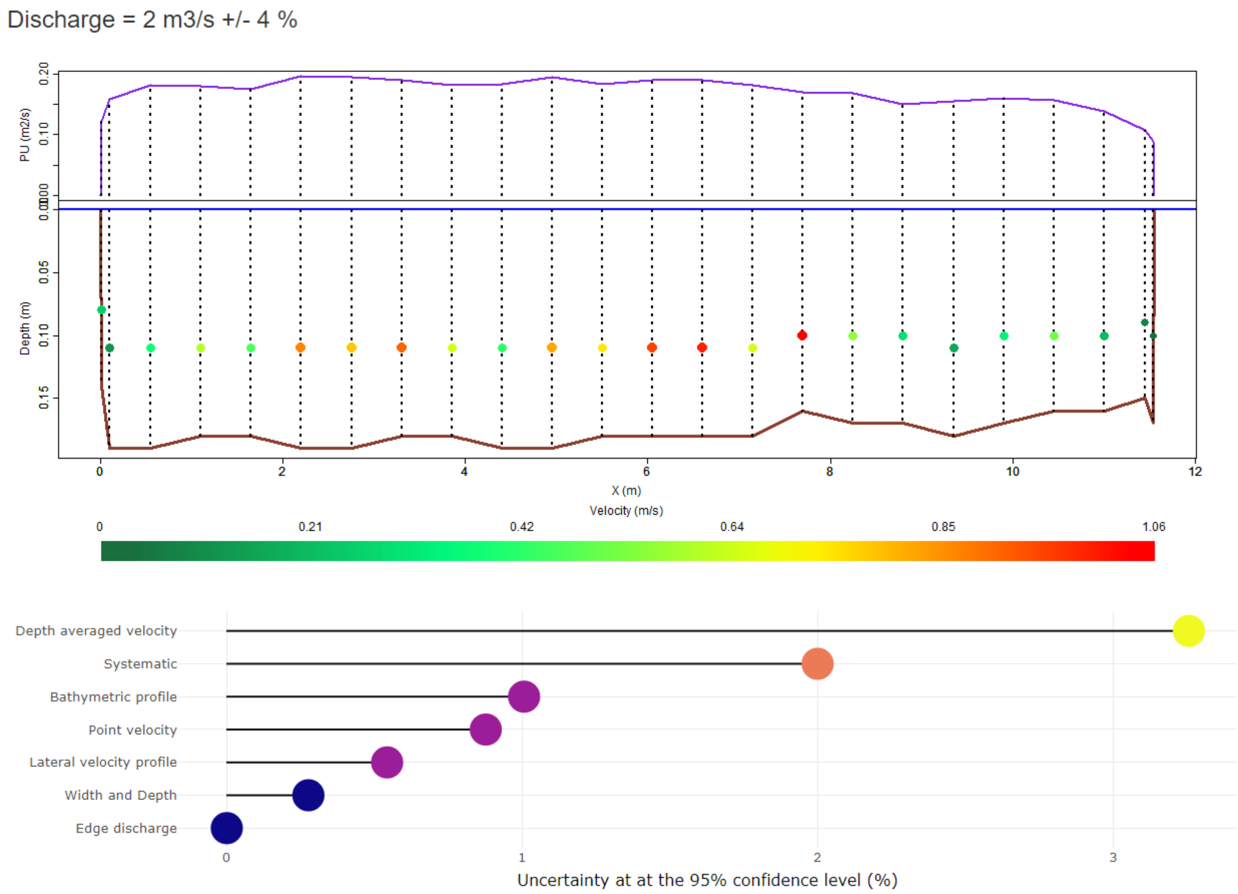

Figure 8: Measurement with 1 point per vertical

4 Conclusions

In this report, we analyse the uncertainty of all the Vinge current-meter gaugings stored in NVE's database using the Flaure framework. It consists in about 749 measurements, ranging 1 L/s to 260 m^3/s.

The total expanded uncertainty, at the 95% confidence level, ranges from 2,7 to 39%, with a mean and median values of 7,5% and 6,3% respectively. The most represented uncertainty values are 5 to 7%.

The dominant errors sources are related to the number of verticals (bathymetric profile and transverse velocity profile) and to the number of points measured by vertical.

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