Incorporating Sharp-Crested Weirs into Irrigation SCADA Systems

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Background

Partially contracted sharp-crested weirs have been difficult to integrate into SCADA systems. Automated flow measurement and monitoring are key elements of modern irrigation SCADA systems. Many newer flow measurement technologies are developed with easy SCADA integration in mind, but older devices still make up a significant part of most district’s flow monitoring network.

Sharp-crested weirs of many types are common water measurement structures throughout the world. When they are installed in a fully contracted flow condition, most have simple rating equations, so with the addition of a water level sensor they can be easily incorporated into a SCADA system. Fully contracted flow occurs when the approach channel is sufficiently large that the flow and sidewalls of the approach do not influence the flow through the weir opening (i.e., the flow contraction is the same as it would be if the box were of infinite size).

Sharp-crested weirs that have a restricted approach channel (weir box is too narrow or too shallow) experience “partially contracted” flow. This changes the discharge coefficient of the weir, making standard laboratory calibrations inaccurate, because they assume fully contracted flow. The weir will deliver more water than the amount that is measured.

Application to Rectangular Weirs

\[ Q = C \left( \frac{2}{3} \right) \left( \frac{h_g b h^3}{e} \right) \]

\[ h = h + K_b \]

\[ h = h + K_h \]

\[ (K_b = 0.001 \text{ m for all cases}) \]

Kindsvater-Carter Calibration Method

Method accounts for changes in weir performance caused by partial contraction

The Kindsvater-Carter method is based on straightforward rating equations that incorporate three factors, \(C\), \(K_b\), and \(K_h\), which are determined graphically from charts showing their variation as a function of various dimensionless ratios of weir parameters. The method has been adopted by several organizations as the most accurate method for calibrating sharp-crested weirs with full or partial contraction. The method is described in Reclamation’s Water Measurement Manual, and in many other flow measurement texts and standards.

Application to V-Notch Weirs

\[ Q = \frac{8}{15} \left( \frac{2 g \tan \theta}{h^2} \right) \]

\[ h = h + K_b \]

\[ h = h + K_h \]

The first three types of weirs can be calibrated for either fully or partially contracted flow (Kindsvater and Carter 1957). The last two can only be calibrated for fully contracted flow. Although Cipoletti weirs are not addressed by the Kindsvater-Carter procedure, the spreadsheet does adjust Cipoletti weir calibrations for velocity of approach using a procedure described by Box (1989). V-notch weirs with included angles other than 90° can only be calibrated in fully contracted conditions, because there is little laboratory data on partially contracted flow through these weirs.

Use of the Spreadsheet

The user chooses the weir type and enters basic weir and approach channel dimensions into the spreadsheet, along with the expected range of operating heads. After each entry is made, the spreadsheet determines whether the weir can be calibrated, and whether it is fully or partially contracted. The user is given suggestions to assist them in achieving a design that can be calibrated.

Once the dimensions are entered, the rating table can be generated by clicking the Recalculate Rating button. The spreadsheet also uses the rating table data to generate a power-curve type rating equation by regression analysis. The rating tables, rating curves and rating equation can all be printed easily.

Unlike typical compiled stand-alone applications, the working parts of a spreadsheet model are usually fully accessible to the user. To prevent accidental modification of its computational algorithms, the spreadsheet has been protected using standard security features in Microsoft® Excel. A complete description of the procedure used to apply this protection is given in the paper included in the conference proceedings.

Obtaining the Spreadsheet

The USBRWeir.xls spreadsheet is freely available to the public from the Bureau of Reclamation’s Water Resources Research Laboratory through our web site, at http://www.usbr.gov/pmts/hydraulics_lab/usbrweir/index.html