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

In Reply Refer To:
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November 18, 2013

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM 2014.02

SUBJECT: Policy on Required Minimum Screening Distance for the RiverSurveyor M9

This memorandum establishes a minimum screening distance of 0.52 ft (16 cm) from the bottom of a SonTek RiverSurveyor M9 acoustic Doppler current profiler (ADCP) that must be used to ensure unbiased data and provides instructions on how to apply this policy in the RiverSurveyor Live software.

Recent review of comparison measurements assembled by the USGS for the purpose of evaluating the M9 and S5 showed a negative bias in velocities measured near the water surface (transducer) for the M9 when data were collected with the 3 MHz beams in HD mode (water velocity < 1.3 ft/s (0.4 m/s) and depths < 4.9 ft (1.5 m)). Through analysis of field measurements and numerical modeling it has been confirmed that velocities measured by RiverSurveyor M9 within 0.49-0.66 ft (15-20 cm) of the transducers are negatively biased by the flow disturbance caused by the ADCP and its deployment platform (Appendix A). The negative bias caused by the flow disturbance around an ADCP is described in Mueller and others (2007). Although the negative bias can be observed visually in data collected with the 3 MHz beams in the HD mode, this bias is present in all of the operating modes and frequencies, but is either hidden by the larger cell sizes or reduced by larger blanking distances for the 1 MHz beams. If the whole cross section were measured using the 3 MHz HD mode and a constant extrapolation were used to estimate the unmeasured area at the top of the profile, this bias in measured velocity would result in a measured discharge that is negatively biased by between 1.3 and 6 percent depending on transducer depth and the depth of flow. The M9 automatically changes frequency and profiling modes during a measurement, based on velocity and depth of flow. Therefore, in order to minimize the potential bias in discharge measurements made with a RiverSurveyor M9 it is necessary that the screening distance in RiverSurveyor Live (RSL) be set so that all data within 0.52 ft (16 cm)

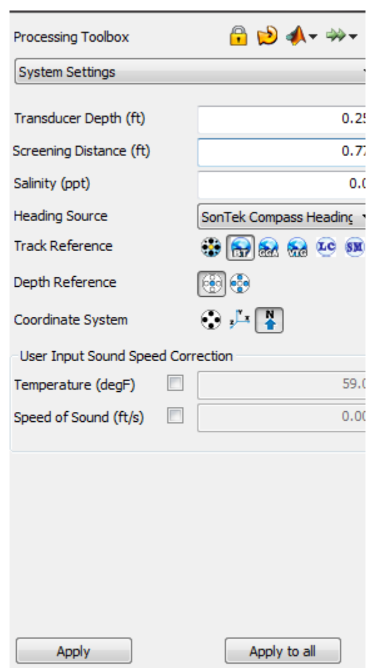


Figure 1. Example of entering Screening Distance in RiverSurveyor Live.

of the transducer are marked invalid and not used for computing discharge or documenting velocities. Although documentation for RSL indicates that the screening distance is the distance from the bottom of the transducer, all currently released versions of RSL apply this screening distance from the water surface. Therefore, the screening distance must be set to the transducer depth plus 0.52 ft (16 cm). For example, if the transducer depth was 0.25 ft, a value of 0.77 ft (0.25+0.52) would be entered for the screening distance (figure 1). The screening distance should be set prior to data collection. However, if data were collected without setting the screening distance, it must be set in post-processing prior to exporting data for evaluation in extrap and processing to the final discharge. This requirement should be followed until the Office of Surface Water has determined that SonTek has made appropriate changes that eliminate this bias.

No action is recommended for measurements made with a RiverSurveyor S5, even though a thorough evaluation of the RiverSurveyor S5 was not completed. The reason for this is that (1) field observations have not indicated a potential bias, (2) less flow disturbance is expected for the S5 because its diameter is smaller than the M9, and (3) prior evaluation of an ADCP having a similar diameter (TRDI StreamPro) found no significant bias due to flow disturbance. Thus, the bias due to flow disturbance and the recommended action is limited to the RiverSurveyor M9 only.

Reference

Mueller, D.S., Abad, J.D., García, C.M., Gartner, J.W., García, M.H., and Oberg, K.A., 2007, Errors in acoustic Doppler profiler velocity measurements caused by flow disturbance: Journal of Hydraulic Engineering, v. 133, no. 12, p. 1411–1420.

Appendix A. Summary of Supporting Analyses

Field observations have indicated that discharge measurements made with the RiverSurveyor M9 often display a bend back in the top 0.49-0.66 ft (15-20 cm) cm of the velocity profile, especially when collecting data with the 3 MHz beams in HD mode (water velocity < 1.3 ft/s (0.4 m/s) and depths < 4.9 ft (1.5 m)). The effect of flow disturbance is most evident when the M9 is operating in 3 MHz HD mode because the blanking distance and depth cell size are small resulting in velocity measurements very close to the transducers (within about 0.23 ft (7 cm)). Several comparison measurements confirm the bend back in the velocity profile measured with a RiverSurveyor M9 (figures 1-3).

The numerical simulations of the M9 in the large hydroboard using (1) a uniform flow field, (2) no influence of a bottom boundary, and (3) approach velocities of 2 ft/s (0.6 m/s) and 4 ft/s (1.2 m/s) indicated a 1% or greater bias in the velocity profile due to flow disturbance to a distance of about 19 cm. The difference between the infinite flow field simulations and the field data is likely due to a constriction of the velocity profile caused by the flume bottom and a flow depth of less than 0.6 m. An additional simulation was completed using the M9 deployed in the large hydroboard and the geometry of the Lower Colorado River Authority Plant No. 2 flume as solid boundaries to validate that the source of the difference between the prior numerical simulations and field data was in fact due to the solid boundary and shallow flow depth. The result of this numerical simulation (figure 4), show very close agreement in the shape of the simulated profile with the measured profiles and validates the inflection point of the profile at about 15 cm (0.49 ft) for a flow depth of less than 0.6 m (2.0 ft).

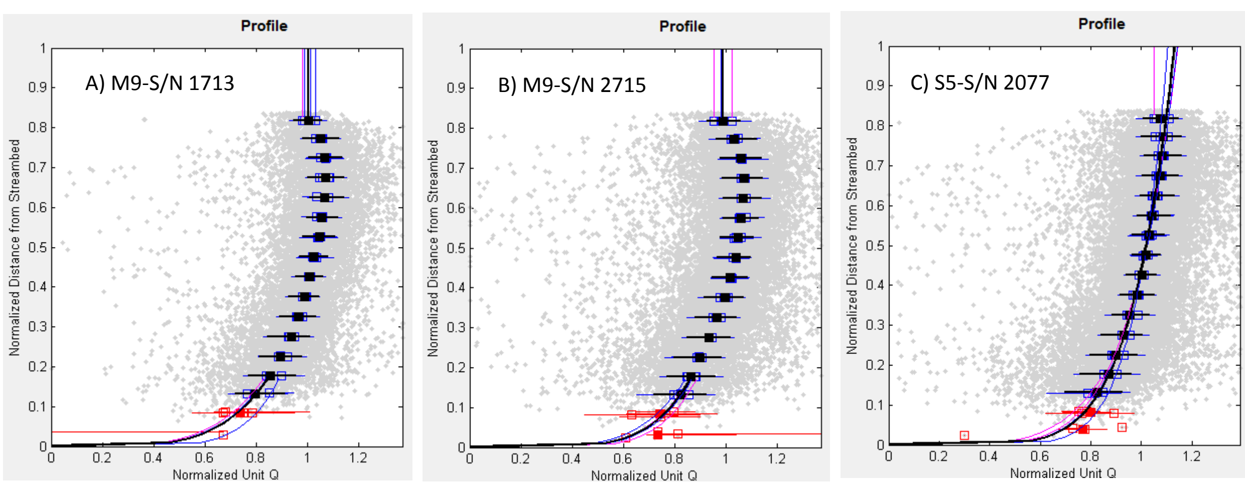
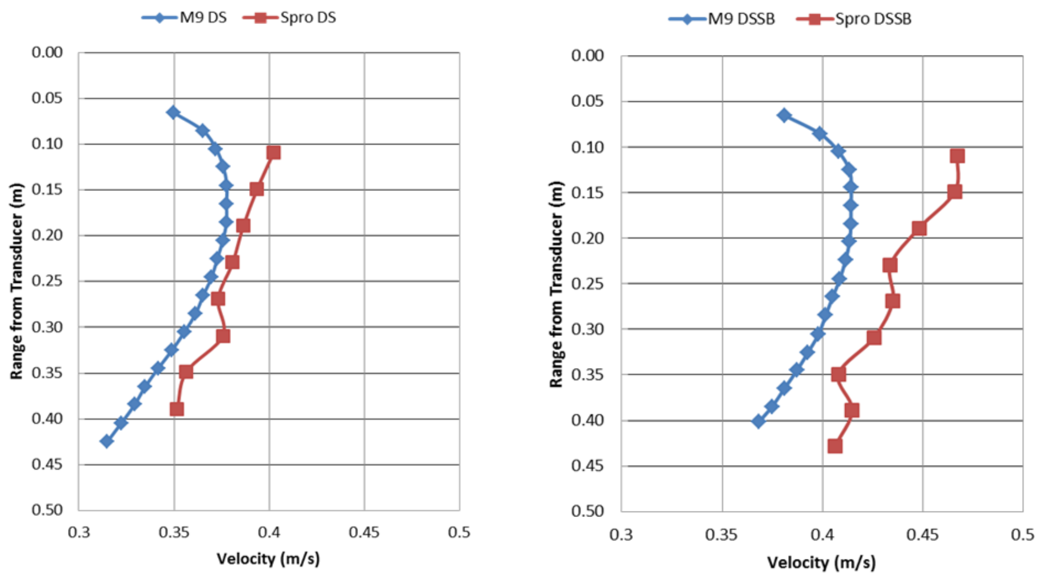


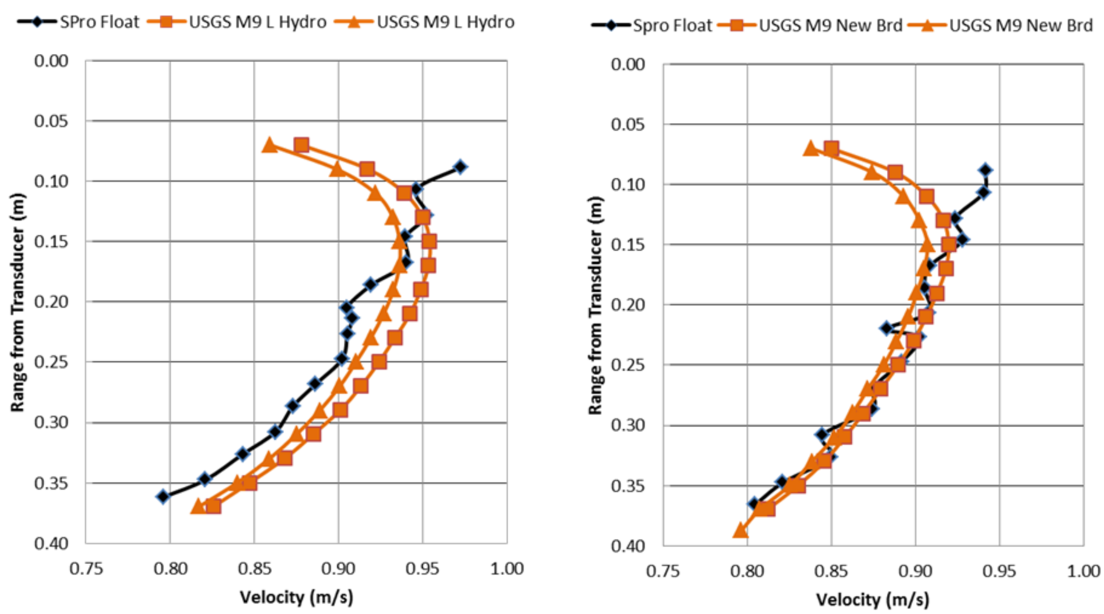
Figure 1. Profiles of the normalized unit discharge from extrap for measurements at West Branch Brandywine Creek at Coatesville, PA using two different M9's and an S5, for mean velocities of about 0.23 ft/s (0.07 m/s) and depths ranging from 1.6 to 3.1 ft (0.5 to 0.95 m).



A) Data from downstream tagline

B) Data from downstream side of bridge

Figure 2. Comparison of average stationary velocity profiles collected on the Salt Fork near St. Joseph, IL.



A) M9 in Large Hydroboard

B) M9 in New Hydroboard

Figure 3. Comparison of average stationary velocity profiles for M9 in large and new hydroboards to StreamPro in float provided with the instrument in the concrete flume portion of the canal at Plant 2 pumping station on the Colorado River operated by the Lower Colorado River Authority.

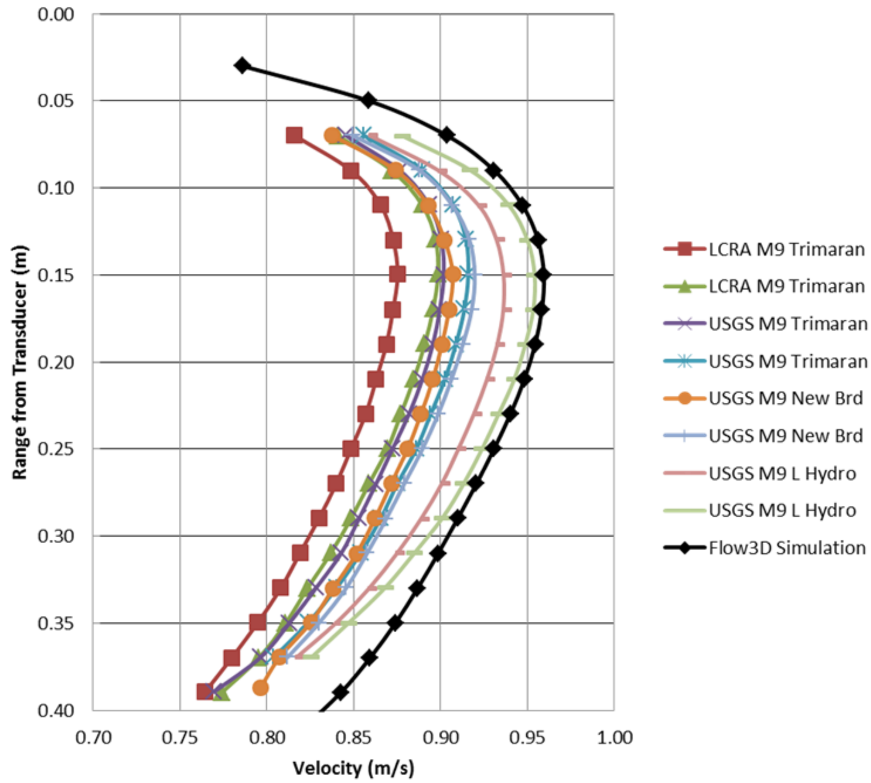


Figure 4. Comparison of numerical simulation results with velocity profiles measured using the SonTek RiverSurveyor M9 for the LCRA flume.

The negative bias in the velocity profile caused by flow disturbance will negatively bias the measured discharge in two ways:

1) the measured portion of the profile affected by the negative bias will result in a negative bias of the computed discharge for this portion of the cross section; and
2) the negative bias in the profile will lead to the selection of an incorrect profile extrapolation method and result in the extrapolated discharge being negatively biased.

From field data and model simulations the location of the bend back was 0.49 ft (15 cm) from the transducer for a flow depth of approximately 2.0 ft (0.6 m) and up to 0.72 ft (22 cm) for infinite flow depths. The maximum range of the 3 MHz HD mode for the M9 is 4.9 ft (1.5 m). Analysis of the potential effect of the velocity profile bias on discharge will assume the bend back begins 0.46 ft (14 cm) from the transducer for a flow depth of 0.4 m and 20 cm from the transducer for the maximum flow depth of 4.9 ft (1.5 m). A 0.33 ft (10 cm) draft with the center of the first 2-cm cell located 0.23 (7 cm) from the transducer and a power velocity profile with an exponent of 0.1667 will also be assumed. Given these assumptions, the effect of the negatively-biased velocity profile on the measured discharge varies from about 6% at a flow depth of 1.3 ft (0.4 m) to about 1.3% for flow depths near 4.9 ft (1.5 m).

The negative bias present in the top 0.49 – 0.66 ft (15-20 cm) of profiles collected with the 3 MHz transducers is also present in profiles collected with the 1 MHz transducers. Model simulations for the 1 MHz beams indicate that flow disturbance causes a 1% or greater to a range of about 0.66 ft (20 cm). This bias often is not seen in field data because the large cell size averages across the bias and unbiased portions of the profiles. The bias is more readily seen in the 3 MHz HD mode because the blanking distance and cell sizes are small. The use of the 1 MHz HD blanking distance of 16 cm for all modes would reduce the small hidden bias in the 1 MHz data and the observed bias in the 3 MHz data. Using the assumptions of the previously discussed analysis of percent error in discharge and assuming that any time the negative bias occurs (even slightly for 0.3 ft (1 cm)) a constant extrapolation is used, reduces the discharge bias to less than 1.5%. This is worst case, as typically several depth cells with a prevalent negative bias would be required to select a constant extrapolation. Thus, the use of a constant blanking distance of 0.52 ft (16 cm) would provide more reliable data for all operating frequencies and modes of the RiverSurveyor M9.

/signed/

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