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Open Channel Flowmeters

By Brian Dawson, Isco, Inc.

Open channel flow is defined as flow in any channel in which the liquid flows with a free surface. Examples include rivers and irrigation channels. Certain closed channels such as sewers, when flowing partially full and not under pressure, are also classified as open channels.

Open channels are used to conduct liquids in most sewer systems, sewage treatment plants, industrial waste applications, and irrigation systems.

There are three methods for automatically measuring open channel flow.

- Hydraulic Structures
- Area Velocity
- Slope-Hydraulic Radius

Hydraulic Structures

The most common method of measuring open channel flow is the hydraulic structures method. A calibrated restriction inserted into the channel controls the shape and velocity of the flow. The flow rate is then determined by measuring the liquid level in or near the restriction.

The restricting structures are called *primary measuring devices*. They may be divided into two broad categories–weirs and flumes.

A *weir* (Figure 1) is an obstruction or dam built across an open channel over which the liquid flows, often through a specially shaped opening. Weirs are classified according to the shape of this opening. The most common types of weirs are the triangular (or V-notch) weir, the rectangular weir, and the trapezoidal (or Cipolletti) weir.

The flow rate over a weir is determined by measuring the liquid depth in the pool upstream from the weir.

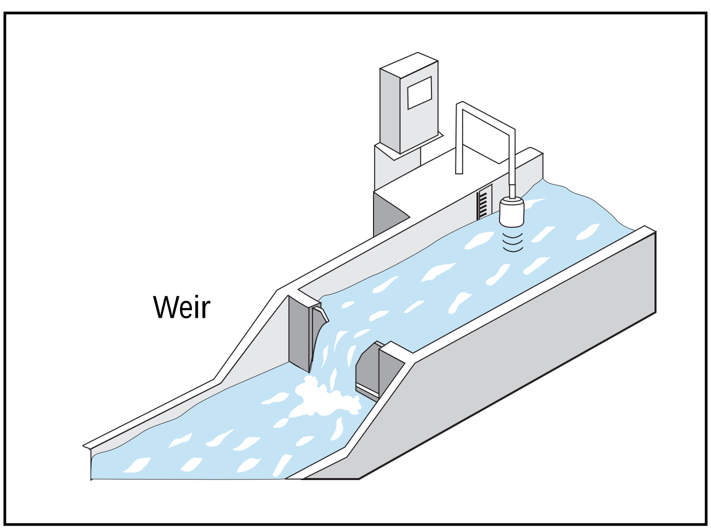

Figure 1. Non-contacting ultrasonic sensors are often used to measure the level upstream from a weir.

Weirs are simple and inexpensive to build and install. Common materials of construction include metal, fiberglass and wood. However, they represent a significant loss of head, and are not suitable for measuring flows with solids that may cling to the weir or accumulate upstream from it.

A *flume* is a specially shaped open channel flow section providing a restriction in channel area and/or a change in channel slope. The flow rate in the channel is determined by measuring the liquid depth at a specified point in the flume.

The most common flume is the *Parshall flume* (Figure 2). The flow rate through a Parshall flume is determined by measuring the liquid level one third of the way into the converging section.

Parshall flumes are designated by the width of the throat, which ranges from one inch to 50 feet. The throat width and all other dimensions must be strictly followed so that standard discharge tables can be used. Also, note the drop in the floor of the flume, which makes it difficult to install a Parshall flume in an existing channel.

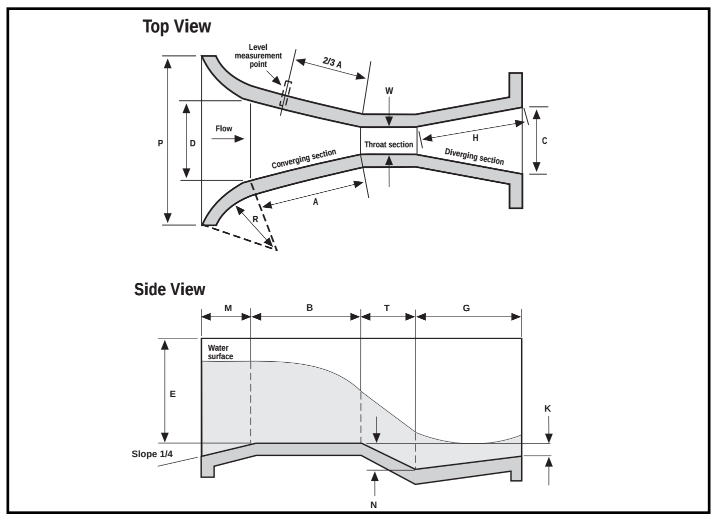

Figure 2. Parshall flumes are self-cleaning and measure a wide range of flow rates.

In contrast, the *Palmer-Bowlus flume* (Figure 3) is designed to be installed in an existing channel with minimal effort. The flow rate through a Palmer-Bowlus flume is determined by measuring the liquid depth at a point one-half pipe diameter upstream from the flume throat.

Palmer-Bowlus flumes are designated by the size of the pipe into which they fit. Standard sizes range from four to 42 inches. The dimensional configuration is not rigidly established for each flume size. However, a Palmer-Bowlus flume with a trapezoidal throat with a flat bottom has emerged as the standard design for circular pipes.

Flumes are more expensive and more difficult to install than weirs. Common materials of construction include fiberglass, concrete and metal. However, flumes result in a lower head loss and are self-cleaning, requiring less maintenance than a weir.

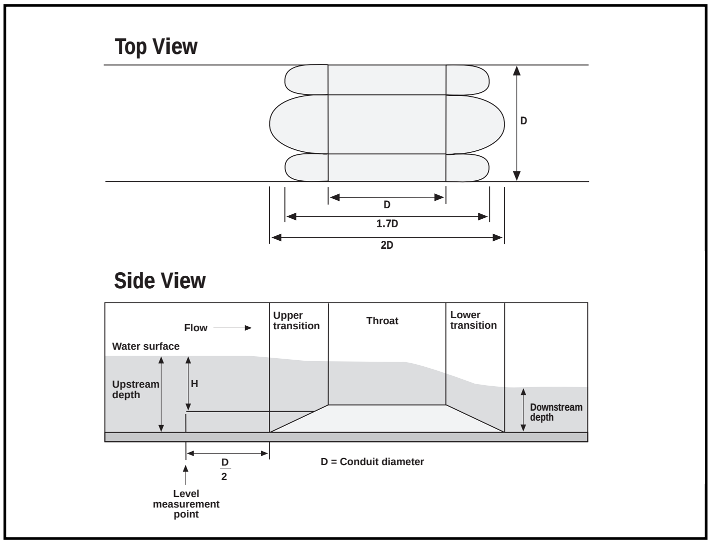

Figure 3. Palmer-Bowlus flumes are designed to be installed in existing channels with minimal effort.

Preferably, weirs and flumes are installed so that *non-submerged flow* exists, that is, so that downstream conditions do not affect the flow rate through the primary device. This allows the flow rate to be determined by making a single level measurement. If *submerged flow* occurs, both upstream and downstream levels must be measured, and reference made to submerged flow tables.

A *secondary measuring device*, or open channel flow meter, is used in conjunction with a primary device to measure the rate of flow in an open channel. The flow meter measures the liquid level at one point in the channel, and then converts this measurement into flow rate based on the known level-to-flow rate relationship of the weir or flume.

There are a number of technologies for measuring the level in the channel. The most common are *ultrasonic sensors, bubblers* and *submerged pressure transducers*. Most modern open channel flow meters use software to convert the measured level into flow rate.

Area Velocity

The *area velocity* method calculates flow rate by multiplying the area of the flow by its average velocity. This is often referred to as the continuity equation, Q=AxV.

For convenience, most area velocity flow meters use a single sensor to measure flow rate (Figure 4). *Doppler ultrasonics* is used to measure average flow velocity, while an integral

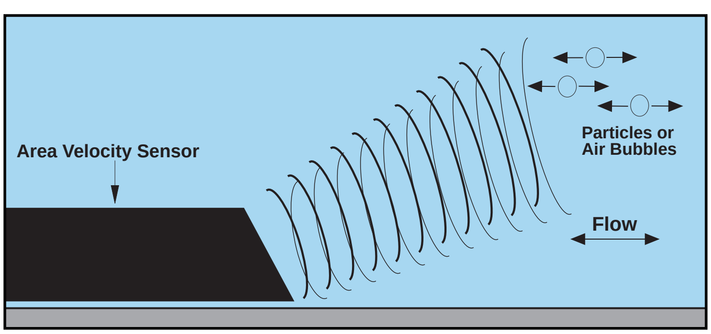

Figure 4. Area velocity flow meters commonly use Doppler ultrasonics to measure average flow velocity.

pressure transducer measures the level in the channel. The flow meter converts this level into the area of the flow based on the size and shape of the channel.

The main advantage of the area velocity method is that it can be used to measure flow under a wide range of conditions.

- Open Channel
- Surcharged
- Full Pipe
- Submerged
- Reverse Flow

In addition, the area velocity method does not require the installation of a weir or flume.

Slope-Hydraulic Radius

Various resistance equations are used to estimate flow rate based on measurements of the water surface slope, cross-sectional area, and wetted perimeter over a length of uniform channel. The most popular of these equations is the *Manning formula* (Figure 5):

$$Q = \frac{K\ A\ R^{2/3}\ S^{1/2}}{n}$$

where: Q = flow rate
A = cross sectional area of flow
R = hydraulic radius (cross sectional area divided by wetted perimeter)
S = slope of the hydraulic gradient
n = roughness coefficient based on channel material and condition
K = constant dependent upon units

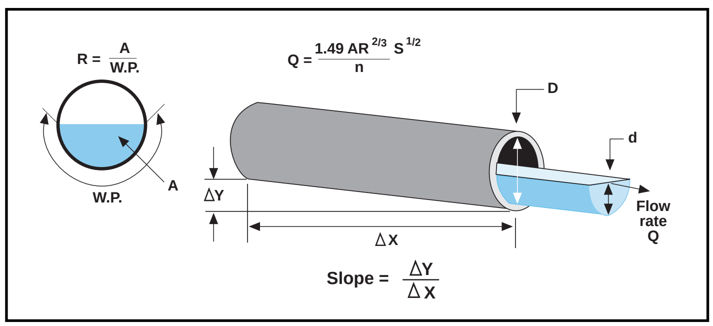

Figure 5. The Manning formula estimates flow rate based on the area and hydraulic radius of the flow, and the slope and roughness of the channel.

The cross-sectional area A and the hydraulic radius R are calculated based on the liquid depth, and the size and shape of the channel. The slope S is often estimated based on installation drawings of the channel. The roughness coefficient n is selected from standard references based on the material of construction of the channel, and its condition.

Given the size, shape, slope and roughness of the channel, an open channel flow meter can calculate flow rate using the Manning formula based on a measurement of the liquid depth.

The Manning formula is not as accurate as the hydraulic structures and area velocity methods, but it can provide sufficient accuracy in some applications. In addition, no weir or flume is required.