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Are Your Open-Channel Meters Accurate?
How a $5,000 meter saved a city $300,000

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The City of Lowell, Massachusetts installed an area-velocity meter to supplement an existing flume as part of its CSO reduction plan. To the city's surprise the two provided significantly different readings when measuring flow. This result begged the question: Which one was correct, the flume that had been installed 25 years earlier, or the new area-velocity meter? With billing of $25,000 per month between Lowell and neighboring Tewksbury, the stakes were high.

During high flow conditions, Lowell would use its collection system as temporary storage by adding downstream control structures. This storage would cause a controlled back-up in the system, calculated to submerge the 24-inch Parshall flume at the Burnham Road Metering Station. Since area-velocity meters can measure submerged flow easily, the city, along with design engineer Maguire Group Inc., added the Isco area-velocity meter to this station. The flume would provide the primary read during normal flow conditions, while the area-velocity meter would provide the read during submerged flow conditions. Submergence would be determined by reading level at two points of the flume (Ha and Hb) and allow a PLC to use a standard flume calculation.

The area-velocity meter was installed during normal dry-weather flow conditions. Once good readings were established, the project team looked for correlation between the existing flume and the new area-velocity meter; however, the area-velocity meter read nearly double the flow rate of the flume. The project team assumed the Parshall flume was the standard by which the newcomer should be judged, yet the area-velocity meter's readings were strong, and the onboard diagnostics indicated dependability.

If the area-velocity meter was right, the flume had to be wrong. The team looked for clues that this may be the case. The first visual clue was the approach pattern to the throat of the flume (see figure 1). Flumes require that "The approaching flow should be well distributed across the channel, and relatively free of turbulent waves. Generally a site with high velocity of approach should not be selected [Isco Open Channel Flow Measurement Handbook, fifth edition, p. 65]." Standing waves, as seen in the approach of this flume, indicate either an improper approach velocity or flow in excess of the flume rating. This was enough to merit an investigation by Lowell's engineers and a third party flow expert.

Additional Check Points

Assuming a flume or weir metering site is accurate can be costly for the biller or the customer. Flume or weir flow measurement systems can be quite accurate but must be used within their sometimes narrow range of proper conditions. If the conditions for the flume or weir fall outside their capability, the resultant inaccuracy is almost impossible to predict. Beyond a normal, periodic calibration check of the flow meter, consider doing one or more of the following:

- Install another flow meter in series with your existing meter
  - Area-velocity meters are portable and fairly easy to install
    - These are available to lease
  - Flow service professional service companies can install one for you on a temporary basis
    - Make sure it is installed correctly
  - Choose an accurate one
    - This means stable, accurate level
    - This means true average velocity
- Perform a dye dilution calibration of the flow
  - This is done in-situ
  - Will require the services of a specialty company
  - Considered to be +/- 2% accurate
- Perform a thorough visual inspection of the metering site
  - Read-up on the right visual clues in an engineering handbook (such as the Isco Open Channel Flow Measurement Handbook)
  - If in doubt, contact your engineering firm or a flow service professional organization

Camp Dresser & McKee Inc. (CDM), the city's CSO program consultant, prepared an engineering memorandum summarizing its observations of the current flow conditions. According to CDM's report: "The primary flow element is a conventional manufactured Parshall flume. It has a 2-foot throat, with dimensions matching a conventional flume and is installed level and straight. The flow enters the station through a 48-inch-diameter pipe.

Figure 1. Flume throat

The plans for the original installation show the pipe entering the vault at an angle of 8 degrees 30 minutes with a slope of 0.00031. Measurements taken on August 9 indicate the angle is about 4 degrees, 43 minutes and the slope greater than 0.007. The invert of the pipe and the floor of a transition section before the flume are at the same elevation as the flume inlet section. The floor of the transition section is also very close to level."

CDM noted the measured slope was 20 times greater than the designed slope and the transition from the Tewksbury interceptor to the flume was skewed, causing an imbalance in the approach velocity pattern (Figure 2). The CDM report also noted the level transmitters being used at the flume were out of calibration. It verified that the specifications of the area-velocity meter matched this project's requirements and its settings were proper for this installation.

The Maguire Group made a series of measurements to confirm the observed flume problems. Physical measurements started with velocities across the channel at two locations: 5 feet upstream of the flume and at the flume's flow (level converted to flow) measuring point (Ha). The measurements confirmed the flow was in the "super critical" regime. According to Maguire Group's report: "The definition of sub and super is most easily remembered as related to the critical depth line of any channel for a 'given' flow rate. In hydraulics of open channel flow, this means that there are 'two' possible depths in any channel for any 'given or same' flow, one above the critical depth line and one below. In other words, the unintended supercritical flow condition had caused the depth measurement at Ha of the flume to correlate to the wrong flow rate."

To visually prove that the approach velocity was causing the inaccuracy, Maguire Group held a large wooden board in the upstream flow approach to dissipate the energy (see Figure 3). The results were a dramatic and almost instant increase of the flume flow reading to agree with the area-velocity meter.

An independent third-party expert in flow measurement, Flow Assessment Services, reviewed the CDM and Maguire Group reports. FAS suggested installing a third meter to see if it would correlate with either of the first two meters. FAS selected, with the client's approval, the Isco area-velocity meter. After careful installation of the meter, and a thorough measurement of the pipe I.D., the readings of the temporary area-velocity meter matched the existing area-velocity meter. The temporary check meter was left in place for 60 days, and the readings were posted on an Internet site for the convenience of all parties. The results were conclusive: the two area-velocity meters agreed, and the existing flume agreed with these readings when the upstream velocity problems were addressed.

Figure 2. CDM picture of imbalanced approach velocity pattern

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Figure 3. Maguire Group's temporary energy dissipater

Figure 4. ISCO area-velocity meter probe

The project team thus set out to increase the accuracy of the existing flume, and eventually supplemented the area-velocity meter with a redundant ultrasonic meter. Two independent level measurements tracked well, giving the team assurance in those readings. The velocity readings provide good diagnostics, so both sides of the Q=V*A basic flow equation were satisfied with reliable readings. Unlike the flume, the area-velocity meter provided a wider range of flow measurement from low flow through surcharge conditions. ■

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