Comparative testing of water level and flow velocity sensors in natural conditions

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Abstract

Only 20 or 30 National Hydrological Services out of 189 WMO member countries have well developed networks of the newest hydrometric instruments and measurement techniques established over the last few decades. In the other countries, these techniques are still on trial or measurements are made by conventional methods.

Russian Federation (Federal Service of Russia for Hydrometeorology and Environmental Monitoring (ROSHYDROMET) within the framework of the project "Upgrading and re-equipment of ROSHYDROMET institutions and organizations" started to upgrade its hydrological network and test various techniques and methods for measuring water levels and flow velocities in the rivers. The purpose of the tests was to find the best technical solution to upgrade hydrological observational system in the flood regions of Russia.

Shaft encoders, pressure and bubble sensors, radar sensors and acoustic Doppler current profilers (ADCP) for measuring discharge and flow velocity were tested.

The tests were carried out in the Lower Kuban river at the Temriuk gauge. The width of the river at the test site was 60 m, the discharge about 300 m³/sec. Good precision of measurements by means of level sensors was revealed. The water discharge readings obtained using ADCP were within ±7% of the discharge measured by the current meters.

Introduction

In 2006 Federal Service of Russia for Hydrometeorology and Environmental Monitoring (ROSHYDROMET) started to implement the project "Upgrading and re-equipment of ROSHYDROMET institutions and organizations".

The hydrological component of the project is aimed at improving quality and extending the volume of information on current hydrological conditions used by ROSHYDROMET in producing forecasts.

The project involves activities on adaptation of advanced means of measurement, automated measurement systems and other technical means of performing observations in accordance with WMO standards, on-line transmission of the results of observations, data assimilation in prediction models and data directory, and collection of data in the State Water Cadastre.

Comprehensive analysis of the present state of the hydrological network, WMO technical regulations, state-of-the-art of the observational practices, re-equipment funding and the number of qualified hydrologists provide principal directions for technical re-equipment of the hydrological network.

Well developed hydrological network provided with advanced professional equipment and providing uniformity and consistency of the observational techniques applied at the ROSHYDROMET network with advanced techniques for discharge and level measurements applied by leading manufacturers of hydrological equipment is necessary to perform the task.

Comparative testing of the techniques for level and discharge measurements applied by leading manufacturers of hydrological equipment and standard means adopted by ROSHYDROMET was carried out on the Kuban river, Temriuk gauge, 16 May-6 June, 2007. The OTT, SEBA and RDI devices were tested.

Technical means and techniques used in tests

Stationary staff gauge GR-4 with points value 2 cm and digital float level gauge UPC transmitting current value of water level in digital form to a recorder were used as base means of measuring water level applied at the ROSHYDROMET network. Discharge measurements were carried out at regular intervals by standard methods making use of current-meters. Six discharge measurements were performed during the tests.

Level gauges of four types (shaft encoder, pressure, bubble and radar sensors) were submitted for testing: shaft encoder MDS "Surfloat" manufactured by SEBA, pressure sensors MDS Dipper II (SEBA) and OPS-1 (OTT), bubble sensors PS-Light, PS-LCD (SEBA) and Nimbus (OTT), radar sensors SEBAPULS (SEBA) and Kalesto (OTT).

Shaft encoders were set in tubes of a small diameter (150-300 mm) to compensate for the influence of wind-induced waves and waves generated by river vessels. The detecting elements of the pressure and bubble sensors were located either directly in the stream or in the tubes of a small diameter. Radar sensors were fixed on a bracket about 2 m above water level (Fig.1, 2).

Figure 1: Installation of shaft encoders

Figure2: Installation of a radar sensor

Automated flow velocity measurements were performed making use the acoustic Doppler stationary current profiler SLD supplied by the OTT company. Flow velocity sensing units were mounted on a light, specially manufactured frame fixed on a quay wall at the gauge site. Measurements were carried out in three stream segments 10 m from the sensor.

Data on water level and flow velocity were collected in the data acquisition, processing, storage and transmission unit (MDS 5 COM, UniLog – SEBA and LogoSens 2, DuoSens - OTT) and transmitted to data centers by GSM communication line. Data processing was supported by DEMAS (SEBA) and HYDRAS 3 (OTT) programs.

Figure 3: Arrangement of an automated gauge

The results of water level measurements from all the sensors were compared with those from digital float level gauge UPC (Russia) located in a well damped portable well.

The acoustic Doppler profiler StreamPro ADCP (RDI) supplied by the SEBA company was tested as a device for water discharge measurements. Water discharge measurements were carried out at the estuary of the Petrushin arm, the Kuban river, in three branches not more than 4 m deep.

Results of comparative testing

Figure 4 represents the results of measuring water level by the pressure and bubble sensors manufactured by the OTT company. The results were processed by the HYDRAS 3 program.

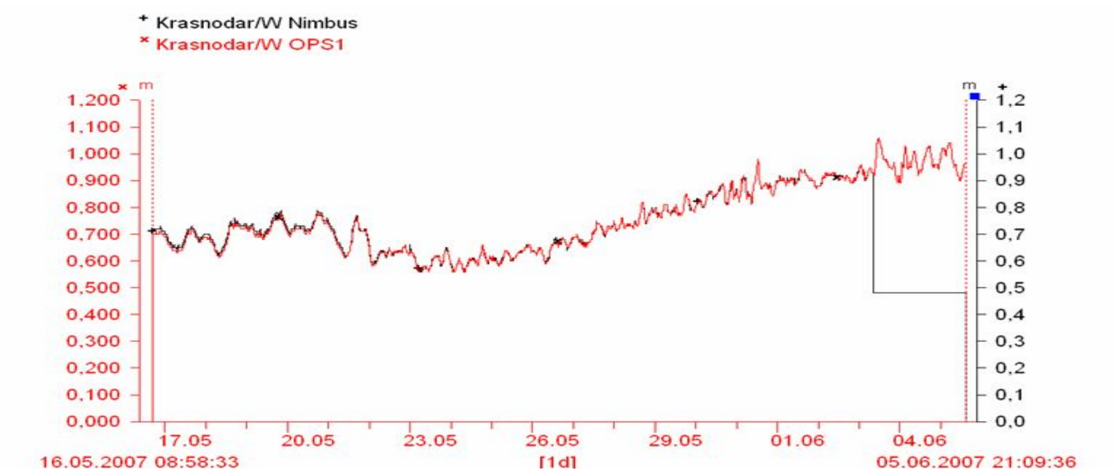

Figure 4: Values of water level from pressure (OPS1) and bubble (Nimbus) sensors (OTT).

Data from the sensors manufactured by the SEBA company was processed by the DEMAS program.

Table 1 contains deviations (average, root-mean-square, maximum) of water levels measured by the sensors tested from those measured by the standard level gauge UPC.

	SEBA					OTT		
	Surfloat	Dipper	PS Light	PS LCD	Sebapuls	OPS-1	Nimbus	Kalesto
Average deviation, cm	-0,7	0,9	0,2	0,1	0,0	-0,7	-0,3	-0,7
Root-mean-square deviation, cm	1,1	0,9	0,8	1,0	1,1	0,7	0,5	1,1
Maximum deviation, cm	14	6	6	7	12	2	2	6

Table 1: Average, root-mean-square and maximum deviations of values measured by the sensors tested from those measured by the standard level gauge UPC applied at the ROSHYDROMET network.

Water discharge was computed by the data from the acoustic Doppler stationary profiler (SLD) and the portable Doppler profiler from catamaran (StreamPro ADCP).

Figure 5 represents average velocities in the three segments as measured by the stationary profiler SLD and the discharges computed making use of the HYDRAS 3 program.

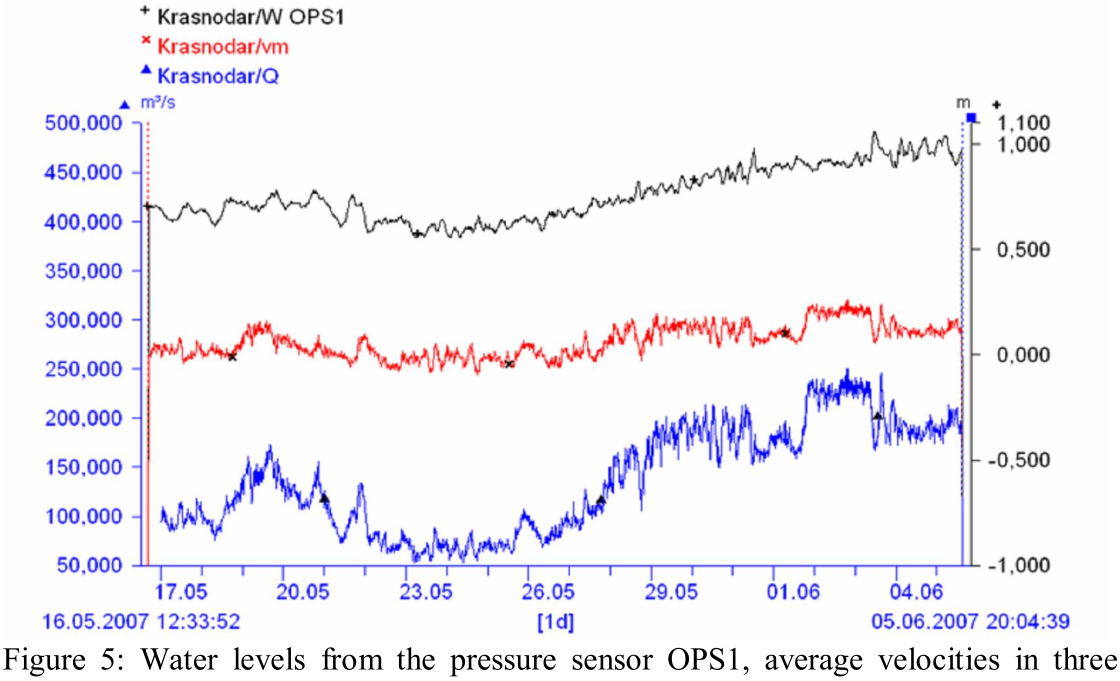

Figure 5: Water levels from the pressure sensor OPS1, average velocities in three segments and the discharges computed at the Temriuk gauge.

The velocities obtained were compared to the water level in order to reveal the dependency of the average flow velocity on water level at the gauge site at the SLD operating depth. The dependency considered is represented in the Fig. 6

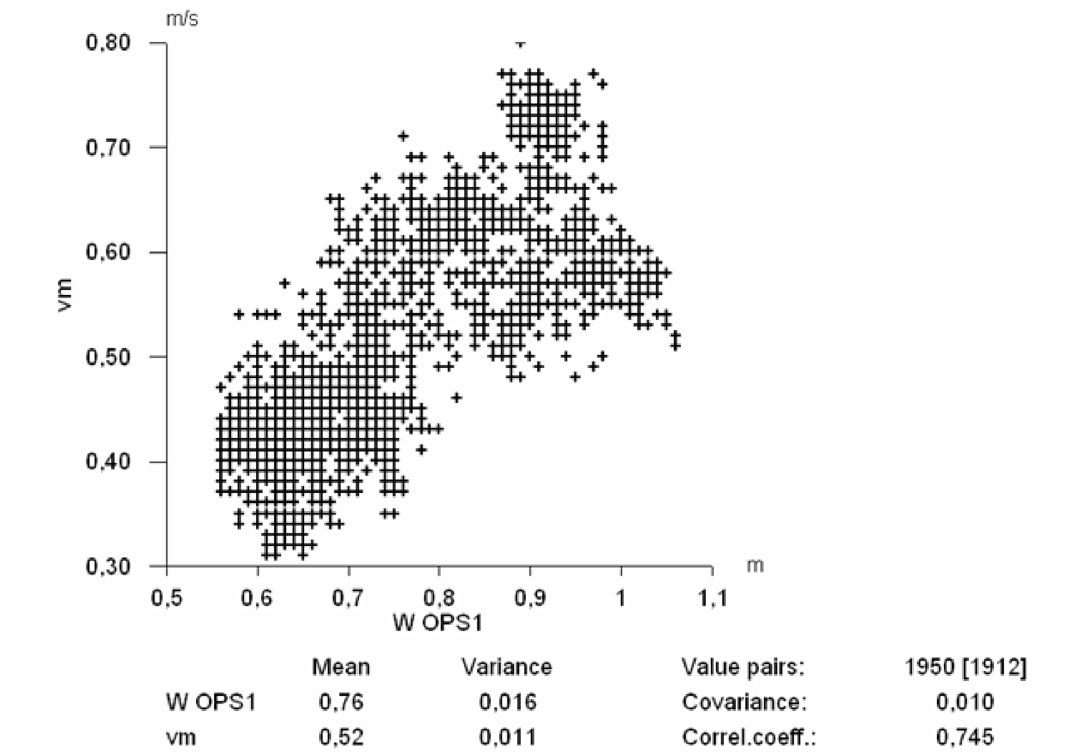

Figure 6: Dependency of average flow velocity measured by acoustic profiler SLD on water level.

Water discharge was measured by the portable Doppler profiler from catamaran (StreamPro ADCP) at the estuary of the Petrushin arm, the Kuban river, in three branches, and was different from the one measured by current meters by 7 %.

Summary and conclusion

Water level measurements

All the sensors tested revealed average deviation within 1 cm, which is within normal for water level measurement as recommended by WMO.

Root-mean-square deviation of the levels measured was also less than 1.1 cm, which provides ±3 cm precision of current measurements at a confidence coefficient 95%. This precision may be considered satisfactory for measurements in open water conditions without any dampers.

Maximum deviations were 12-14 cm for not averaged measurements performed without any shelters. This was the case for the shaft encoder and radar sensors SEBA which were not sheltered from wind-induced waves and waves generated by passing and mooring vessels.

Deviations of data from all the devices tested from the standard measurements by the float gauge UPC and the staff gauge applied at the ROSHYDROMET network appeared insignificant and in accordance with WMO technical regulations.

On the whole, this gives grounds to conclude that the changeover to measuring water level with pressure, bubble and radar sensor would not affect the consistency and comparability of water level measurements at the ROSHYDROMET network.

Flow velocity and discharge measurements

Flow velocity measurements with stationary acoustic profiler and using this data for computing water discharge are feasible for gauges with a complex dependency of discharge upon water level. This technique is applied at gauges with changes in water level caused by nonsteady flow and backwater- and surge-induced changes in water level not associated with changes in water content or discharge. In such conditions, it is possible to use data on flow velocity in combination with data on water level to compute real-time discharge in complex runoff recording.

Flow velocities from SLD obtained at the Temriuk gauge, the Kuban river, indicate a complex dependency of water level on average velocity at the operating depth with correlation coefficient 0.75 (Fig.6). As this data suggests a complex dependency of discharge on water level, data on flow velocity may increase the precision of calculating discharge and runoff recording.

Figure 5 represents time changes of the discharge plotted with account of changes in SLD velocities at the operating depth.

Discharge measurements with portable acoustic profiler StreamPro ADCP are the most efficient with the gauges where the installation of the stationary profiler is impossible. They had a satisfactory precision (7%).

On the whole, the comparative discharge measurements with stationary and portable profilers performed on the Kuban river are yet not enough for reliable determination of their possible inaccuracy and field of application. Further tests in various conditions and at various sites are necessary.