Acoustic Velocimetry for Riverine Environments

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Acoustic instruments are rapidly replacing conventional current meters for measurement of velocities in natural and man-made open channels. Greater efficiency, improved performance, and numerous safety considerations at comparable costs have provided the motivation for their broad adoption in hydrologic data-collection operations. They have no moving parts, offer relatively high spatial and temporal sampling resolution, and require fewer calibrations. Moreover, they allow measurements in field settings where conventional measurements were very difficult or costly to obtain and facilitate documentation of flow features that previously could only be documented in the laboratory (Dinehart and Burau 2005).

Rapid development of acoustic velocimeters has continued since the early work on acoustic Doppler current profilers (ADCPs) by Christensen and Herrick (1982), Simpson (1986), and Gordon (1989). Likewise, the development of acoustic Doppler velocimeters (ADVs) in the early 1990s (Kraus et al. 1994) has revolutionized the measurement of two- and three-dimensional mean velocities and turbulence characteristics in both laboratory and field studies. These technologies have profoundly changed the way that hydraulic data are collected by researchers, engineers, and technicians alike, being applied to measure velocity and thereby estimate important velocity-derived hydrodynamic quantities in support of riverine research and to complement numerical simulations and laboratory studies. Acoustic instruments are currently used for routine operations on water delivery projects, water treatment plants, stream gauging stations, and many other water resources-related projects.

Given the growing interest in acoustic measurements and associated instrumentation, the Hydraulic Measurements and Experimentation Committee (HME) of the Environmental and Water Resources Institute (EWRI) decided in 2005 to produce a special issue of the *Journal of Hydraulic Engineering* focused on Acoustic Velocimetry for Riverine Environments. The HME is a technical committee founded in 1989 within the American Society of Civil Engineers and more recently its Environmental and Water Resources Institute. The committee consists of volunteer scientists and practitioners from academia, federal and state water resources agencies, and the private sector. The committee's mission is to disseminate information on instrumentation, measurement methods, and experimental techniques applicable to the field of hydraulic engineering. Typically, information is shared by sponsoring special sessions at EWRI congresses or organizing specialty conferences, such as the highly successful series on Hydraulic Measurements and Experimental Methods (Buffalo, N.Y., 1994; Estes Park, Colo., 2002; and, Lake Placid, N.Y., 2007).

This special issue reports on the latest developments in the field of acoustic velocimetry and their implications for documenting river hydrodynamics and related processes. It compiles timely papers addressing important aspects of acoustic-based velocimeters that could have not been adequately covered in conference proceedings or other publications. The technical papers contributed to the special issue were subject to the rigorous review standards of ASCE journals and were prepared by a wide variety of specialists from academia, research institutes, and federal and state water resources agencies with a special mission of monitoring and studying rivers. Major contributors to the special issue are colleagues from the U.S. Geological Survey (USGS), since perhaps no one U.S. agency has experienced more change in its routine hydrologic-data-collection operations since the advent of these acoustic technologies. In fact, the USGS has been leading the way in developing, adopting, and improving these acoustic instruments in their hydrologic data-collection programs, as well as disseminating their experience to the broader river measurement community. In 2006, 33% of all USGS discharge measurements were made by using acoustic instruments. Approximately 57% of all USGS discharge measurements that could be made from a boat, cableway, or bridge were made with an ADCP, whereas 27% of all wading measurements were made with an ADV. As of this writing (2007), an estimated 250 ADCPs and 627 ADVs are actively being used for making streamflow and velocity measurements in USGS water science programs.

The special issue consists of 13 original papers reporting instrument capabilities, limitations, operational considerations, innovative applications, and uncertainty analysis, with special emphasis on practical considerations regarding the use of the instruments in measurement campaigns. This emphasis is important from two perspectives. First, acoustic velocimeters were rapidly adopted in practice; hence, their measurement protocol, performance, and accuracy are all still under scrutiny. Second, this family of instruments is surprisingly versatile in providing additional quantities that were not targeted in the original design (e.g., measurement of turbulence, sediment transport, and riverbed composition) such that research needs to be conducted to further develop these capabilities. Although important advances have been made on these aspects, the science and engineering of these instruments is still incomplete and worthy of further research and critical evaluation. The technical papers can be grouped by topics as follows:

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Performance and Operational Considerations

- Verification of ADCP performance using alternative operational approaches (Szupiany, Amsler, Best, and Parsons).
- Capabilities of ADCPs to capture turbulence characteristics (Nystrom, Rehmann, and Oberg).
- Feasibility of the ADCP to measure bedload transport rates (Gaeuman and Jacobson).
- Procedures for correcting ADCP measurements conducted over moving river beds (Mueller and Wagner).
- Improved methods for estimating the boat velocity for ADCP measurements acquired over moving river beds (Rennie, Rainville, and Kashyap).
- Innovative ADV operation for capturing mean flow and turbulent fluctuations (Clunie, Nikora, Coleman, Friedrich, and Melville).

Special Applications

- Use of ADCPs for documenting the hydrodynamics of gravity currents (Garcia, Oberg, and Garcia).
- Use of ADV for measuring velocity and turbulence distribution in ecohydraulics studies (Stone and Hotchkiss).
- High-order statistical analysis of turbulence in mountain streams using ADV (Strom and Papanicolaou).

Uncertainty Analysis and Instrument Intercomparison

- Implementation of standardized uncertainty analysis framework for ADCP measurements (Gonzalez-Castro and Muste).
- Investigation of the errors caused by flow disturbance in ADCP measurements (Mueller, Abad, Garcia, Gartner, Garcia, and Oberg).
- Validation measurements for ADCPs (Oberg and Mueller).
- Validation measurements for Flow Tracker ADVs (Rehmel).

The special issue closes with an invitation by a World Meteorological Organization (WMO) working group leading a worldwide collaborative project in hydrometry. The WMO project was motivated by the dramatic changes in the instrumentation available for use in hydrometry and in the procedures for the measurement of discharge. The hydroacoustic community is invited to participate in a collaborative program assessing the performance of the newly developed instruments and improving the understanding of accuracy of various types of hydrometric instruments.

With the publication of this special issue, the HME Committee intends to convey that, despite the fast pace of development and implementation of the new generation of acoustic velocimeters, research is still needed to understand more completely instrument capabilities and to assess more thoroughly their measurement uncertainty. The HME Committee hopes that this special issue will stimulate the development of new lines of research, instrument configurations, operational procedures, and practical applications that will advance our knowledge of the vital riverine environment and provide a sound scientific basis for guiding their application in routine monitoring activities.

The special-issue editors (all HME committee members) gratefully acknowledge the contributions of the 30 authors, the 42 reviewers, and the HME committee members who initiated this project. The members and officers of the committee are: C. Rehmann (chair), D. Admiraal (vice-chair), M. Ansar, E. Cowen, W. Frizell, M. Muste, T. Nakato, K. Oberg, C. Rennie, J. Replogle, A. Schmidt, M. Stone, and T. Vermeyen.

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