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Venturi Solution for Measuring Flow at Flumes under Risk of Submergence

New measurement system provides accurate measurements for flat, open canals under a range of water level conditions.

What Is The Problem?

The ability to measure flow throughout a delivery system is key to managing water. Much of these flows are carried in open canals designed with flat slopes. Conventional structures, such as weirs or flumes, that measure these flows require a significant drop in water surface elevation from above to below the structure to provide accurate measurements. This water level drop can not be created at many locations where flow measurements are needed—without reducing the flow capacity.

Flat canal slopes maximize the area that water can be delivered under gravity flow. The energy required to move water in a canal is derived from the slope of the canal. The flat slopes create low flow velocities with limited erosion potential and lower energy losses in transit (as there is less friction). However, with these flat slopes, conventional flumes or weirs will often become excessively submerged (where the downstream water depth is over an allowable proportion of the upstream depth) and thus not be able to provide measurements.

Historically, stream gauging techniques have been used where conventional structures are not viable. Stream gauging can be a comparatively time-intensive process where flow velocity is determined for multiple segments of a cross-section location. A number of products (including acoustic-doppler technology) have become available to measure flows where conventional flumes and weirs cannot. Cost-effectiveness for agricultural water systems of the high-end products and observed inconsistent performance with some of the less costly products are concerns with these devices.

What Is The Solution?

This Science and Technology Program project used long-throated flumes with a two-level measurement system to obtain flow measurements even under highly submerged conditions. The approach section, reduced cross-section area and throat section of a long-throated flume must be shaped like a prism for enough distance so that flow lines become parallel. This enables flow measurements to be obtained by accurately measuring flows at both the approach and throat sections of the flume. This two-level measurement uses the same solution that is used for measuring flow with pipe venturi meters. The "venturi solution" is the simultaneous solution of the equations for conservation of mass and for conservation of energy.

The water level differential between the approach and throat sections of a highly submerged long-throated flume may be as little as a few hundredths of a foot. The comparatively complex computations required for the venturi solution coupled with this high need for a high degree of resolution to measure water levels prompted Reclamation engineers to develop an electronic system for level measurement and flow calculations.

Field tests using this measurement system were initiated at four sites in the Yuma Arizona vicinity in 2008. As field test data have verified, flow calculated using the venturi solution will be valid whether a flume is excessively submerged or not.

A field test site at the Unit B Irrigation District near Yuma

Who Can Benefit?

This measurement method for long-throated flumes could be used on practically any open channel conveyance system. It can be particularly cost-effective at existing long-throated flumes subject to occasional excessive submergence.

Where Have We Applied This Solution?

The four field test sites near Yuma, Arizona remain in operation. Three new venturi solution flumes were installed in 2009 at the Mohave Valley Irrigation District in western Arizona. A paper on this study was presented at a U.S. Committee on Irrigation and Drainage conference in Sparks, Nevada, in June, 2009.

Future Development Plans

Interested irrigation managers can view the laboratory submerged venturi flume facility at the Technical Service Center's (TSC) Hydraulics Lab or in the field. This technology is incorporated into TSC's Modern Methods of Canal Operations and Control and the Basic Principles and Developments in Flow Measurement courses.

More Information

http://www.usbr.gov/pmts/hydraulics_lab/pubs/PAP/PAP-0987.pdf

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