Comparison between different Instruments for Discharge Measurements in Rivers

Robert Schatzl
Office of the Styrian Government, Department 14 – Water management, resources and sustainability – Hydrography, Graz, Austria

The discharge measurements in rivers and open channels are one of the key tasks of the Hydrographical Service in Styria. Approximately 130 flow gauges are part of the monitoring net with about 800 discharge measurements per year. These are carried out during the operational work in order to calculate rating curves. In the last few years, there has been a rising demand to use ADCP technology also in smaller rivers. Some new instruments based on this technology were developed. One of them is the so called "AquaProfiler" (Seba Hydrometry in Kaufbeuren, Germany), which has the big advantage in contrast to the current meter, that the flow velocity in the verticals is not measured in points but as a whole profile. In this paper, the results of comparison measurements between current meter, ADCP and AquaProfiler as well as the advantages and problems of all systems are shown.

Keywords: discharge measurements, current meter, ADCP technology

1 INTRODUCTION

The Hydrographical Service of the Office of the Styrian Government (HD Steiermark) operates a monitoring network of about 130 flow gauges covering rivers with catchment areas between ~ 5 and 10.000 km². At these gauges, water level data are recorded and stored continuously. To calculate discharges as a basis for all water management issues, rating curves have to be built for all gauges. Based on the Austrian Water Law, a minimum of 6 discharge measurements per gauge and year have to be performed. Therefore around 800 discharge measurements have to be made each year.

2 HISTORY OF DISCHARGE MEASUREMENTS IN STYRIA

The first discharge measurements in Styria were performed in the 1950's using current meter devices. From this time till 2005, the current meter was the standard instrument. With the development of the Accoustic Doppler Current Profiler (ADCP) – technology, Styria was one of the first states in Austria using this method operationally as complementary device for shallow rivers. The Rio Grande (RD Instruments) type has been used since 2005 and the Stream Pro (RD Instruments) type since 2007.

In the last years, the Hydrographical Service of Styria tried to find alternative instruments for discharge measurements in small rivers, where both ADCPs can't be used due to their restrictions in needed minimum water levels (about 30 cm, for Stream Pro; about 60 cm for Rio Grande). Therefore, some test measurements with different instruments have been performed. This paper presents first results of measurements with the "Aqua Profiler" (Seba Hydrometrie) compared to current meter measurements.

3 INSTRUMENTS FOR DISCHARGE MEASUREMENTS

In the following, instruments used by the Hydrographical Service in order to perform discharge measurements will be described.

3.1 Current meter

As already mentioned in chapter 2, the current meter is the traditional instrument for discharge measurements, not only in Styria, but in the whole world. In Styria, current meters are used mainly on the rod but also on cableways (see fig. 1)., although more or less replaced by ADCP instruments. The performed measuring method (Kreps - method) is a 2-point measurement developed by Kreps and exclusively used in Austria [1]. Similar to the "American method", where the velocities in 80% and 20% of the water depth are used to calculate the mean velocity per vertical, the Kreps method uses the velocities near the surface (v_0) and 38% of the depth ($v_{0,38}$) using the following equation [1]:

$$v_m = 0.31v_0 + 0.634v_{0,38} \qquad [1]$$

3.2 ADCP instruments

The origin of the ADCP technology lies in oceanography. Around 2000, also the hydrographical sector recognized the advantages offered by this measuring method. Compared to the point measurements of the current meters, the big advantage of the ADCP method is that flow velocities and water levels are measured continuously through the whole cross profile. A description of the ADCP technology can be found in Adler and Nicodemus [2].

In Styria, two different types of ADCPs (both from

RD Instruments) are used: RDI Rio Grande for the bigger rivers, mainly for gauges equipped with cableways, where a minimum water level of about 60 cm is given and RDI Stream Pro for rivers with a minimum water level of about 30 cm.

The big advantage of Stream Pro in comparison with Rio Grande is that there are relatively few parameters (max. water depth, max. water velocity, number of cells, profiling mode, bottom tracking mode) which have to be fixed before the measurement. Fig. 2 shows the Rio Grande and Stream Pro instruments in action. Detailed specifications to both instruments can be found under http://www.seba-hydrometrie.com/fileadmin/files/05_Hand_Mobile Geraete/B25_Mobile_ADCP-Systems_e_S1-8_%26.pdf

3.3 *"AquaProfiler"*

As already mentioned in chapter 2, the aim of HD Styria in the last years was to find alternative methods of discharge measurements combining the advantages of the current meter and the ADCP technology. In this way, different instruments were tested and compared with the existing methods. The so called "AquaProfiler" (Seba Hydrometry) showed the best performance using ADCP technology.

The "AquaProfiler" sensor can be used on the rod as well as on cableway devices. Its big advantage is that the flow velocity in the verticals is unlike the current meter not measured in points but delivered as a 2-D flow profile.

Details of the instrument can be found under http://www.seba-hydrometrie.com/fileadmin/files/05_Hand_Mobile Geraete/B06_AquaProfiler-M-Pro_mobile_e_S1-4_%26.pdf

4 COMPARISON OF THE RESULTS OF DIFFERENT DISCHARGE MEASUREMENT INSTRUMENTS

The following chapter presents the most important results comparing the different methods and instruments for discharge measurements and highlights the advantages of each method.

4.1 Comparison between different measuring methods for current meters

As already mentioned in chapter 3, in Styria current meter measurements are performed as 2-point measurement based on the method of Kreps [1]. There is an ongoing discussion on expert level whether the accuracy of 2-point measurements is satisfying compared to multipoint measurements. Therefore comparison measurements were performed at 4 gauging stations using different numbers of verticals and different numbers of measuring points in the verticals.

Table 1 shows the results of the discharge measurements using different numbers of points at gauge Schwanberg/Sulm as example (the results for the other gauges were very similar). The differences between the different methods are very small, leading to the conclusion that the accuracy of 2-point measurements is satisfying compared to multipoint measurements if the cross profile is homogenous, which is the case for gauging stations.

In table 2 the results (gauge Schwanberg/Sulm) are shown using different numbers of verticals and different numbers of measuring points in the verticals. The differences in the discharges are minimal also in this case and therefore one can conclude that in homogenous cross profiles it is sufficient to use about 10 verticals and 2 points in each vertical. In inhomogenous profiles, the experiences have shown that the accuracy of the measurements rather depends on the number of verticals and not on the number of measuring points in the vertical.

4.2 Comparison between current meter and ADCP instruments

The comparison measurements between the ADCP instruments and the current meters were mainly performed with the Stream Pro method due to the fact that about 70% of the gauges in Styria are situated at more or less shallow rivers. Nevertheless, some comparisons were made at the cableway stations at bigger rivers mainly using the Rio Grande instrument.

In summary, the results in measured discharges are very similar in homogenous cross profiles (differences max. ±5%), because the big advantage of the ADCP method of continuously monitoring velocity and water level is not as relevant as in inhomogenous profiles.

Another advantage of the ADCP technology is that also backwater zones can be measured since negative velocities can be integrated.

Despite the advantages of the ADCP method, some problems occurred as summarized below:

- Problems in getting reliable results for rivers with higher velocities than ~ 3 m/s
- The use of Stream Pro is limited by a sediment transport of ~ 1 g/l
- For Rio Grande it is very important to find the right measuring parameters as varying from river to river and having an important influence to the accuracy of the measurement. These experiences were also made when ADCP comparison measurements, were performed in Austria in 2010 and 2012 [3]

- Under moving bed conditions (sediment transport on the riverbed), the moving boat method (continuous measurement) cannot be used. Alternatively, the section by section method has to be chosen, where flow velocities are measured only in verticals

4.3 Comparison between current meter and "AquaProfiler"

As already mentioned, a relatively high percentage of gauges in Styria does not allow the use of the ADCP instruments Rio Grande and Stream Pro, as below the required minimum water levels of about 30 cm (Stream Pro). At these gauges, the discharge measurements are still performed using current meters with all their advantages and problems mentioned above.

For this reason, the Styrian Hydrographic Service tried to test different instruments based on the same method as the current meter (measuring flow velocities only in points). The only instrument combining the philosophy of current meter and ADCP technology was the so called "AquaProfiler" (see chapter 3.3).

In the testing phase of the "AquaProfiler" about 20 measurement comparings with the current meter were performed. In the first version of the "AquaProfiler" many problems in the measurement of the velocities in the verticals occurred, where the main problem was the correct signal processing for generating the mean velocity. After the correction of this error, the second version allows very accurate velocity profile measurements. The big advantage is that also in inhomogenous cross profiles reliable vertical velocity profiles can be measured. Furthermore, the online visualization of the measurement as a whole - including the vertical and horizontal velocity profiles, the water levels and the actual discharge - is possible (Fig. 4).

In Fig. 5, some typical results of the comparison measurements between current meter and AquaProfiler can be seen. The figures show flow velocity profiles of the Aqua Profiler (blue lines) compared with point velocities of the current meter (red dots). Generally, in the littoral zones (vertical 1 or vertical 9), there are more differences in the velocities especially near the surface of the water. In the central zones of the rivers, a more or less very good correlation has shown. Generally, the differences in the discharges between Aqua Profiler and current meter for the performed measurements lies in a very narrow range of about ±5%, whereas the difference in the measured velocities can increase up to ±30% especially in the littoral zones.

As the blanking of the "Aquaprofiler" (the zone where no velocities can be measured due to restrictions in the ADCP technology) is very small (about 2 cm) and the height of the transducer is about 5 cm, even rivers with minimum water levels as low as 10 cm can be measured.

The only problem detected so far in the present version 2 of this instrument is that only measurements from the bottom to the top can be performed, which can be problematic in the case of graveled river bed. Since the body covering the ADCP sensor is relatively big, the water level cannot be measured accurately when bigger stones lie in the riverbed. This problem should be solved in version 3. Then, this instrument should be a perfect device combining the advantages of current meter and ADCP technology.

4.4 Tables

Table 1: Comparison between different numbers of measuring points and difference to the 2-point Kreps method using 10 verticals (gauge Schwanberg/Sulm) .

method	Q (m^3/s)	Difference (%)
1 point	3.66	1.4
2 point Kreps	3.61	
2 point amer.	3.58	0.8
3 point	3.59	0.6
5 point	3.59	0.6

Table 2: Comparison between different numbers of verticals for different numbers of measuring points in the verticals (gauge Schwanberg/Sulm) .

method	Q (m^3/s) 20 vert.	Q (m^3/s) 10 vert.	difference (%)
1 point	3.57	3.66	2.5
2 point Kreps	3.58	3.61	0.8
2 point amer.	3.55	3.58	0.8
3 point	3.52	3.59	2.0
5 point	3.53	3.59	1.7

4.5 Figures

Figure 1: Current meter on the cableway (left side) and on the rod (right side) (Copyright: Seba Hydrometry)

Figure 2: ADCP RDI Rio Grande (left side) and RDI Stream Pro (right side) (Copyright: Hydrographical Service of Styria)

Figure 3: “AquaProfiler sensor (Copyright: Seba Hydrometry)

Figure 4: AquaProfiler user interface (Copyright: Seba Hydrometry)

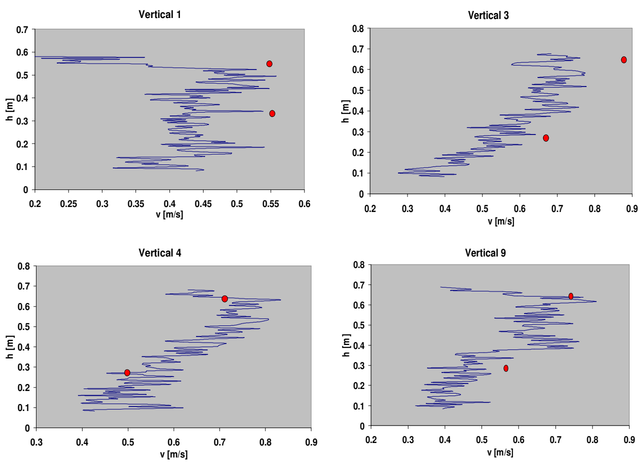

Figure 5: Comparison between flow velocity data from current meter (Kreps method) (red dots) and AquaProfiler measurements (blue line) in different verticals

5 SUMMARY

In the last 10 - 15 years a rapid development regarding discharge measurement instruments has occurred. Up until 2000, the current meter was used more or less exclusively. Once the ADCP technology, originally coming from oceanography, had been discovered for the needs of hydrology, major improvements in the area of discharge measurements were made.

In this paper, the experiences of the Hydrographical Service of Styria using and comparing different instruments for discharge measurement were shown. Summarizing, it can be said, that there is a wide variety of water levels and flow velocities at the operationally monitored gauges of the Hydrographic Service of Styria. Therefore, it’s not possible to measure all gauges only with one instrument. Based on the gained experiences with the different instruments, it was possible to find a good balance in when and where to use which instrument.

In the near future it is expected, that the current meter, despite all its advantages, will be replaced by instruments based on the ADCP technology such as the “AquaProfiler”.

REFERENCES

[1] Kreps H.: Näherungsverfahren bei hydrometrischen Feldarbeiten und ihrer Auswertung; Österreichische Wasserwirtschaft Jahrgang 6, Heft ½, Wien (1954)

[2] Adler, M. & U. Nicodemus (2008): AGILA – Software for the Advanced Evaluation of Discharge Measurements with Acoustic Doppler Current Profilers (ADCPs), Conference “Measurement and Data Processing in Hydrology”, Plitvice Lakes National Park, (2008)

[3] Schatzl R.: Österreichweite ADCP-Vergleichsmessungen am Pegel Hart im Zillertal/Ziller; ; Interne Veröffentlichung, Graz (2012)