United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

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July 19, 2013

Memorandum

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM 2013.04

SUBJECT: Validation of new ADCPs and their use in Water Programs

The USGS, Office of Surface Water (OSW) previously validated the use of Rio Grande, StreamPro, and Broadband ADCPs for streamflow measurements (Oberg and Mueller, 2007 and Morlock, 1996). Three new ADCPs, the SonTek M9 (M9) and SonTek S5 (S5), and the Teledyne RD Instruments (TRDI) RiverRay, began to be used in USGS Water Mission Area (WMA) programs in 2009. Since that time, OSW and USGS Water Science Centers (WSCs) have been conducting field validation measurements with these new ADCPs. The OSW required each WSC to make comparison measurements over the range of operating conditions in which the new instruments were used until sufficient measurements were available and analyzed. The purpose of this memo is to document the results of our analyses of M9, S5, and RiverRay ADCP validation measurements.

Validation Measurement Data

Because collection of sufficient field validation measurements for making statistical comparisons is both time consuming and expensive, the OSW created a system to assemble and store field validation measurements. Data are submitted via a Web portal to the Hydroacoustic Testing SharePoint site, allowing OSW to effectively and efficiently compile and share hydroacoustic instrument evaluation data. To date, USGS and cooperating agency personnel uploaded 329 M9, S5, and RiverRay validation measurements to this SharePoint site. Figure 1 shows the states from which the validation measurements were submitted. Some validation measurements were submitted by international agencies as well.

As data were being collected, they were periodically analyzed, allowing OSW to identify deficiencies in the new ADCPs and associated software. ADCP manufacturers responded by correcting deficiencies in firmware and (or) software and introducing new features. An example of how changes in firmware/software for M9/S5 ADCPs altered validation measurement results is shown in Figure 2. Early versions of M9/S5 firmware (e.g. firmware 0.8x) had greater variability and were biased as compared to more recent firmware versions (2.00+).

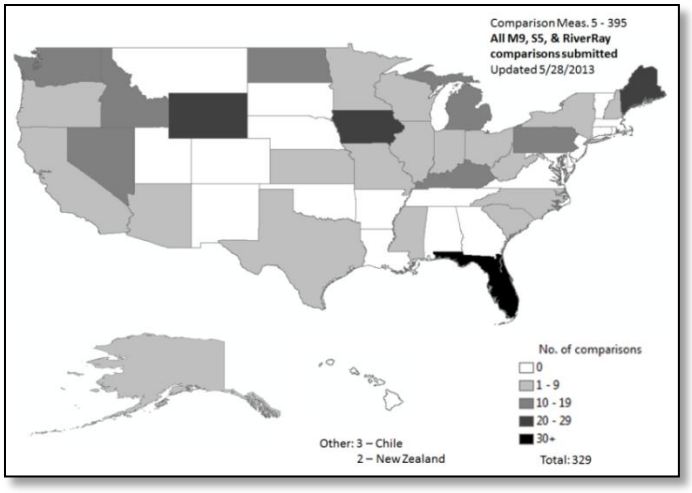

Figure 1. Number of validation measurements and the state in which they were collected.

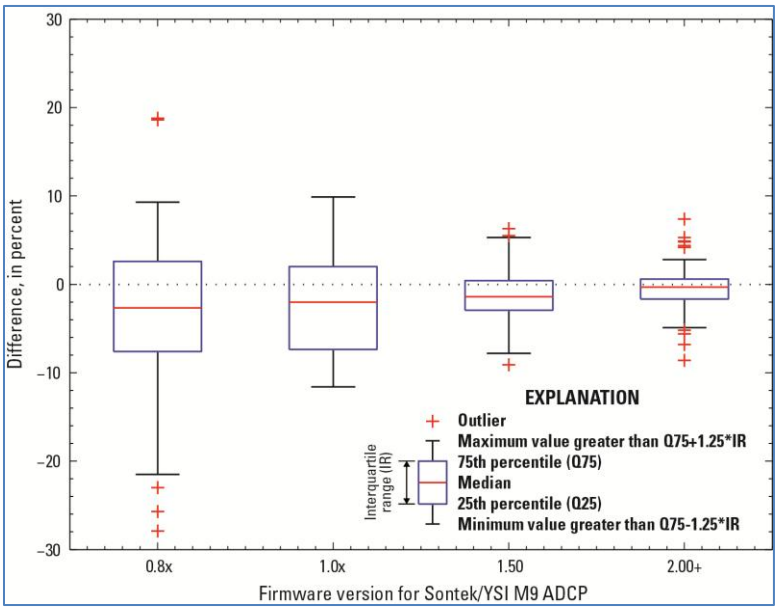

Figure 2. Boxplots showing changes in validation measurement accuracy for SonTek M9 ADCP firmware versions.

Presently (May 2013), 68 M9/S5 validation measurements using firmware 2.00 or later and 56 RiverRay validation measurements using bottom track (BT) for the boat velocity reference are available for analysis. For the SonTek M9/S5 validation measurements, GPS reference data were often collected in conjunction with bottom-track reference data. Two independent GPS reference velocities were available, GGA, a position-based GPS reference, and VTG, a Doppler-based GPS reference velocity. For the M9/S5 validation measurements, 47 GGA-referenced and 49 VTG-referenced validation measurements were available for analysis.

Results of ADCP Validation Data Analysis

The median and the standard deviation of the percent differences between M9/S5-measured discharges and the discharge measured using the reference instrument are shown in Table 1 for each velocity reference (BT, GGA, and VTG). Statistical analysis indicates that there is

no significant difference between M9/S5-measured discharges and the reference discharges. A similar conclusion can be made for the RiverRay validation data.

Table 1. Median, mean, and standard deviation of differences in ADCP-measured discharges and reference discharges.

ADCP	ADCP Boat Velocity Reference	Percent Difference		
		Median	Mean	Standard Deviation
SonTek M9/S5	BT	-0.3	-0.4	2.7
SonTek M9/S5	GGA	-1.0	-0.7	3.5
SonTek M9/S5	VTG	-0.5	-0.6	3.7
TRDI RiverRay	BT	0.3	0.7	3.4

These data and analyses indicate that measurements made with the M9/S5 using firmware 2.00 or later or the RiverRay are unbiased and can be used to make discharge measurements in the USGS WMA streamgaging program. Therefore, it is no longer required that WSCs make comparison measurements covering the range of conditions. However, in the case of the M9 and S5, there are some important considerations for future measurements.

Fifteen percent of the M9/S5 validation measurements submitted to the Hydroacoustics Testing SharePoint site with a BT reference had serious quality issues and were therefore excluded from the final analyses. Since these quality issues were not documented in the submission, it is likely that many of these problems were not noticed by the hydrographers submitting them. The quality issues associated with the excluded measurements are shown in Figure 3.

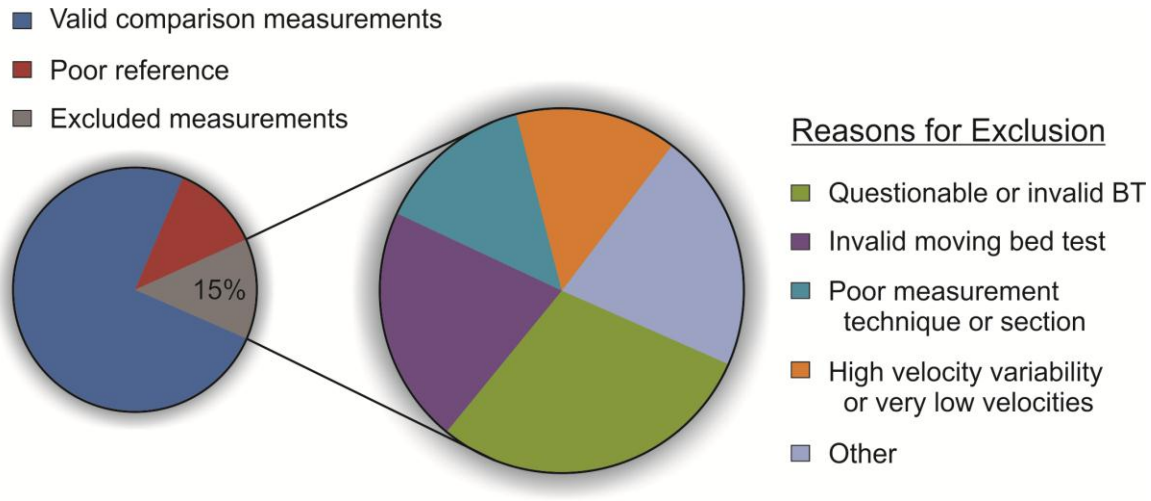

Figure 3. Quality issues associated with excluded SonTek M9 validation measurements.

If the measurements with these quality issues had not been excluded, statistical analysis indicates that the M9/S5-measured discharges would be biased low relative to the reference discharges. Therefore careful review of M9/S5 data is critical to achieving unbiased discharge measurements of acceptable quality. No RiverRay validation measurements were excluded from analysis except those that were expressly obtained to document a known, previously-identified issue.

OSW is continuing to work with SonTek to resolve documented deficiencies in the compass calibration technique employed in the M9/S5 ADCPs. Because loop moving bed tests and use of GPS requires accurate compass calibration, hydrographers should pay close attention to obtaining valid compass calibrations. See "Best Practice for Calibrating RiverSurveyor M9/S5" available at http://hydroacoustics.usgs.gov/. Until the M9 and S5 compass calibration issues are resolved, OSW recommends that stationary moving bed tests (SMBTs) be performed instead of loop moving bed tests. Presently, OSW requires a minimum of 1 SMBT in order to detect a moving bed condition. However, if a moving bed condition is detected, a minimum of 3 SMBTs are required in order to correct for the moving bed condition, if GPS is not used as the boat velocity reference.

Based on these analyses and other work, WMA staff should begin to use up-to-date firmware and software versions for the M9/S5 and the RiverRay. The required minimum firmware and software versions for M9 and S5 discharge measurements in the WMA are firmware version 3.0 and RiverSurveyor Live version 3.50. For RiverRay ADCP measurements, the required minimum firmware and software versions are 44.15 and 2.10, respectively. The firmware and software upgrades should be implemented no later than September 30, 2013, though OSW recommends that these changes be implemented as soon as is practical. For more information on firmware and software versions, please go to the Hydroacoustics Software and Firmware page.

OSW will continue to evaluate ADCP performance and encourages WSCs to conduct and submit additional field comparison measurements. We also encourage the submission of reports of specific problems or failures related to these ADCPs as well as other acoustic instruments. Questions or comments about the policies and guidance in this memo should be directed to Kevin Oberg (kaoberg@usgs.gov) or the OSW Hydroacoustics Work Group.

/signed/

Robert R. Mason, Jr.
Deputy Chief, Office of Surface Water

References Cited

Morlock, S.E., 1996, Evaluation of acoustic Doppler current profiler measurements of river discharge: U.S. Geological Survey Water Resources Investigation Report 95–4218, 37 p.

Oberg, K.A., and Mueller, D.S., 2007, Validation of streamflow measurements made with acoustic Doppler current profilers: Journal of Hydraulic Engineering, v. 133, no. 12, p. 1421–1432.

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