Appendix — Step-by-Step Procedures for Using the Loop Method

Careful field procedures are absolutely critical to the successful application of the loop method. Failure to accurately return the instrument to the starting point, an uncalibrated or improperly calibrated compass, or loss of bottom track during the loop will result in unpredictable errors that render this technique unusable. Current research (which is limited by the amount of available field data) indicates that site-specific characteristics and data-collection techniques, such as the shape of the measurement section, distribution of the moving-bed velocity, time spent at the banks, boat speed, and uniformity of the boat speed, can affect the discharge correction by 10 percent or greater. When applied properly, however, this technique should consistently yield total corrected discharges that are within 5 percent of the actual discharge.

Field Procedures

1. **Calibrate the acoustic Doppler current profiler (ADCP) compass using internal calibration routines.** A compass calibration accuracy of better than 1 degree is desired. Calibrations with errors greater than 1 degree should be repeated. If after several attempts a calibration of less than 1 degree cannot be obtained, appropriate field notes should be recorded to document the problem. Compass errors greater than 1 degree result in increased errors in the loop-method correction.
2. **Establish a marked starting point where the ADCP can be returned to the exact location.** This point is not required to be as near to a bank as the end of a regular transect. For example, with a tethered boat it can be hard to control the boat at the edge because of conditions such as slack water, eddies, or vegetation; therefore, establishing a point farther out in the flow could make navigating the boat back to the starting point more practical. Use of a buoy or other fixed object is recommended.
3. **Make a steady pass back and forth across the stream as a standard discharge measurement, but do not stop recording at the far bank.** At the starting point make sure the boat is ready to begin the transect before beginning to record. **A uniform boat speed is important.** Do not spend extra time at the edges. Plan the loop so that a smooth change in boat direction can be achieved near the far bank. Too much time near the banks will result in a low bias.
4. **Maintain the proper boat speed.** The recommended maximum boat speed should be the lesser of a boat speed that requires no less than 3 minutes to complete the loop or a boat speed that is less than 1.5 times the mean water speed. **1. 2. 3. 4.**
5. **Return to the starting point.** Return position accuracy is very important.

Processing for Moving-Bed Test

1. **Process the loop file to the end.** Record the Distance Made Good (DMG) and the time required to complete the loop. *Note*: The DMG in a moving-bed condition should be in the upstream direction (see figure 1 in main text). If the primary direction of the DMG is in a direction other than upstream, this distance may be the result of compass or bottom-track errors and no moving bed will be assumed.
2. **Compute the mean moving-bed velocity.**

$$\overline{V}_{mb} = \frac{D_{up}}{T},$$

where

$\overline{V}_{mb}$ is the mean velocity of the moving bed;

D_{up} is the Distance Made Good (DMG); and

T is the measurement time required to complete the loop.

3. Compute the ratio of the mean moving-bed velocity to the mean water velocity.

4. Determine if the ratio exceeds the recommended criteria. When using the loop method, a measured mean moving-bed velocity of at least 0.04 ft/s indicates the presence of a moving-bed. If the measured moving bed velocity exceeds 0.04 ft/s, the ratio of the mean moving-bed velocity and mean water velocity should be computed by dividing the mean moving-bed velocity by the mean water velocity. If this ratio is greater than 0.01, the apparent bed movement will cause at least a 1-percent negative bias in the computed discharge and application of the loop method is recommended.

Processing for Discharge Correction

Two processing methods—the mean correction method and the distributed correction method—can be used to correct biased-measured discharge using the measured mean moving-bed velocity from the loop method. The mean correction method is simple to apply but does not account for the cross-section shape and spatial distribution of the sediment transport. The distributed method uses a near-bed water velocity

computed from the ADCP data to distribute the mean moving-bed velocity through the cross section and can be applied using the "LC.exe" computer program.

Mean Correction Method

1. **Process the loop file to the end.** Check for excessive bad bottom-track data and other problems that could reduce the accuracy of the loop. Record any observed problems.
2. **Record the DMG and the time required to complete the loop.** *Note:* The DMG in a moving-bed condition should be in the upstream direction (see figure 1 in main text). If the primary direction of the DMG is in a direction other than upstream, this distance may be the result of compass or bottom-track errors, and no moving bed will be assumed.
3. **Compute the mean moving-bed velocity.**

$$\overline{V}_{mb} = \frac{D_{up}}{T},$$

where

$\overline{V}_{mb}$ is the mean velocity of the moving bed;

D_{up} is the Distance Made Good (DMG); and

T is the measurement time required to complete the loop.

4. **Change area computation method to "Perpendicular to Mean Flow," if available.**
5. **Review and process the discharge measurement.** Use appropriate U.S. Geological Survey guidance and policies to determine the mean unadjusted discharge.
6. **Record the cross-sectional area.** The cross-sectional area should be the mean cross-sectional area for all transects used to determine the mean discharge.
7. **Compute the final discharge.**

$$Q_{TC} = Q_{TM} + \overline{V}_{mb} A,$$

where

Q_{TC} is the discharge corrected for the moving-bed bias;

Q_{TM} is the measured discharge;

$\overline{V}_{mb}$ is the mean velocity of the moving bed; and

A is the cross-sectional area perpendicular to the mean flow direction.

Distributed Correction Method

The use of the distributed correction method requires that the program LC.exe and any necessary libraries be installed on the computer being used for processing. The program, installation files, and installation instructions can be found at *http://hydroacoustics.usgs.gov*.

1. **Review the loop file.** Check for excessive bad bottom-track data and other problems that could reduce the accuracy of the loop. Record any observed problems.
2. **Review and process the discharge measurement files.** Use appropriate U.S. Geological Survey guidance and policies to determine the mean unadjusted discharge.
3. **Generate RD instrument-compatible ASCII output files for the loop and discharge measurement files.**
4. **Start the LC.exe computer program.** *Note:* It may take a long time for the program to initialize.
5. **Process the loop file with LC.** Click on the "Select Loop File" button, and browse for the ASCII output of the loop measurement. The program will process the loop and determine if a correction is required. The "Select Measurement Files" button will become active. If no correction is required, proceed to step 7.
6. **If a correction is required, process the discharge measurement files with LC.** Click on the "Select Measurement Files" button. Select the ASCII output for all discharge measurement files using Control and Shift click to select multiple files (standard Windows multiple file collection procedures). The program will distribute the moving-bed correction to all ensembles and provide both an unadjusted and adjusted final discharge.
7. **Save, print, and file the results.** Click on the "Save Results" button to save the results to a text file. Print the text file and attach the printout to the hard-copy field notes. Place the text file in the corresponding directory with the rest of the measurement files for archive.