OSW Informational and Technical Note 2016.17 *March 16, 2016*

SUBJECT: Limitation of Loop Moving-Bed Test

Introduction

The Office of Surface Water (OSW) policy is that "*every moving-boat measurement made with an ADCP must have a recorded moving-bed test*" (Mueller and others, 2013, p. 25). The use of the loop moving-bed test has been encouraged because the test captures the moving-bed characteristics of the entire measurement cross section (Mueller and others, 2013; Mueller and Wagner, 2006). The criteria for conducting a loop moving-bed test are summarized below (Mueller and others, 2013).

Requirements	Detection threshold	Minimum duration
• Precisely start and end at same location • Accurate heading • Mean water velocity >0.8 ft/s • Consistent boat speed • Valid bottom track	• Moving bed velocity >0.04 ft/s and >1% of mean water velocity	• 3 minutes (180 s)

The loop moving-bed test is not appropriate when headings are inaccurate or bottom track cannot be maintained (Mueller and others, 2013, p. 75-76). This note addresses an additional limitation of the loop moving-bed test for streams that are wider than 180 ft. This limitation is caused by the combined effect of potential heading errors of a well calibrated compass, stream width, and test duration (or boat speed).

Discussion of Limitation

Results from loop moving-bed tests completed on wide rivers indicated a potential issue with the reliability of loop tests. OSW investigation of this issue indicated that for a typical one-cycle compass error (1 degree heading error in each direction) the loop test may not be reliable if *the duration of the loop test in seconds is less than the width of the cross section in ft, which equates to a boat speed of 2.3 ft/s or less*. Thus, for a 1,200 ft wide stream the duration of the loop test should be at least 1,200 s (20 min). Loop moving-bed tests that do not meet these criteria may have loop closure errors caused by heading errors and not by moving-bed conditions. The limitation presented here is based on an assumed 1-degree one-cycle compass error and an approximate 180-degree rotation of the boat during the out and back legs of the loop. Larger heading errors would require a longer duration moving-bed test (slower boat speed).

Practical Application

When deciding on the type of moving-bed test to collect, consider if the width of the river would necessitate a duration that is longer than practical by estimating the needed duration in seconds to be equal to the stream width in ft. During any loop moving bed test, the boat operator should be mindful to keep the boat speed below 2.3 ft/s. If a loop test is not practical due to the requirements from Mueller and others (2013) repeated above or from the limitation discussed herein, a stationary moving-bed test should be used.

Supporting Analysis

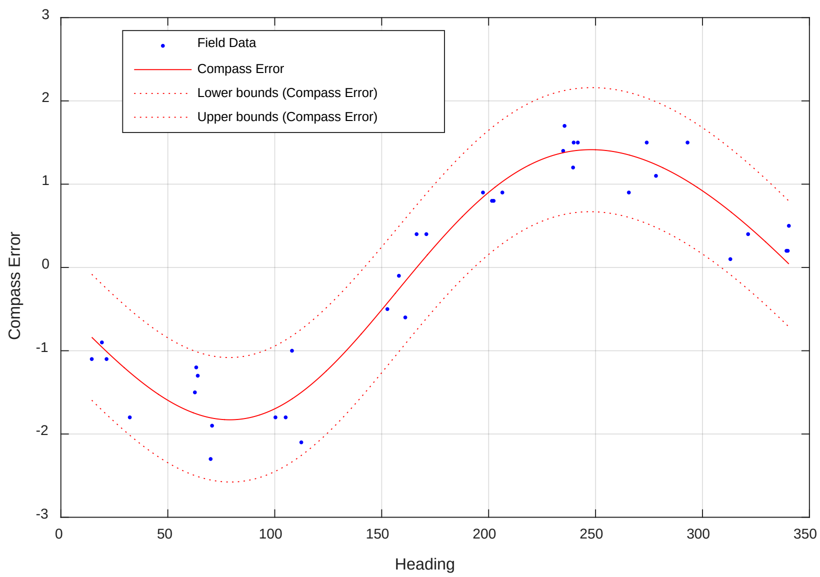

Figure 1. Example of one cycle compass error.

Most compasses used in ADCPs have a specified accuracy of +/- 2 degrees. Even after on-site calibration heading errors of up to 1 degree could be expected. Compass errors are a function of heading and can be characterized as one-cycle or two-cycle errors. Figure 1 shows a one-cycle compass error. Note that the maximum heading errors are opposite in sign and approximately 180-degrees apart. If we create a hypothetical loop that travels across the river at a heading of about 300 degrees and back to the starting point at about 125 degrees, the heading error on the outbound leg is +1 degree and on the return leg -1 degree. Figure 2 shows that these two heading errors result in a loop closure error. Note: there is no flow direction in Figure 2 so the closure error could be either upstream or downstream. The closure error can be computed as,

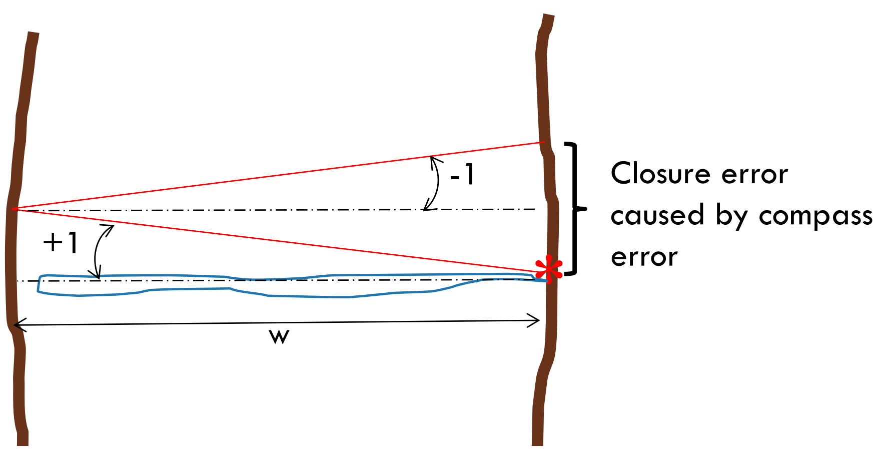

Figure 2. Illustration of loop closure error with a 1-degree one cycle compass error.

$$E_c = w * \tan\left(\left|\theta_1\right|\right) + w * \tan\left(\left|\theta_2\right|\right) \quad (1)$$

where

E_c is the loop closure error;

w is the width of the stream; and

θ_1, θ_2 are the heading errors on the outgoing and return legs, respectively.

If we assume,

$$\theta = \left|\theta_1\right| = \left|\theta_2\right| \quad (2)$$

then

$$E_c = 2 * w * \tan\left(\theta\right) \quad (3)$$

The equation for computing the moving-bed velocity from a loop test is

$$V_{mb} = \frac{E_c}{D} \quad (4)$$

where

V_{mb} is the moving-bed velocity and

D is the duration of the loop (s).

Substituting equation 3 for E_c yields,

$$V_{mb} = \frac{2 * w * \tan\left(\theta\right)}{D} \quad (5)$$

The loop method assumes the moving-bed velocity is negligible unless the moving-bed velocity is greater than 0.04 ft/s (0.012 m/s). If we apply this velocity threshold and assume a typical one-cycle compass error of 1 degree, equation 5 becomes,

$$0.04 = \frac{2 * w * \tan\left(1\right)}{D} \quad (6)$$

Equation 6 can be solved for w as a function of duration, D , in seconds,

If w is in feet, $w = 1.15 * D$ (7)

If w is in meters, $w = 0.35 * D$ (8)

Thus the width in ft is nearly equal to the duration in seconds.

Recognizing that

$$V_{boat} = \frac{2 * w}{D} \quad (9)$$

We can also solve for the maximum allowable boat velocity threshold,

$$V_{boat} < 2.3\,ft/s \qquad (10)$$

$$V_{boat} < 0.7\,m/s \qquad (11)$$

Unfortunately this limitation was not identified in the original loop method development (Mueller and Wagner, 2006). Of the 28 field measurement used to evaluate the loop method limitations only two exceeded the above criteria and although, the actual heading errors for those measurement are unknown, the compass calibrations indicated errors less than 0.5 degrees.

Therefore, assuming a one-cycle compass error of 1-degree or less, a loop test should be valid if the average boat speed is kept below that specified in equations 10 and 11 or the width of the stream does not exceed the threshold defined by the duration of the test in equations 7 and 8. Larger heading errors would further reduce the width of the stream or boat velocity for which the loop method could be used.

References

Mueller, D.S., Wagner, C.R., Rehmel, M.S., Oberg, K.A, and Rainville, Francois, 2013, Measuring discharge with acoustic Doppler current profilers from a moving boat: U.S. Geological Survey Techniques and Methods 3A–22, 72 p., http://pubs.usgs.gov/tm/3a22/.

Mueller, D.S., and Wagner, C.R., 2006, Application of the loop method for correcting acoustic Doppler current profiler discharge measurements biased by sediment transport: U.S. Geological Survey Scientific Investigations Report 2006–5079, 26 p.

/signed/

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For the Office of Surface Water

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