Pollution Engineering

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MEETING THE ENVIRONMENTAL CONCERNS FOR AIR, WATER AND WASTE

Doppler Technology Captures Open Flow

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Accurate, reliable measurement of flows in municipal sewer systems is essential for effective management of routine wastewater operations as well as infrastructure planning and regulatory compliance. A flow monitoring program helps to adequately understand the condition and performance of a collection system under varying conditions for both short- and long-term needs.

However, simply collecting and processing flow data is not enough. The phrase "garbage in, garbage out" applies here; the information derived from flow data is only as good as the data collected from the flow stream. This article focuses on some of the critical concerns in deploying area velocity flow monitoring equipment to collect accurate, reliable measurement data in a cost effective manner.

Measuring open channel flow

Open channel flow is constrained liquid flowing with a free surface. Rivers and uncovered conduits are obviously open channels, but enclosed channels such as sewers, when flowing partially full and not under pressure, are also classified as open channels. The three most common methods for continuous measurement of open channel flow are:

- Hydraulic structures
- Slope-hydraulic radius
- Area velocity

A restrictive hydraulic structure (primary device) in the channel, such as a weir or flume, controls the flow's shape and velocity. A secondary device used in conjunction with the primary device measures the liquid level and converts this into an appropriate flow rate, based upon the known level to flow relationship of the primary device.

In some situations, the flow conduit itself serves as the primary device. A resistance equation, such as the Manning formula, is used to estimate flow rate based on the channel shape, dimensions, slope and a roughness coefficient that represents the friction the conduit material exerts on flowing water. Generally speaking, this information is configured into the monitoring instrument and used with fluid depth measurements to calculate flow rate.

The main advancement in open channel flow measurement technology has been the evolution of instruments that use the area velocity method. An area velocity flow meter is configured for channel shape and dimensions but there is no need for variables such as slope or roughness coefficients. The depth of flowing water is measured at a specific point and then the instrument calculates the cross-sectional area of the flow

...ment Technology ...System Studies

By Kaushal Trivedi and Diane K. Walkowiak, M.A.

stream at that point. The average velocity of the flow is measured at the same point, and the meter multiplies the area (A) of the flow by the average velocity (V) to calculate flow rate (Q). This is represented by the continuity equation, Q = A x V.

Area velocity flow meters measure flow velocity using technologies such as Doppler ultrasonics, electromagnetics and transit time. There are variations within these types, specifically in the Doppler systems. Most commonly, a flow meter has a single sensor that uses Doppler technology to measure flow velocity and a built-in pressure transducer to measure level. This level is converted into the area of the flow based on the channel's size and shape [**see Figure 1**].

The area velocity method can be used where weirs and flumes are not practical, and is generally less expensive to install than a primary device. An area velocity flow meter can accurately measure flow under a variety of conditions:

- Open channel
- Surcharged
- Full pipe
- Submerged
- Reverse flow

Because of their versatility and cost effectiveness, area velocity flow meters have become a common solution for monitoring flow in collection systems.

Site selection

Selecting the most relevant and suitable flow monitoring site is critical for obtaining useful data. Without going into too much detail here, a review of collection system maps and preliminary field inspections, and a thorough analysis of the goals of the monitoring program, are some of the determining factors in site selection.

Site conditions are another important component in getting the most out of a monitoring program. To calculate distances of straight-run pipe upstream from the point of measurement, the rule of thumb is ten pipe diameters upstream, although site-specific conditions can have an impact on this figure. Try to monitor in locations that have a smooth, laminar flow. Attempting to measure at locations with significant turbulence or swirling will likely compromise data quality. Flow meter manufacturers should be able to provide technical data and support in evaluating site conditions.

Data collection

Site selection greatly impacts the quality of flow data, but there are also features to look for in a flow meter and sensor that will ensure accurate data collection. A few factors to consider when evaluating area velocity flow meters are:

• *Durability* – For long-term, dependable operation, the sensor needs to be mechanically durable as well as resistant to fouling by oil and grease, and to attack by chemicals in the flow stream. The design of the sensor itself is important. A low-streamlined profile minimizes the effect of debris and obstructions. If the flow meter itself is installed where it is subject to submersion, such as in a manhole, the enclosure should be rated NEMA 6P, IP68.

• *Drift* – Drift in the level measurement adds inaccuracy to the total flow calculation. Various factors can cause drift, such as calibration errors, temperature changes and electrical noise. All manufacturers recommend spot calibrating the sensor for level reading in the field. Generally speaking, a microprocessor-based sensor will be immune to the typical sources of drift.

• *Span Calibration* – In addition to spot calibration, some manufacturers' flow meters require span calibration specific to the installation site, which means recalibrating each time the equipment is moved to a different site or the spot calibration is revised. A sensor that requires a single-point calibration minimizes inaccuracies due to calibration error, makes field installation a more efficient process, and should be a preferred option.

• *Temperature* – Changes in temperature can affect the level reading too. A typical specification for temperature error is 0.004 feet per degree of Fahrenheit, resulting in more than a 1-inch change in the level reading if the temperature varies 25 degrees. Large variations in temperature are more common in industrial wastewater than in residential trunks. Microprocessor-based sensors using an established temperature compensation algorithm will minimize the effects of temperature fluctuations and any resulting errors in flow data.

• *Electromagnetic Interference* – The method of communication between the instrument and sensor is another factor to consider. Transmission of analog signal data is generally more susceptible to the effects of electromagnetic noise. Digital communication between the sensor and instrument will reduce, if not eliminate, the effects of noise and avoid compromising data quality.

• *Doppler Wavelength* – Consider the ultrasonic frequency of area velocity sensors using Doppler technology. A higher frequency signal is better suited for ultra-clean water applications, although the overwhelming majority of applications do not involve ultra-clean water. A lower frequency will provide a more representative velocity measurement in dirty water because it penetrates the flow to a greater distance and thus returns a reflected signal representing the average velocity over a wider area. However, if the frequency is too low, the sensor will require an abundance of reflective particles in the flow in order to obtain a measurement. A sensor that uses an intermediate frequency is able to balance between these extremes.

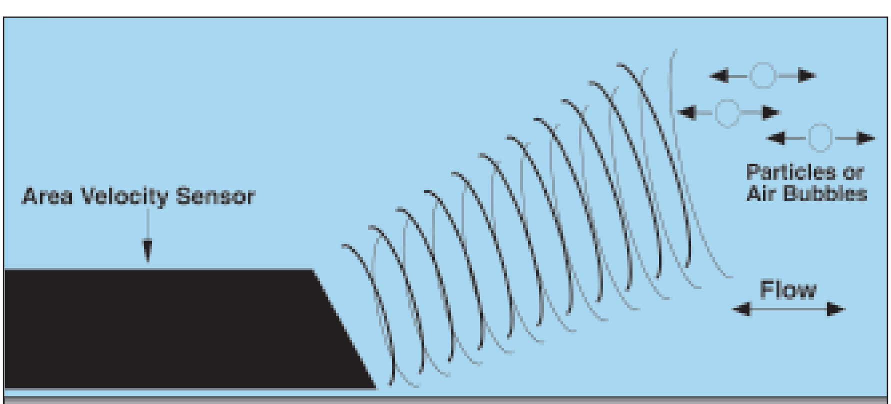

Figure 1: A sensor using Doppler technology transmits a sound wave into the flow and measures the frequencies of the sound waves reflected by air bubbles and particles in the flow.

Data storage

Data that span a substantial period of time will be the most valuable for characterizing flows in a collection system. Ideally, data that include multiple rain events of varying intensities provide the best assessment of overall or singular-event inflow and infiltration response. Such data also provide a better understanding of average daily and peak flows for both wet and dry periods.

Factors to keep in mind for data storage are:

• *Storage Capacity* – A large data storage capacity reduces the risk of data loss due to full memory. The ability to store several months' worth of data can also serve as a backup in case data previously downloaded to a computer is lost or damaged. Rollover memory ensures that newer data is not lost.

• *Variable Data Storage Rates* – Under normal and repeatable conditions, longer data logging intervals will conserve both battery life and storage capacity. However, it is also important to maximize the collection of data during an exceptional event, such as a surcharge. This is possible with a flow meter that can be configured to alter the data storage interval when a predefined condition such as a level, flow or other parameter threshold occurs. A variable data storage rate provides maximum information about an event due to the increased data resolution with the more frequent measurements. Power and memory are conserved during normal conditions using a less frequent storage interval, while still getting the best understanding of exceptional events with more frequent measurements.

• *Security* – Data storage must be secure. For instance, data stored in dynamic RAM is lost if the power is interrupted, whereas using so-called "flash" memory to store data protects against loss in case of a power failure. When upgrading a system, the user should be able to download new operating software without adversely affecting the stored program or data.

• *Power Options* – Batteries are a recurring operational cost that can add up rather quickly through multiple sites and meters. Carefully examine the number and type of battery required, along with life expectancy. For a flow meter taking readings at 15-minute intervals, battery life typically ranges from two to 15 months, depending on the manufacturer. Equipment should have some method of informing the user of battery voltage and remaining capacity, in order to determine when to change batteries. Also, the instrument should have a means to stave off the ultimate depletion of battery power and thus continue to measure under low power conditions. An instrument with a variable data rate storage capability should be able to reduce measurement frequency under low power conditions and thus elongate battery life until batteries can be replaced.

• *Secondary Flow* – Some area velocity flow meters have the ability to use a secondary flow conversion, such as the Manning formula. This provides a readily available reference to which the user can compare primary flow data.

Data retrieval

The ability to use different communication options to retrieve and transfer data can provide significant operational cost savings. In addition to directly connecting to the flow meter, the user should be able to retrieve data remotely using a land line modem, cellular phone and/or a wireless modem. Remote data retrieval reduces the exposure of field crews to confined space entry and the hazards of servicing monitoring sites in the midst of high traffic areas. Aside from safety issues and cost savings, remote control offers the convenience of downloading data directly to a computer in a vehicle or office.

An increasingly desirable capability is direct transfer of flow meter data to a SCADA system or process control network using communication protocols such as Modbus. This capability is crucial where flow data is used for real-time operational control.

Future expansion

A flow meter system should be adaptable and upgradeable to meet evolving needs. Does the flow monitoring equipment allow a user to easily add options or modify existing components within the system in the field? This flexibility is important when a monitoring program involves portability, i.e. equipment is moved from site to site, yet offers advantages to permanent monitoring applications as well. **PE**

For more information about flow meters, please contact Kaushal Trivedi, flow meter product manager at Teledyne Isco Inc. at (800) 228-4373, e-mail ktrivedi@teledyne.com, or visit www.isco.com

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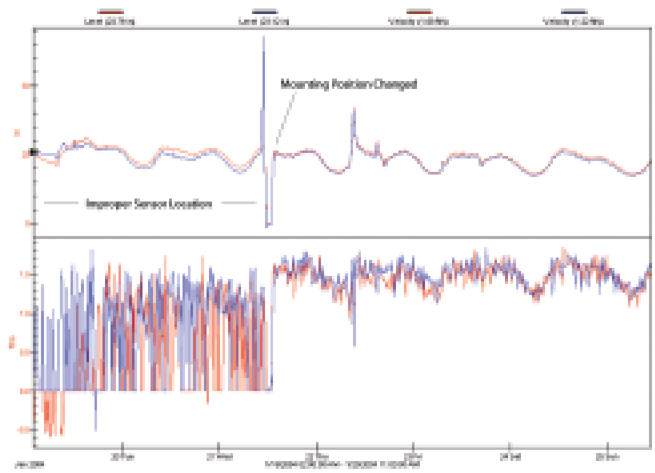
The Importance of Quality Flow Data Analysis

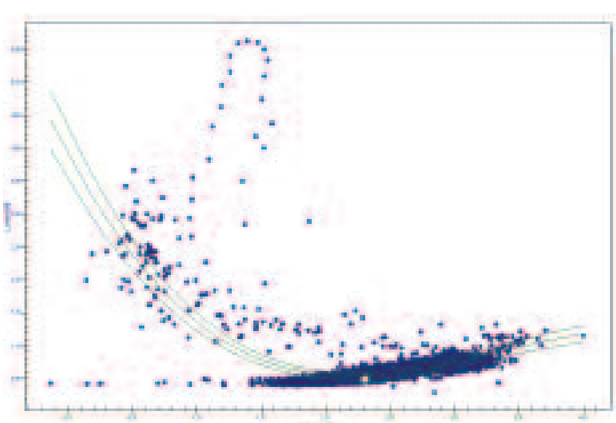
A beneficial flow monitoring program begins with having dependable, first-rate instruments in the field. Site selection, proper installation, and a solid data analysis program are also essential.

The graph to the right demonstrates the importance of a good installation. This data is the result of a redundant area velocity flow monitoring system. The first half of the graph shows sensors installed in an improper location. Although the pipe was cleaned when the sensors were first installed, there was a significant silt bed. The sensors were rapidly covered with sediment and it became difficult for the instrument to obtain any velocity measurements. Once this issue was identified, the mounting position of the sensors was raised above the silt bed, with dramatic results.

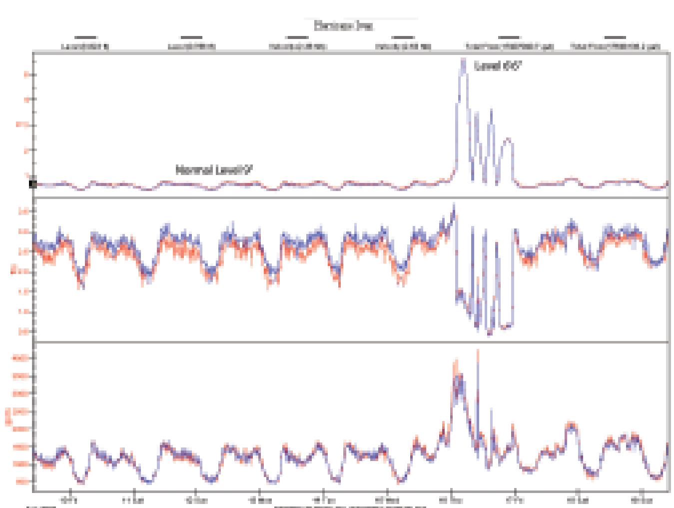


However, a poor analysis program will negate the best data collected from the finest instrumentation available, regardless of the care taken with site selection and installation. You need to accurately discern what your data is telling you.

Professional software will provide you with a variety of analytical tools, such as standard and comparative graphs, scatter plots, tables, reference curves, best fit curves, and summary reports to aid you in determining what your data actually means. The program should help you decide if and when corrective action is necessary, and make data correction a more accurate and logical process.



There is a program that will help you meet these needs: Teledyne Isco's Flowlink®5. All the graphs seen on this page where created using Flowlink®5. The scatter plot and the graph below indicate the performance of a customer's monitoring program under very dire circumstances: Hurricane Ivan. The scatter plot of a surcharge condition during the hurricane indicates that the system does not conform to conventional gravity flow conditions. Results like this inspire confidence in your analysis program!



Flowlink®5 is the most powerful and flexible analytical tool available for your flow monitoring data. Standard graph, table, and summary formats can be generated and saved that can then be applied to all sites with ease. Custom report formats can be quickly generated as well.

Automated functions provide multiple site analysis reports at the touch of a button. Data quality analysis is simple with the aid of a number of analytical tools. Editing and data correction can easily be performed with confidence from within Flowlink®5.