TEST PLAN FOR RIVERSURVEYOR M9 AND S5

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INTRODUCTION

SonTek/YSI has introduced two new ADCPs for discharge measurement and velocity surveys. Two models have been released, the M9 and the S5. The M9 is a 9-beam 3-frequency ADCP. It has 4 beams operating at 1 MHz for water profiling and bottom tracking, 4 beams operating at 3 MHz for water profiling, and one vertical beam operating at 500 kHz for depth measurements. discharge measurement and velocity surveys The M9's nominal velocity profiling range is ~0.3 m to 30.0 m. The range of the vertical beam for depth measurements is 0.2 to 80 m. The S5 is a 5-beam 2-frequency ADCP. It has 4 beams operating at 3 MHz for water profiling and bottom tracking, and one vertical beam operating at 1 MHz for depth measurements. The S5's nominal velocity profiling range is ~0.3 m to 5.0 m. The range of the vertical beam for depth measurements is 0.2 to 15m.

Thorough testing of these new ADCPs is necessary to insure that the instruments are suitable for use in streamgaging by the USGS and other national hydrologic services. This includes testing of the software, hardware, and evaluating the resulting discharges. The development and implementation of this test plan does not mean that M9 and S5 cannot be used, however, when operating the equipment the user should be careful to look for potential problems and, if possible, collect data and make discharge measurement comparisons that can be shared with the Office of Surface Water to help validate the current firmware and software releases.

FIRMWARE AND SOFTWARE

Tests conducted using this test plan for guidance should be made with firmware and software recommended by the USGS, Office of Surface Water. At present (above date), the firmware version that should be used is 0.72. The software version that should be used in comparison measurements is RiverSurveyor Live version 1.00. As it is possible that enhancements and bug fixes to the firmware and software may be released before this document is updated, check with OSW to verify which versions should be used.

LABORATORY TESTING

Although laboratory testing cannot reproduce the hydraulic and environmental conditions typical of field sites, it provides a set of controlled conditions that allow various operations of the system to be evaluated independently. The tests conducted in the hydraulics laboratory at the HIF will include testing water tracking in the large tow tank, bottom tracking and beam matrices in the tilting flume, and beam depths in the large tank. All tests will be conducted by OSW (including HIF and associated contractors) personnel.

WATER TRACKING

Water tracking test will utilize the large tow tank and be conducted using the following procedures.

1. The tow tank will be seeded with hydrated lime.
2. One of the instruments being tested will be moved slowly through the tank with stationary data collected a various locations as necessary to evaluate acoustic interference and uniformity of backscatter.
3. Reasonable adjustments will be made to correct significant problems found in step 2.
4. Two or more of each type of instrument (S5 or M9) will be tested.
5. The instrument will be manually configured to have:
    a. Zero blank
    b. Bottom track disabled
    c. Vertical beam disabled
    d. Automated frequency and mode switching disabled
    e. Default bin size for mode and frequency being tested
6. Data will be collected in beam coordinates and processed in XYZ coordinates.
7. Each instrument will be tested at 3 rotations differing by 45 degrees. This will allow all beams to be tested parallel, transverse, and oblique to the direction of motion.
8. Each frequency, mode, bin size, and instrument rotation will be tested for velocities ranging from 3 cm/s to 200 cm/s.
9. Notes for each test will consist of:
    a. Instrument serial number
    b. Rotation
    c. Frequency
    d. Bin size
    e. Operating mode
    f. Direction of tow cart movement
    g. Speed of tow cart

BOTTOM TRACKING / BEAM MATRICES

The bottom tracking and beam matrices will be tested using a distance test in the tilting flume using the following procedures.

1. The bottom of the tilting flume will be covered by a layer of gravel.
2. Start and stop blocks will be surveyed and installed approximately 100 ft apart.
3. One of the instruments shall be used to evaluate the configuration.
    a. There should be no invalid bottom track data
    b. The test should be repeatable to within 0.1 percent of the distance
4. The flume and/or procedures will be adjusted to correct significant problems identified in step 3.
5. The instrument will be manually configured to have:
    a. Water tracking disabled
    b. Vertical beam disabled
    c. Automated frequency switching disabled

    d. Bottom track set to the desired frequency
6. Data will be collected in beam coordinates and processed in XYZ coordinates.
7. Each instrument will be tested at 3 rotations differing by 45 degrees. This will allow all beams to be tested parallel, transverse, and oblique to the direction of motion.
8. Each test will be repeated (2 data sets per rotation).
9. A test will consist of:
    a. Positioning the instrument at the starting location
    b. Starting recording of data
    c. Noting the instrument serial number, rotation, and data file name
    d. Moving the instrument at a smooth and reasonably steady speed to the stop location
    e. Stopping recording of data.

BEAM DEPTH TEST

Testing will be conducted in the Jet Tank facility of the HIF. Depth ranging from approximately 1 foot (0.3 m) to 6 feet (2 m) will be conducted in the Jet Tank's volume tanks and depths ranging from approximately 6 feet (2 m) to 9 feet (3 m) will be conducted in the main Jet Tank tank using the instrument carriage's instrument arm to position the RiverSurveyor relative to the tank's floor.

FIELD TESTS

It is critical to test instruments in the environment in which they will be used. Several field tests are defined herein to extend the tests completed in the laboratory but more importantly to test the instruments ability to accurately measure discharge in field conditions.

SPECIAL TESTS

BOTTOM TRACKING / BEAM MATRICES TEST

The bottom tracking and beam matrices test conducted in the laboratory only used bottom tracking at a shallow depth. If the beam matrices were valid in the laboratory test this test becomes a test of the accuracy of bottom tracking at deeper depths and different streambed conditions. If the beam matrices were determined to be invalid in the laboratory this test is a check on the validity of the shallow water bottom tracking capabilities. Each test should be conducted for the instruments tested in the laboratory using the following procedure.

1. Find a location that will allow a straight course for about 500 m where there is no moving-bed and where RTK GPS is available.
2. No special configuration of the instrument is required.
3. Start the boat moving along the path.
4. Once the boat has achieved the speed that will be maintained start recording data.
5. When the end of the path is near stop recording data before the boat slows down.
6. Record:
    a. Instrument serial number
    b. Rotation
    c. Data file name

7. Repeat steps 3-6 for 3 rotations differing by 45 degrees. This will allow all beams to be tested parallel, transverse, and oblique to the direction of motion.

GPS LATENCY / ACCURACY

While the accuracy of the GPS for measuring discharge will be primarily evaluated using by comparing GPS and BT referenced discharge measurement data at sites where there is no moving bed, a couple of special test will be conducted to provide additional evaluation of the GPS system.

The latency or time between when other data are collected and the GPS data is received can be checked by comparing GPS to BT using the following procedures.

1. Find a location with room to maneuver the boat that has no moving bed and good GPS coverage (either RTK GPS, DGPS,or both).
2. Collect data with both valid GPS and BT.
3. During data collection maneuver the boat in numerous sharp turns to evaluate if the GPS reference shows the turns at the same time as the BT. This may have to be analyzed outside the RiverSurveyor software.
4. Similarly while driving the boat on a consistent course vary the boat speed sharply and evaluate if the GPS and BT referenced boat speeds change simultaneously. This may have to be analyzed outside the RiverSurveyor software.
5. Complete these test for RTK GPS and DGPS at the same site, if possible.

One method of evaluating the accuracy of the GPS is to collect stationary GPS data over a period of approximately 1 hour and compute the 95% deviation from the mean. This should be accomplished in both ideal and not so ideal conditions for both RTK and DGPS configurations.

DISCHARGE COMPARISONS

Comparison of RiverSurveyor measured discharges to those of accepted techniques is a critical component of this testing plan. In the field the true discharge is never known, but it is important to identify and changes in measured discharge that may be associated with a change in instrumentation. Thus, while no statistically significant bias between the discharges measured by the tested equipment and the accepted reference is desirable, it is possible that a bias may exist because the new equipment is making a more accurate measurement. Such a conclusion would require both empirical and theoretical support.

An accurate reference measurement is critical in the success of these comparisons. Therefore, while comparisons are desired in a variety of site conditions, the reference measurement should be accurate for the site conditions measured.

SITE CONDITIONS

The flow at the measurement location should be approximately steady (not changing with time). Defining the variety of site conditions for which data are desired results in a huge matrix that becomes nearly unusable to determining where data should be collected. Data are needed at both ideal and difficult sites to define the limits and accuracy of the system. Therefore, data collected at any site is generally helpful. The following are guidelines that may be useful in prioritizing where data are collected.

1. Depth ranges were determined based on automated bin size and frequency changes.
    a. 1 to 2.5 ft
    b. 2.5 to 10 ft
    c. 10 to 16 ft
    d. Greater than 16 ft
2. Velocity ranges are mostly arbitrary but attempt to capture very low, low, typical, and high velocities.
    a. Less than 0.2 ft/s
    b. 0.2 to 1 ft/s
    c. 1 to 3 ft/s
    d. 3 to 5 ft/s
    e. Greater than 5 ft/s
3. Bed conditions should vary from smooth to rough. Gravel and rougher beds are likely more important in water depths less than about 5 ft.
4. Sites with and without moving-bed conditions are needed. Moving-bed conditions may be most critical to evaluate in smaller streams where GPS may not work as well as on larger streams.
5. Data in streams with both very high and very low suspended sediment concentrations are necessary to define the operating limits of the various frequencies. Typically this is a range issue and measurements at sites with depths greater than 10 ft are desirable.
6. Sites with no moving bed that have configurations that make GPS data collection difficult. This allows the GPS referenced discharges to be compared to BT referenced discharges.
    a. Canyon with steep walls
    b. Sites with tree canopy
    c. RTK GPS
    d. DGPS

REFERENCE DISCHARGE

A reliable reference discharge is required with every measurement. The priority order for reference discharge methods are:

1. Simultaneous Rio Grande or Streampro measurements. Note: The 1200 kHz Rio Grande will interfere with the 1 MHz beams and a 600 kHz Rio Grande will interfere with the 500 kHz vertical beam. If data are collected simultaneously the instruments should be separated by at least 5 times the maximum depth of flow in the cross section.
2. Simultaneous FlowTracker or mechanical current meter measurement. RiverSurveyor transects should be collected for the entire time the point current meter measurement is collecting data.
3. Sequential Rio Grande, Streampro, FlowTracker, or mechanical current meter measurements before, after, or preferably both before and after RiverSurveyor measurements. Stage change during all measurements should be recorded.
4. Sites where there is a dam with accurate ratings for gates and/or hydropower outflow.
5. Stable stage-discharge, especially those where few shifts have been necessary to adjust the rating

It is desirable that more than one of these reference discharges are available. An example would be a site where there is an accurate stage-discharge rating and no recent shifting of the rating in the portion of the rating being measured and a measurement described in 1 – 3 above.

FIELD PROCEDURES

1. Follow standard USGS streamgaging procedures, unless specified differently in this test plan.
2. Use standard USGS Acoustic Profiler Discharge Measurement Notes (Form 9-275) and other appropriate USGS forms for the reference measurements as appropriate.
3. Reference measurements made with Rio Grande or StreamPro instruments should be collected and processed with WinRiver II version 2.04 or later.
4. Select a cross section with uniform flow conditions and minimal flow reversals at edges, if possible.
5. Take digital photographs to document site conditions.
    a. Location of measurement section(s)
    b. Location of GPS base station and and tree canopy nearby
    c. Photos of the ADCP and tethered/manned boat used to collect data
6. Record an independent measurement of water temperature
7. Synchronize time on all instruments being used.
8. Complete a compass calibration on the RiverSurveyor. Make sure the calibration passes. Consider repeating the calibration until you receive and excellent and a Q9 (although this is not absolutely necessary).
9. If a Rio Grande is used as the reference instrument a compass calibration should be completed and the evaluation should be within 1-degree, if possible.
10. Complete all built-in predeployment tests for instruments used.
11. Setup and verify that the RiverSurveyor GPS is working as configured (RTK or DGPS).
12. Setup and verity the GPS for the reference instrument, if appropriate.
13. Accurately measure the instrument depth for the RiverSurveyor and reference instrument, as appropriate.
14. Configure reference instrument as appropriate.
15. Complete a loop method moving-bed test for the RiverSurveyor and, if appropriate, the reference instrument, using procedures defined in OSW Memos 2009.05 and 2006.04. Identify the loop test on in the field notes.
16. If a moving-bed is present, collect three 5-minute stationary moving-bed tests at distances of 25, 50 and 75 percent of the channel width (assuming that measurements are made using a tethered boat or an anchored manned boat) with the RiverSurveyor and the reference instrument, if appropriate. Identify the SMBT and locations in the field notes.
17. Identify and mark (recommended) left and right stopping points that allow at least 2 good bins at each edge. If this is not appropriate, document reason for deviation.
18. Measure the left and right edge distances from the established marks. If fixed markers are not used the edge distances must be measured for each transect.
19. Record beginning stage.
20. Collect 12 transects (if possible) with each ADCP (RiverSurveyor and reference). If 12 transects cannot be collect, collect the maximum number that is reasonable. Make sure that reciprocal pairs of transects are collected. Maintain as smooth a boat speed as possible.
21. Document any observed reverse flow at the edges.
22. Record ending stage.
23. Record detailed notes, including information about the weather conditions, wind, and other factors that may affect the discharge measurement.

DATA TO PROVIDE TO OSW

Test data should be submitted to

David S. Mueller
U.S. Geological Survey, Office of Surface Water
9818 Bluegrass Parkway
Louisville, KY 40299
Phone: 502-493-1935
Email: dmueller@usgs.gov

Note: USGS personnel may upload data to:
If uploading data please send a notification of upload to dmueller@usgs.gov.

The following should be submitted for every test measurement.

1. Final processed reference discharge from all references available. These data should be processed in accordance with OSW guidelines.
2. Unit values of stage and rated discharge, if applicable.
3. Original or scanned copies of field notes
4. Station number and name.
5. Digital photographs
6. All RiverSurveyor measurement data, including compass calibration.
7. All reference measurement data, including compass calibration and any other predeployment test data.
8. Any other observations or historical information about the site that may be helpful.