International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, 2008. p:271-277

Measuring Water Flow Velocity and Discharge with Acoustic Doppler Velocimeter (ADV)

Ramazan Meral Hasan Değirmenci Cefer Gençoğlan
Adil Akyüz Sertan Sesveren

Kahramanmaras Sutcu Imam University, Faculty of Agriculture, Department of Agricultural Structures and Irrigation Kahramanmaras Turkey, rmeral@ksu.edu.tr

ABSTRACT

The discharge measurement in river is the basis for using of water, planning, designing and operating water management and development projects. The traditional method of measuring the discharge is based on measurement of the water velocity and cross section area. Current meters are commonly used to determine of water velocity but they require calibration at frequent intervals in laboratory flumes to get accurate results. Because cup and propeller equipments of current meters may be physically damaged, especially river conditions. Recently, acoustics velocimeters are increasingly used with the advances in remote sensing and data processing techniques. There are currently several manufacturers of commercial acoustic devices but the general principles of operation are based on the Doppler shift effect which is the difference in frequency (shift) between transmitted pulses and received echoes in water. Acoustics velocimeters provide accurate and economical discharge measurements with simple and fast operation under different flow conditions. The purpose of this paper is to present principles of operation of acoustic Doppler velocimeters with results of field and open channel discharge measurements.

Keywords: Flow rating curve,flow velocity, acoustic, dopplers shift,

INTRODUCTION

Accurate flow and discharge measurement is crucial for an efficient river basin management and especially for flood forecasting and planning and management of water storage structures. The traditional method of measuring the discharge in hydrological practice is to measure the water level and to convert into discharge by using the rating curve, which indicates the relationship between the level and discharge. The rating curve is obtained from direct measurements of discharge, which are done at convenient times with measurements of flow velocities at different points over the gauging cross section. (Sen 2003).

There are different methods to measure of the velocity of water, such as, floating material, chemical gaging, and current meters. Measurement of floating material is a simple method but it can not represent profile velocity of water. Current meters are commonly used which two different types: cup and propeller. Current meters should be recalibrated at frequent intervals in laboratory flumes to get accurate results (Usul 2001).

Recently, with the technological advances, acoustic velocimeters are used to measure water velocity in rivers. (Takeda 2002, Chanson at al., 2008, Yau Lu at al., 2006). Acoustic water velocity measurement has been used since 1980s. The early instruments required deep water (more than 3-4m), which limited their use to deep water river or estuaries. In advanced acoustic Doppler instrument was developed that could be used in sallow waters (Yorge and Oberg 2002). In this study an acoustic instrument and principles of operation are presented with a field measurement results at river and channel conditions.

Principles of Acoustic Velocity Measurement

The difference in frequency (shift) between transmitted pulses and received echoes, known as the Doppler Effect, can be used to measure the relative velocity between the instrument and suspended material in the water that reflects the pulses back to the instrument. The acoustic Doppler profiler uses the Doppler Effect to compute a water velocity component along each beam (Kostaschuk et al. 2005)

$$F_D = 2F_S(V / c)$$

Where;

F_D : change in received frequency

F_S: frequency of transmitted sound

V: velocity of source relative to receiver, represents the relative speed between source and receiver (motion that changes the distance between the two).

c: speed of sound

There are different types of acoustic velocimeter and sensors. Although they have different geometric configuration, transducer characteristics, emitting and measuring frequency, etc., they share the same principle and similar properties. The FlowTracker Handheld ADV (Acoustic Doppler Velocimeter) is designed for a variety of current monitoring applications. (Fig.1). The FlowTracker can be used for: river discharges measurement, open-channel flow measurement, current measurements in large pipes, multi-point current surveys, and, current monitoring in water treatment facilities. The principles of velocity measurement with this device as fallows (SonTek/YSI Inc, 2007):

- The transmitter generates a short pulse of sound at a known frequency (Fig 3).
- The sound travels through the water along the transmitter beam axis.
- As the pulse passes through the sampling volume, sound is reflected in all directions by particulate matter (sediment, small organisms, bubbles).
- Some portion of the reflected energy travels back along the receiver beam axes.

• The reflected signal is sampled by the acoustic receivers. The receiver sees an increase in signal strength (fig 3).

• The FlowTracker measures the change in frequency (Doppler shift) for each receiver

Figure 1. FlowTracker with 2D probe.

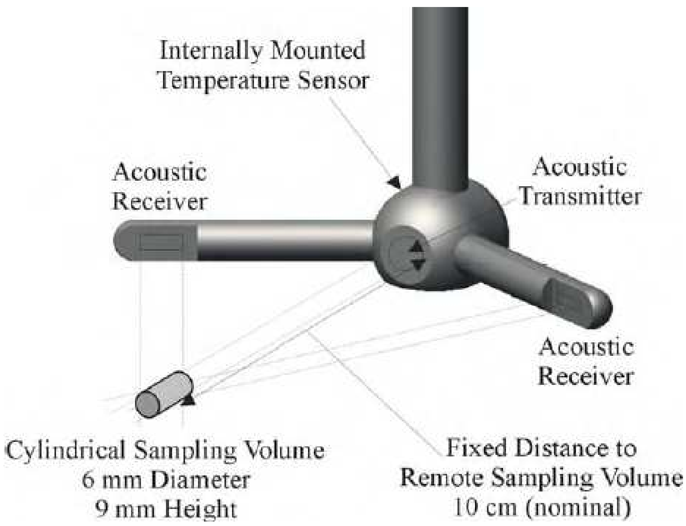


Figure 2. The detail of FlowTraker probe and sampling volume (SonTek/YSI Inc, 2007).

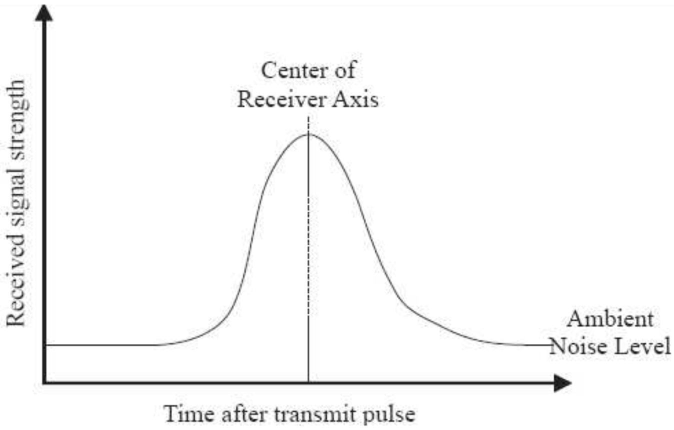
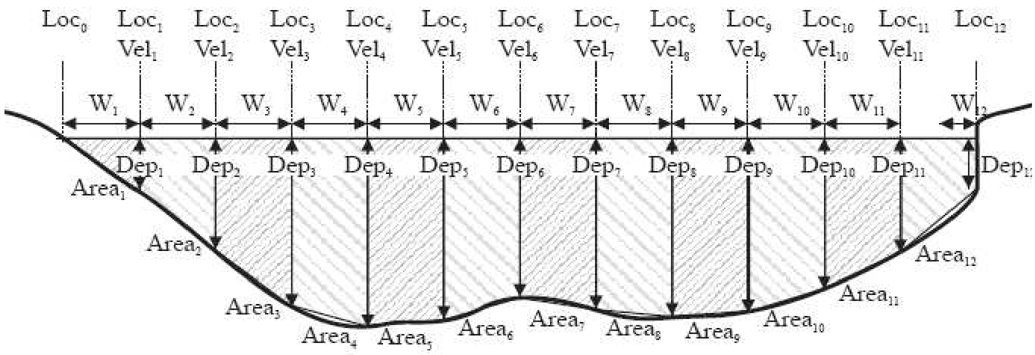


Figure 3. FlowTracker Signal Strength Profile (SonTek/YSI Inc, 2007).

Field Measurements

Field measurements were conducted at river and open channel condition. The average of the velocities at 20% and 80% depth below the water surface is used to estimate the mean velocity in profile. For shallow flow (<50 cm) at 60% depth below the water surface may be used to approximate the mean velocity (Chow, 1959; Usul 2001).In this study flow depth was measured lower than 50 cm and, velocity measurements were taken on 60% depth level. The mean section method was fallowed to calculation discharge calculation with flow depth and velocity values. This method is described in ISO Standard 748 (1992). Figure 4 shows the mean section equation.



i: edge station, j; adjacent station

Station width; $W_i = Loc_i - Loc_{i-1}$;

Station area; $Area_i = W_i * (Dept_i + Dep_{i-1})/2$

Station velocity; $Vel_i = (Vel_i - Vel_{i-1})/2$;

Station discharge ; $Qi = Vel_i * Area_i$;

Total discharge ; $Q = Sum*Q_i$

Figure 4. Mean section discharge equation (SonTek/YSI Inc, 2007)

RESULTS and DISCUSSION

The results of river and open channel discharge measurement with FlowTracker devices were given at Table 1 and 2. In addition, depth, velocity and percentage of discharge values are shown on cross section of river and open channel. Fig (5).

Table 1. FlowTracker discharge measurement summary for river

Units	metric units	Disch. equation		Summary			
Distance : m Velocity : m/s Area : m^2 Discharge : m^3/s		Mean Section		Total Width :20.000 Total Area :5.555 Mean Depth :0.242 Mean Velocity :0.613 Total Discharge :4.206			
Station	Location	Depth	Velocity	Width	Area	Discharge	%Q
0	0	0.000	0.000	0.000	0.000	0.000	0.000
1	1	0.270	0.486	1.000	0.135	0.033	0.780
2	3	0.430	1.043	2.000	0.700	0.535	12.722
3	5	0.460	0.945	2.000	0.890	0.885	21.031
4	7	0.220	0.821	2.000	0.680	0.600	14.274
5	9	0.250	1.058	2.000	0.470	0.442	10.497
6	11	0.180	0.655	2.000	0.430	0.368	8.755
7	13	0.250	0.632	2.000	0.430	0.277	6.578
8	15	0.240	0.586	2.000	0.490	0.298	7.094
9	17	0.380	0.721	2.000	0.620	0.405	9.632
10	19	0.220	0.414	2.000	0.600	0.341	8.095
11	20	0.000	0.000	1.000	0.110	0.023	0.541

Table 2. FlowTracker discharge measurement summary for open channel

Units	metric units	Disch. equation		Summary			
Distance : m Velocity : m/s Area : m^2 Discharge : m^3/s		Mean Section		Total Width :4.400 Total Area :1.783 Mean Depth :0.322 Mean Velocity :1.571 Total Discharge :1.320			
Station	Location	Depth	Velocity	Width	Area	Discharge	%Q
0	0	0	0	0	0	0	0
1	0.350	0.250	0.675	0.350	0.044	0.015	1.119
2	0.700	0.480	0.820	0.350	0.128	0.095	7.238
3	1.450	0.480	0.764	0.750	0.360	0.285	21.610
4	2.200	0.480	0.763	0.750	0.360	0.275	20.833
5	2.950	0.480	0.788	0.750	0.360	0.279	21.160
6	3.700	0.480	0.723	0.750	0.360	0.272	20.614
7	4.050	0.250	0.604	0.350	0.128	0.085	6.424
8	4.400	0.000	0.000	0.350	0.044	0.013	1.001

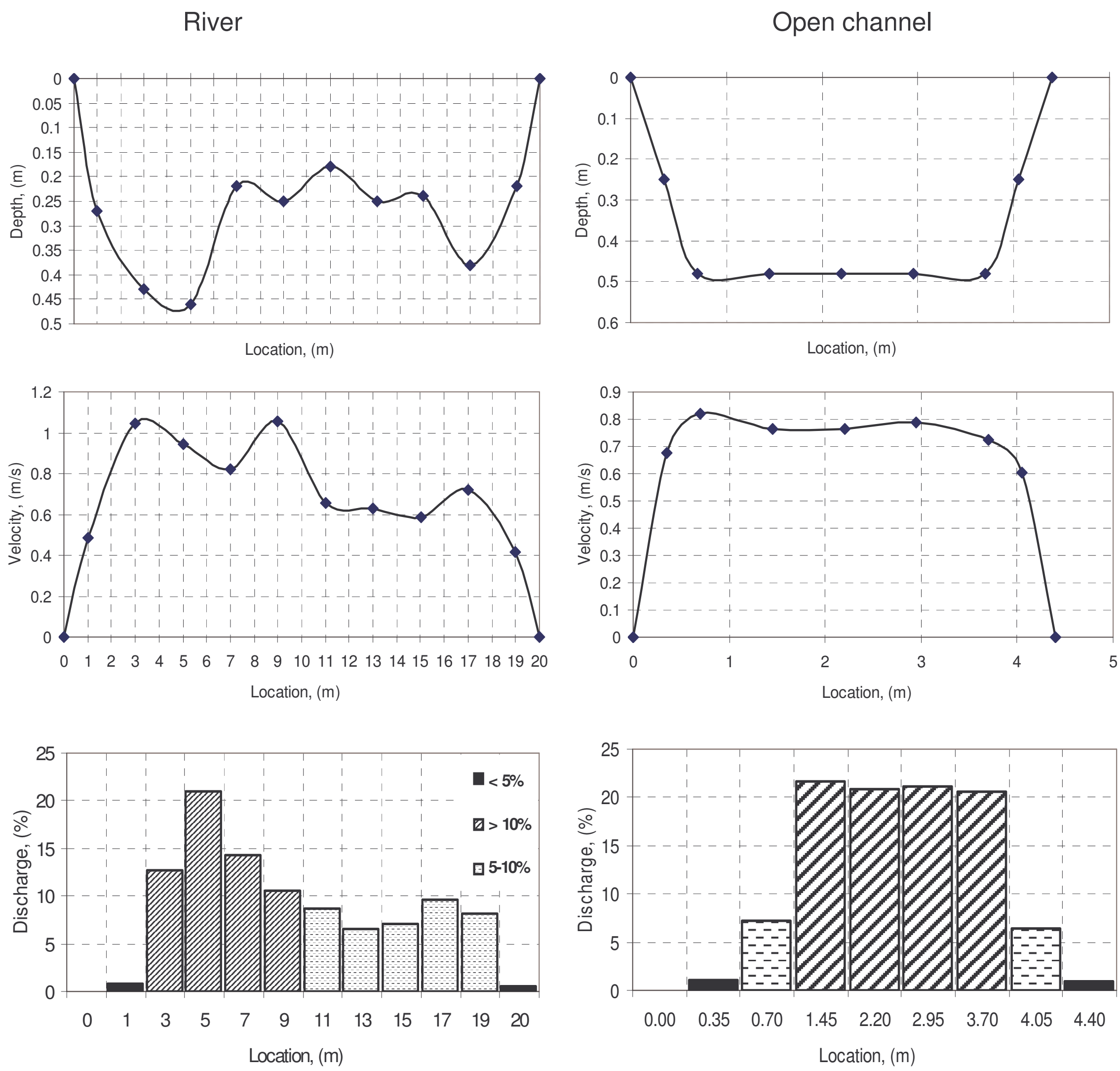


Figure 5. Discharge measurement results on cross section of river and open channel

Acoustic velocimeters provide accurate and economical discharge measurements with simple and fast operation under different flow conditions on rivers and open channel conditions. The other advantage is calibration of devices doesn't change unless the probe is physically damaged and thus periodic calibration is not required. However, water quality and some environmental condition may effect on precisely determine of velocity (Voulgaris at al., 1998; Mueller 2002). It is known that a temperature change of 5^0C or a salinity change of 12 ppt results in sound speed change of ≈1%. Acoustic velocimeters include a temperature sensor and user input value of salinity is used for automatic sound speed correction (SonTek/YSI Inc, 2007). In addition, as with any equipment, the accuracy of velocity and discharge measurements with an acoustic velocimeter depends on the training, skill, and experience of instrument operators. Finally acoustic velocity measurements seem favorable method for continuous monitoring river and open channel discharge studies in future.

REFERENCES

Chanson H, Trevethan, M., Aoki, S., 2008. Acoustic Doppler velocimetry (ADV) in small estuary: Field experience and signal post-processing. Flow Measurement and Instrumentation, 19(5), 307-313 Chow VT. 1959. Open Channel Hydraulics. New York: McGraw-Hill Book Co.

ISO standards 748 , 1992. Measurement of liquid flow in open channels --Velocity-area methods.

Kostaschuk, R., Best, J., Villard, P., Peakall, J, Franklin, M., 2005. Measuring flow velocity and sediment transport with an acoustic Doppler current profiler. Geomorphology , 68, 25–37

Mueller, D.S., 2002. Use of acoustic Doppler instruments for measuring discharge in streams with appreciable sediment transport, in: Proceedings of Hydraulic Measurements and Experimental Measurements, American Society of Civil Engineers, Estes Park, CO.

Sen, Z., 2003. Su Bilimi ve yöntemleri, Su Vakfı Yayınları, (in Turkish).

SonTek/YSI Inc, 2007., FlowTracker, Handheld ADV, Technical manual. SonTek/YSI Inc, USA.

Takeda Y. Ultrasonic Doppler method for flow measurement. In: International symposium on advanced fluid information. 2002. p. 69–76.

Thomas H. Yorke , Kevin A. Oberg. Measuring river velocity and discharge with acoustic Doppler profilers, Flow Measurement and Instrumentation, 13, 191–195 (2002)

Usul, N., 2001. Engineering Hydrology., METU Press.

Voulgaris G, Trowbridge JH.1988. Evaluation of the acoustic doppler velocimeter (ADV) for turbulence measurements. Journal of Atmospheric and Oceanic Technology; 15:272–89

Yau Lu, J., Chiang Su, C., Yi Wang, C., 2006. Application of a portable measuring system with acoustic Doppler current profiler to discharge observations in steep rivers. Flow Measurement and Instrumentation, 17,179–192