



Measuring Point Velocities and Near-Bed Turbulence Parameters with an Acoustic Doppler Velocimeter in Environmental River Studies

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ABSTRACT

Mean point velocities and near-bed turbulence parameters may need to be collected at any location and depth in a river during sediment transport, erosion, and fisheries field studies. Handheld stream gauging instruments mounted on wading rods can be used to measure mean point velocities in shallow water, but cannot be used in deep waters or for collection of turbulence data. Acoustic Doppler velocimeters (ADV) can be used to measure point velocities and turbulence parameters in shallow and deep water systems and near to boundaries, but mounting these instruments for field usage can be challenging. To collect near-bed turbulence measurements in shallow water, a surveying tripod was used to mount, level, and position the ADV. In deep water systems, an ADV was mounted inside a hollowed section of a sounding weight lowered from a boom on a boat. The pros and cons of each of these mounts are discussed.

INTRODUCTION

During environmental river studies, mean point velocities and small-scale turbulence parameters may need to be collected at any location in the river from shallow, low velocity sections to deep, high velocity sections. Traditional stream gauging instruments cannot be used to collect field data in all river applications. Handheld velocity meters mounted on wading rods can be used to measure mean point velocities in shallow river sections, but cannot be used in deep waters and do not have sampling rates high enough to collect turbulence data.

Hot-wire and hot-film anemometers, particle-image velocimeters, and microscale profilers have all been used to measure near-bed turbulence, but their application adds complexity to data collection. Acoustic Doppler profilers have sampling rates high enough to measure turbulence, but side-lobe interference occurs in the 10% of the water depth closest to the boundary, including the logarithmic portion of the boundary layer of interest in near-bed sediment transport studies. As an alternative method, acoustic Doppler velocimeters (ADV) can be affixed to unique mounting systems in order to make these instruments a viable option for data collection in the field.

ADVs can measure three-dimensional point velocities and turbulence parameters in shallow and deep water systems at nearly any location in the water column and close to boundaries as long as air entrainment is minimal. At a fixed distance from the probe, an emitted acoustic signal reflects off of particles present in the water, providing a precise instantaneous reading at a “point” (i.e. sample volumes of about 0.01 in³). Since ADVs collect data at a sampling distance away from the receiver, ADVs are well suited for boundary layer studies.

ADVs typically have an accuracy of $\pm 1\%$ of measured velocity with a velocity range of up to 15 ft/s. With no zero offset, ADVs have excellent low-flow performance. In order to protect the transducers from incidental contact, ADVs with a 10 cm sampling distance are recommended. With data acquired at sampling rates up to 25 Hz, turbulence data can be collected with a 60 second sample. ADVs are readily available, easy to operate, and easy to process and interpret data.

Mounting the ADV to minimize instrument movement, vibration, and uncertainty in the measurement location poses some challenges in the field. Deployment mechanisms must also protect the delicate transducers on the ADV from damage caused by rocks at the bed and floating debris. Floating platforms produce excessive instrument movement in deep, high velocity river sections. Rigid, cantilevered beams produce instrument vibration that artificially increases turbulence readings (Dancey, 1990). Fixed deployment mounts do not easily permit collection of multiple data points.

River applications utilizing ADV instruments include sediment transfer studies (Baird et al., 2002 and Hilldale and Baird, 2002), erosion studies, and fish habitat studies. With a sampling rate of 25 Hz, ADVs can be used to collect small-scale turbulence parameters near sandy beds. Mean velocities and turbulent fluctuations (root mean square values) are used to calculate bed shear stress and shear velocity, fundamental parameters used to estimate sediment transport. During fish habitat studies, boat-deployed ADVs can be used to measure the mean velocity at the location of an observed fish.

SHALLOW WATER APPLICATIONS

In shallow depths, point velocities can be collected with acoustic or electromagnetic handheld stream gauging instruments on wading rods. In wadable river sections, the instrument can be held steady and the measurement location can be easily identified. However, since handheld velocity meters typically have a maximum sampling rate of 1 Hz, turbulence parameters cannot be measured with these devices.

A sturdy fixed mount with a moveable arm produces both the stability and flexibility needed to collect near-bed data. For sediment studies in shallow water, Reclamation researchers have used a surveying tripod to mount, level, and position the ADV for measurement of mean velocities and turbulence parameters (Figure 1). A staff gauge is attached to the surveying tripod at the top plate. The ADV is connected directly to the staff gauge pole in order to define the measurement depth. A “downlooking” ADV is secured in a mounting bracket by tightening the bolts on the clamp. A traditional staff gauge is used to measure the water depth at the measurement location. With a sampling distance of 10 cm, the ADV is able to measure velocities near to the boundary without disrupting the flow.

The surveying tripod is easily set up in shallow water. The level on the tripod is used to balance the support structure. In shallow depths, visual cues can be used to ensure proper instrument location. The greatest challenge with the tripod mount is minimizing scour around the legs of the tripod in a sandy bed. If scour is significant, the surveying mount can become uneven, altering the measurement location. Curved deflectors attached to the upstream face of the legs and metal plates underneath the legs can be used to minimize scour.



Figure 1 – Surveying tripod configured as an ADV mount for shallow water, near-bed measurements.

DEEP WATER APPLICATIONS

Handheld stream gauging instruments on wading rods typically cannot be used to measure point velocities in deep water. Even if the instrument cable and wading rod are long enough to reach the river bed from a boat, it is difficult to keep the wading rod upright in deep water. Therefore, an ADV mount was designed to deploy and protect the instrument for deep water applications.

The transducers on an ADV were mounted inside a hollowed section of a 50-lb sounding weight (Figure 2). The conditioning module of the probe was enclosed in a metal pipe with set screws holding the instrument to the mount. A boom with a pulley was secured to the inside of the boat to suspend the apparatus from a metal cable, similar to measurements taken by Kostachek and Church (1993). A winch with a counter was used to determine measurement depth. With the instrument directly connected to the sounding weight, the boat-deployed instrument orients to the dominant flow direction as long as there is no external interference (Figure 3). A heavy sounding weight keeps the cable vertical and taut, whereas a lighter sounding weight may lag downstream such that the cable is at an angle from the vertical.



Figure 2 – The sounding weight is hollowed out so the transducers are protected by the body of the weight.



Figure 3 – When the boom is lowered down toward the front of the boat, the sounding weight orients into the flow.

The water depth at the measurement location is determined by slowly lowering the sounding weight to the river bottom. The counter is used to raise the instrument off of the sand bed by the sampling distance of 10 cm. The logarithmic boundary layer profile can be estimated by raising the velocity meter slightly with each subsequent reading. Delicate down-looking acoustic transceivers are protected from incidental contact by the body of the weight. If possible, the boom should be designed so that the sounding weight rises completely out of the water to avoid dragging the weight and instrument on the bed as the boat comes into shore.

Prior to field use, calibration tests at Reclamation's Water Resources Research Laboratory were conducted to determine the influence of the sounding weight on velocity measurements (Vermeyen, 1998). Tests were performed with the ADV mounted inside of the weight and six inches below the weight. Results indicated that streamwise and transverse velocities were over 4% higher with the sounding weight near to the instrument due to flow acceleration around the weight, however, velocity fluctuations were not significantly affected by the presence of the weight. Vertical velocities were significantly affected by the sounding weight in the tests, so vertical velocities cannot be used to evaluate flow properties when this mounting system is used. Although studies are limited to a two-dimensional analysis, keeping the ADV attached to the sounding weight assures proper orientation, prevents rotation, and protects the transducers from damage.

Mounting the ADV inside of the sounding weight eliminates the issue of vibration from a rigid mounting system, however, maintaining instrument position due to boat movement is challenging. Keeping the boat steady, especially in high velocity or shear zones, requires a strong boat motor and a skilled boat operator. If velocities are low, the boat may be tied off closely to a tag line to minimize boat movement. Since the ADV must be connected directly to a laptop, an unmanned boat on a tag line is not possible. Another difficulty with deep water, near-bed measurements is the lack of visual cues in determining whether the instrument is obstructed by rocks or other obstacles on the bed. Despite these limitations and challenges, the sounding weight mount is a promising method for estimating near-bed velocity profiles and turbulence parameters in deep river sections.

CONCLUSIONS

ADV's can be used successfully in river studies to measure mean velocities and near-bed turbulence parameters in both shallow and deep water sections. Mounting instruments in the field is always site-specific depending on factors such as river velocities, depths, geometry, bed material, bed movement and debris type and quantity. However, more standardized methods for mounting ADV's in river studies can result in improved measurement accuracy and repeatability as well as reducing the time and cost of evaluations.

In shallow water, the surveying tripod provided a sturdy, adjustable platform for collecting data. In deeper water, the sounding weight technique allowed for reasonable estimates of velocities and turbulence. Further refinements of these mounts or creation of new mounts will improve the applicability of ADV's to environmental river studies.

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