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TELEDYNE ISCO
A Teledyne Technologies Company

Diagnostic Evaluation of Wastewater Monitoring Site Conditions, Equipment Operation, and Data Quality

• white paper

Abstract

Reduction of municipal costs associated with sewer system construction and maintenance, as well as compliance with permit conditions and regulatory laws for wastewater collection and treatment, is dependent upon accurate flow measurement.

Adverse conditions and application issues at the flow monitoring site result in inaccurate flow data and costly errors. While scatterplot analysis of the flow data can provide a general indication of abnormal site conditions, it cannot yield a precise diagnosis, and may even indicate nonexistent problems. In the past, the only way to ensure that data retrieved from a site was reliable and that installation and system components were functioning as desired, was to physically travel to the site and inspect it.

Today, diagnostic verification of data quality provides an added layer of reliability. Teledyne Isco not only provides remote access to primary flow and water quality data, reducing the need for confined space entry; diagnostic data ensures the accuracy of the flow data, helping to diagnose potential problems in real time, as well as identify trends and patterns over longer periods.

Typical Issues in Wastewater Monitoring

Accuracy of flow data is dependent upon conditions at the site. The measurement device can be inhibited or even damaged if the site is unstable due to deterioration of old pipes, unrecorded pipes or manholes due to sewer easement after original construction, malfunctioning pumps or valves, accumulation of silt or debris, misalignment of mounting hardware, obstructions caused by broken pipes or tree roots, excessive solids within the flow, and many other possible factors, depending on site characteristics.

Solutions for each situation differ, and delayed or incorrect troubleshooting can result in significant losses of time and money. One of the largest and most costly challenges in wastewater monitoring is prompt detection of site-related problems, and subsequent accurate diagnosis.

A primary factor in troubleshooting and data validation is the instrument's diagnosis capabilities. This paper presents a brief description of how flow is measured using continuous wave Doppler technology, followed by a discussion of algorithmic features developed by Teledyne Isco, Inc. to utilize this measurement technology for quick and precise detection and diagnosis of site issues.

Continuous Wave Doppler Flow Measurement

Area velocity flow measurement is often expressed as the equation Q=A • V, where Q is the volumetric flow rate, A is the cross sectional area of the flow stream, and V is the average velocity of flow within that cross section. Area velocity flow measurement is achieved with Continuous Wave Doppler (CWD) technology, and without the use of a primary device.

CWD flow sensors measure velocity by transmitting an ultrasonic signal into the flow, and measuring the frequency shift of the return signal reflected back to the sensor off of suspended particles and entrained air within the stream.

Anomalous signal components may be produced by reflections off of rocks, pipe seams, eddies, and other elements not representative of the velocity of the stream.

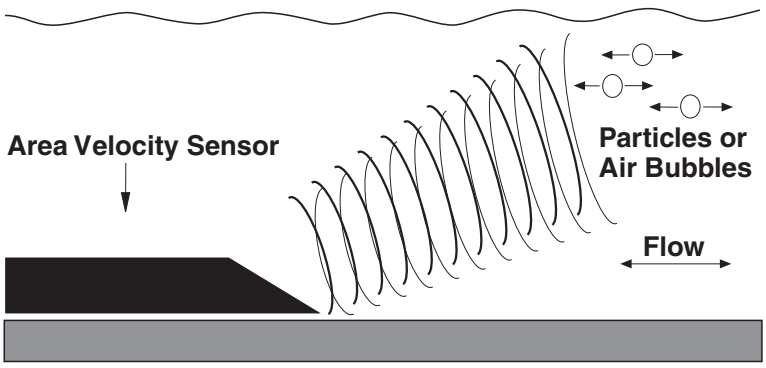


FIGURE 1. AV Sensor operation

An algorithm filters out inconsistencies from the signal, leaving the true velocity readings, which are then used to calculate the weighted average.

The sensor also contains a pressure transducer that measures the liquid depth. The flow meter calculates flow based on the cross-sectional area and velocity of the flow stream, combined with the flow depth.

Diagnostic Data from Continuous Wave Technology

In the past, only hours of diagnostic interpretation could give some measure of flow data validity, and indications of site conditions were even more obscure.

Teledyne Isco's 2150 area velocity flow module provides comprehensive data for level, velocity, and flow. In addition, tools have been developed for optimization of this technology, providing diagnostic data representative of signal qualities. This information can in turn be used to validate the flow data, as well as to evaluate channel conditions and installation stability.

The flow meter provides three distinct diagnostic data types: Signal Strength, Spectrum Strength, and Spectrum Ratio.

These diagnostic data types are available for real-time viewing along with the flow data, with Isco's 2150 continuous wave Doppler flow modules.

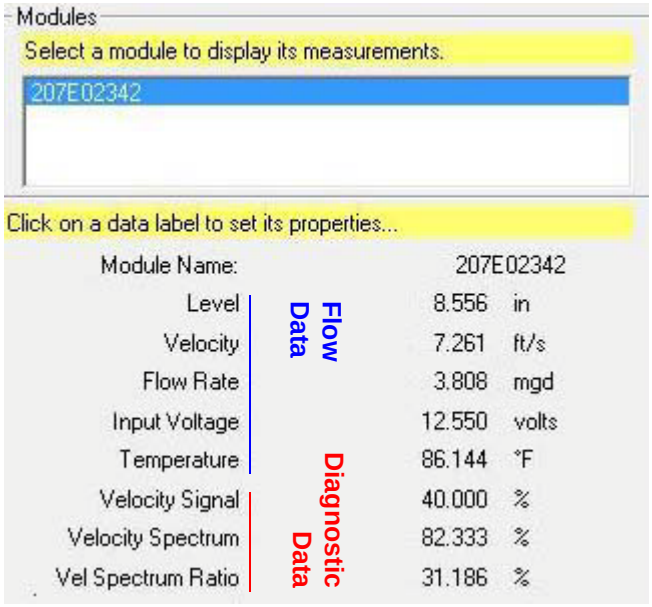


FIGURE 2. Text report displaying real-time flow and diagnostic data

Signal Strength

The **signal strength** represents the amount of signal returned after being reflected off of particles and air bubbles in the media.

Low signal strength is not necessarily an indication of a problem; it may simply be characteristic of a particular site, or an indication of unusually clear water (containing less reflective particles). More important than a specific value is consistency over time.

If the signal strength value suddenly decreases, or shows a steady decline over time, the channel may be in need of inspection for debris or fouling. Erratic signal strength values with wide variation from one reading to the next can indicate turbulence in the flow, or issues with the sensor's mounting/installation.

Spectrum Strength

The amount of valid data that remains after the non-velocity components have been filtered out is indicated by the **spectrum strength**. The higher this percentage, the greater the return of useful signal. For example, a spectrum strength of 55% indicates that 45% of the signal was filtered out.

A lower percentage indicates that there is a greater degree of noise in the return due to turbulent flow, large solids, overly clean water, or other factors that disrupt the velocity profile. If the spectrum strength is less than 20%, the flow meter will flag the reading with a spectrum error.

Velocity readings can still be accurate, even with low spectrum strength. As with signal strength, specific percentages are less important than consistency over time. A steady decline in these values is likely an indication of sensor fouling or sediment build-up within the pipe, while a dramatic change or sudden erratic readings would indicate the presence of large debris or loosening of the sensor's mounting.

Spectrum Ratio

Flows in the channel may be forward, reverse, or layered bi-directional flow, depending on channel and hydraulic characteristics. Continuous wave Doppler technology is capable of measuring velocity in either or both directions simultaneously. The ratio of positive to negative components received in the reflected Doppler signal is indicated by the **spectrum ratio**. The velocity reading will be either positive (forward) or negative (reverse), and the spectrum ratio will be between 0 and 100%.

A high spectrum ratio means that predominating reflected signal components are in the direction of flow indicated by the reported velocity reading. A low spectrum ratio is an indicator of swirling or turbulent flow, i.e., bi-directional signal components. A spectrum ratio of 0% would indicate equal negative and positive velocity components, which will likely result in a displayed velocity error.

Diagnostic Data Storage

The 2150 is also capable of storing this data for historical analysis, providing a readable graphical record of site performance and conditions, as well as early detection of potential problems. This added insight can mean the difference between costly design or repair, and a simple mechanical, programming, or location adjustment.

Interpreting the Data

Below is a graph of flow and diagnostic data retrieved and displayed via Isco Flowlink® software. In this example, the signal strength averages around 40%, while the spectrum strength averages around 60%. These values indicate that the site characteristics include lower than typical particle concentrations and very good hydraulics, and that conditions have remained relatively constant over a period of one week.

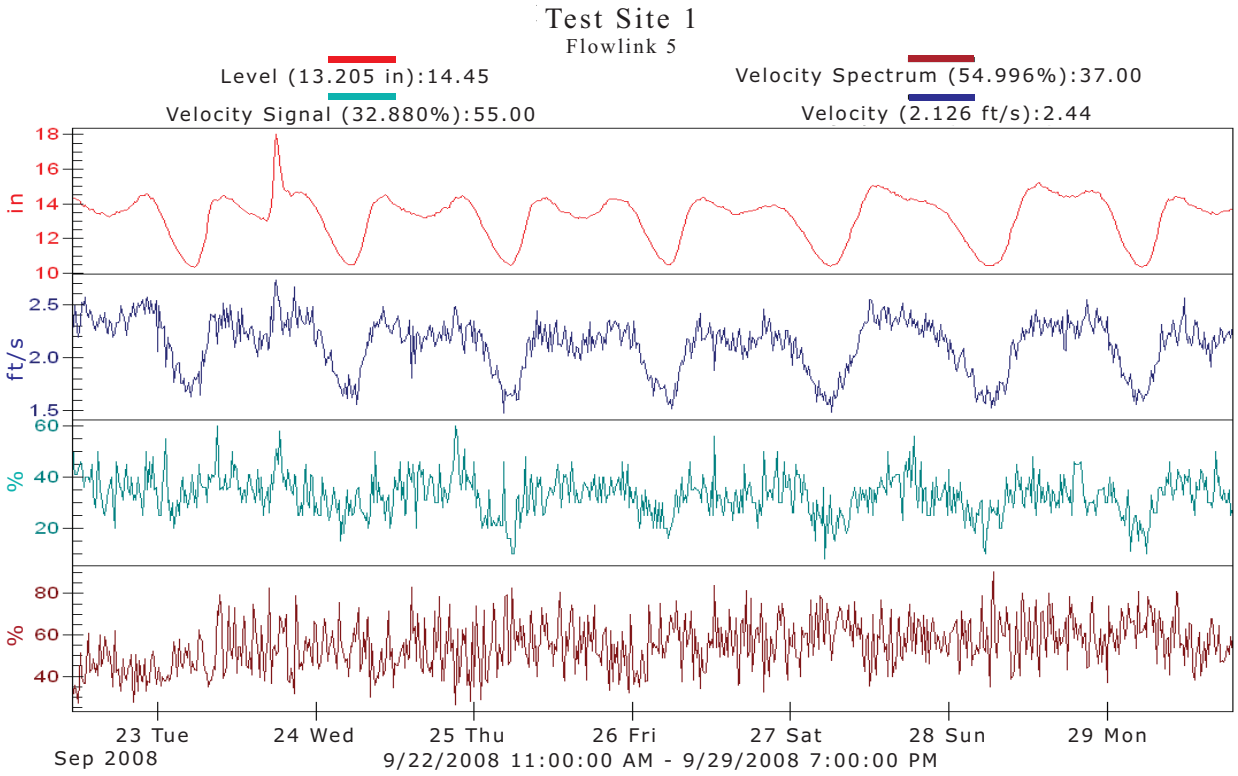


FIGURE 3. Diagnostic and flow data showing consistency over time

As noted previously, every site will have its own set of characteristics. Consistency of data values over time is generally more significant than the actual percentages. Detection and troubleshooting of site or equipment issues, as well as validating flow data over the same time period, can be made more exact by evaluating changes, whether abrupt or gradual, in the signal strength or spectrum strength, or in both. This diagnostic data can often quickly indicate whether or not equipment is installed properly, as well as whether or not the site itself is a suitable location for flow measurement.

Signal and spectrum data are normally adequate in determining proper meter performance, site conditions, and data quality. In some cases, spectrum ratio can also be used to diagnose site related issues.

Once the installation is in place and recording good data under normal conditions, this initial recorded flow and diagnostic data can serve as a reference against future data when determining what “normal” data should look like for a particular site.

Two general criteria should be kept in mind when evaluating diagnostic data for area velocity measurement:

- Signal strength is a good indicator of the amount of particle concentration in the flow. Even a weakened signal can yield velocity readings in suitable hydraulic conditions.
- Spectrum strength indicates how much of the return signal is actually used to calculate average velocity. Therefore, even a strong signal may not yield velocity readings if the spectrum is weakened due to hydraulic interference.

The following chart and corresponding table provide a general key for interpreting trends and anomalies in the signal and spectrum strength, with readings consistent over time.

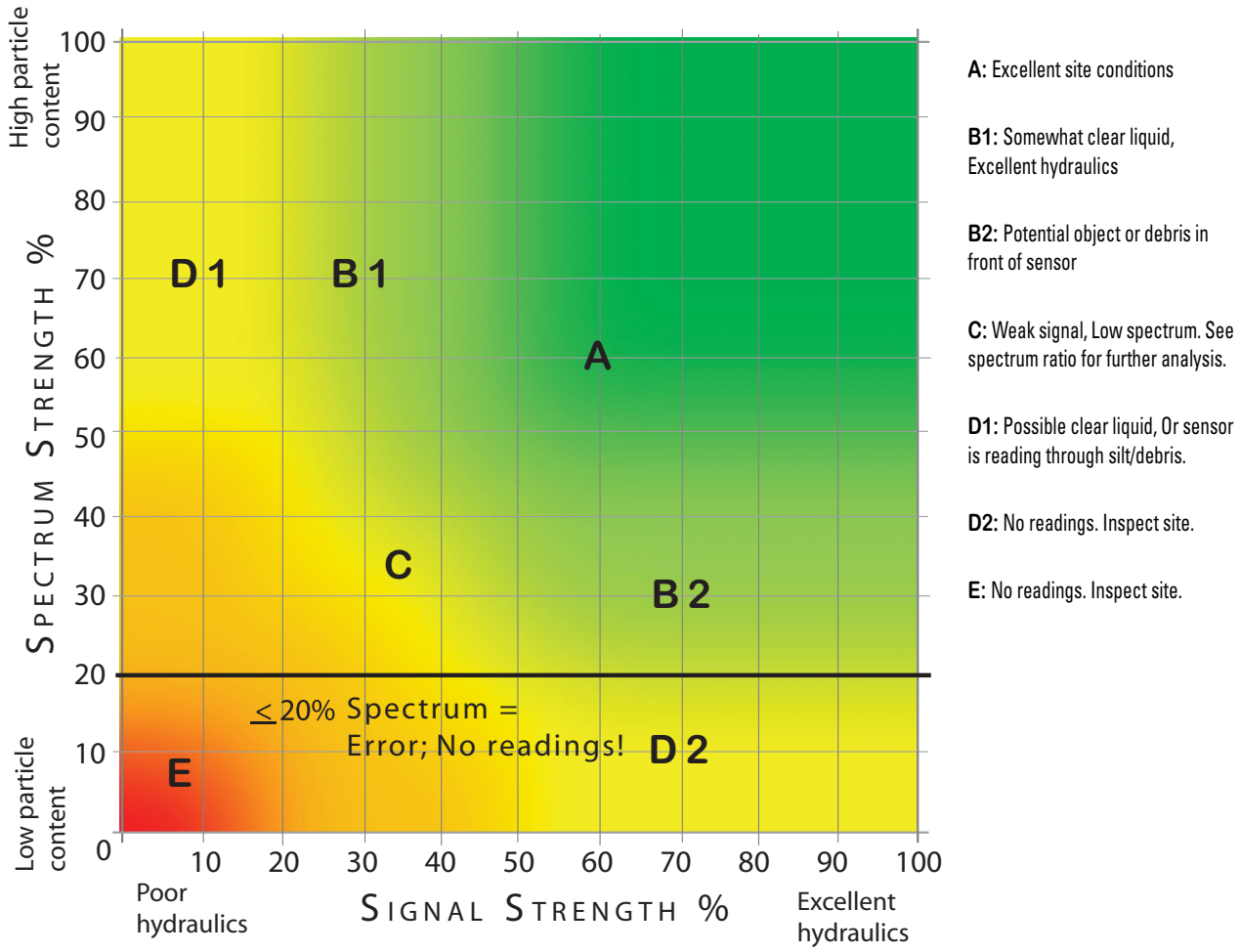
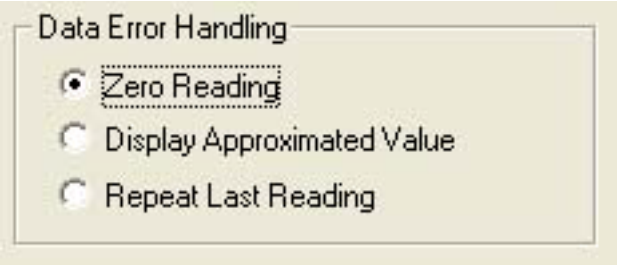


FIGURE 4. Area velocity signal and spectrum quality chart

Zero on Error

Diagnostic data is a powerful post-processing tool when viewed alongside corresponding flow data. In addition to other graphical and tabular properties, Flowlink software provides a number of ways to view problem areas in the flow data. The most commonly used property for handling questionable readings is the zero function, which helps to clearly distinguish them from the rest of the readings.



Following are examples of real monitoring site data where the addition of diagnostic data helps to remotely ascertain how site conditions are affecting the flow readings.

Example: Channel Obstruction

The graph below plots level and velocity, as well as signal strength, spectrum strength, and spectrum ratio, over a period of one week. Flowlink was configured to zero any velocity readings that produced an error. The velocity data (second pane) shows numerous drops to zero, suggesting that something is happening at the site to disrupt the velocity signal every time the water level falls below approximately 6.5 inches.

An even closer look reveals that the spectrum ratio (bottom pane) is low, averaging around 25.6%, dropping even lower when the level is below 6.5 inches. This suggests that there is some kind of obstruction in the channel, or that the sensor is positioned near a bend, causing constant swirling in the flow that becomes more pronounced when water levels drop.

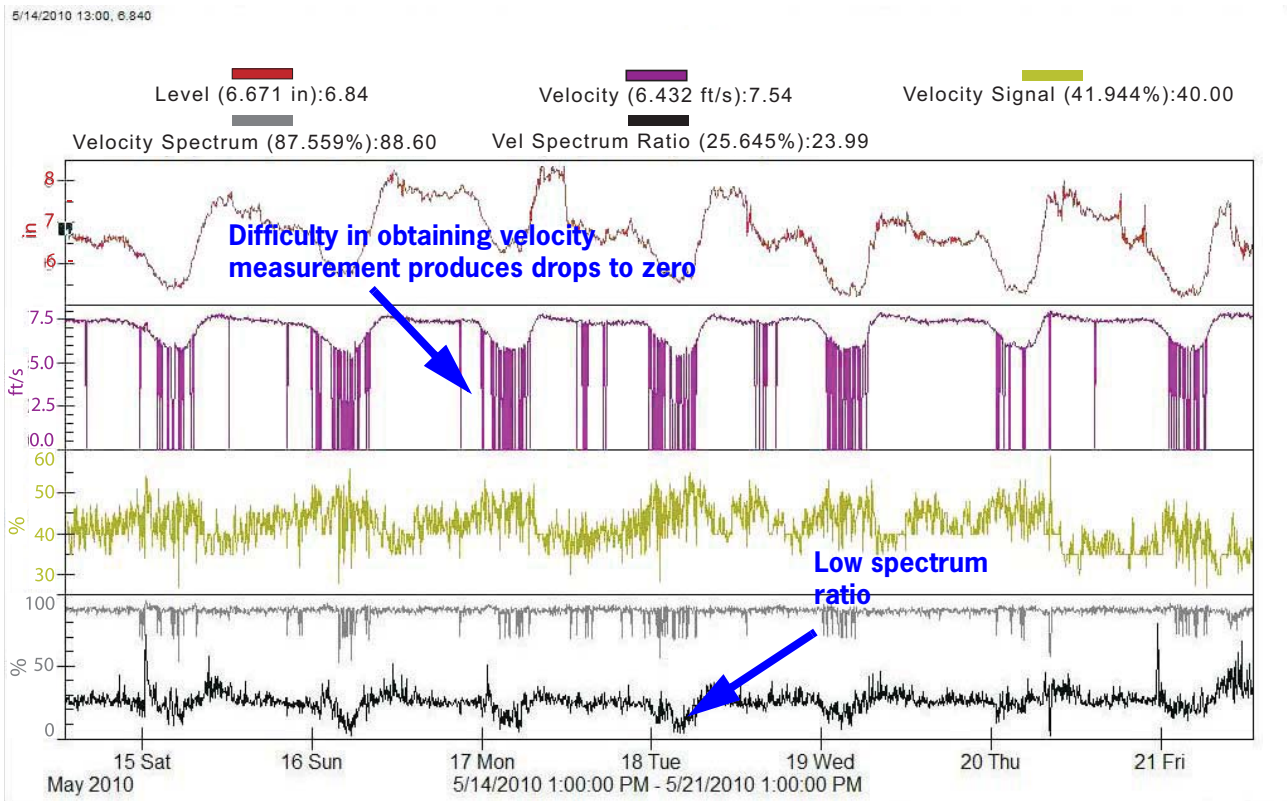


FIGURE 5. Diagnosis of velocity dropouts using spectrum ratio

Example: Debris Build-Up in Channel

Below, signal and spectrum strength are both somewhat erratic, with the spectrum strength dropping out frequently, causing the flow data to flatline (Flowlink is substituting the last usable reading where measurement is inhibited). Notice that when the signal strength decreases, the spectrum strength increases, meaning that although there is a smaller amount of signal, a larger percentage of it is usable for velocity calculation. Then around midnight on Wednesday, a storm event takes place, causing the flow stream to surge. Following the storm, signal and spectrum strength increase and stabilize, and velocity and flow rate no longer flatline.

This graph indicates that, while the level remained steady at about 0.1 to 0.15 meters (4 to 6 inches) in depth, the sensor was covered with increasing debris that interfered with the signal. Between Monday and Thursday, the spectrum dropouts increase steadily, indicating continued degradation of the site. This data should alert the user that maintenance is needed at the site in order to continue recording good flow data.

Fortunately, the storm increased flow depth and speed, washing away the debris and allowing the sensor to read velocity unimpeded.

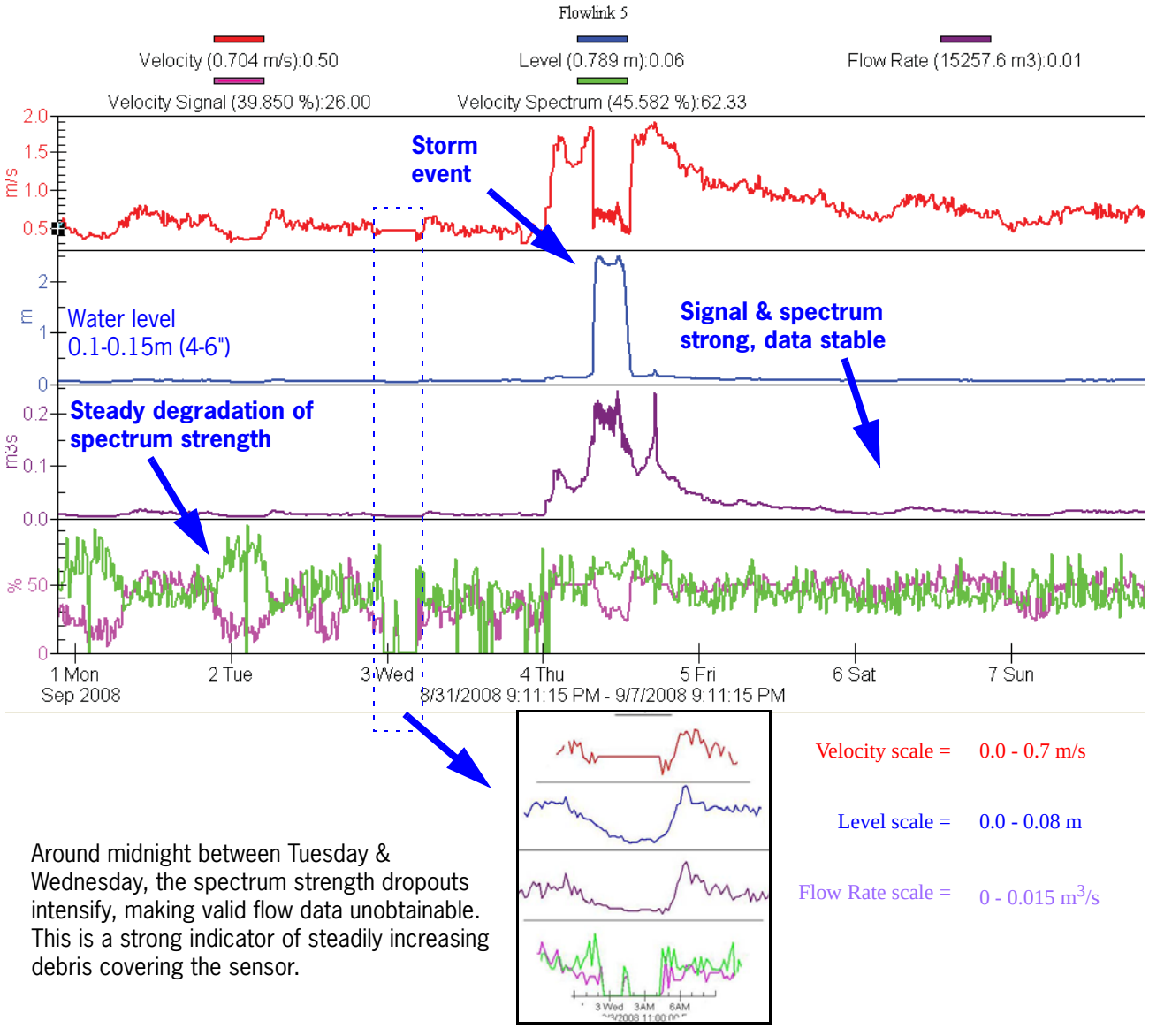


FIGURE 6. Debris build-up on sensor washed away by storm

Quality and Average Gain

An overview of system performance can be retrieved with Flowlink in the form of a text report. **Quality (0 to 100%)** is a meta-analysis referring to overall data quality, and is calculated from the percentage of data sets captured that were suitable for calculation of average velocity. Lower quality percentages indicate that longer scans were required to obtain usable data, which can shorten battery life.

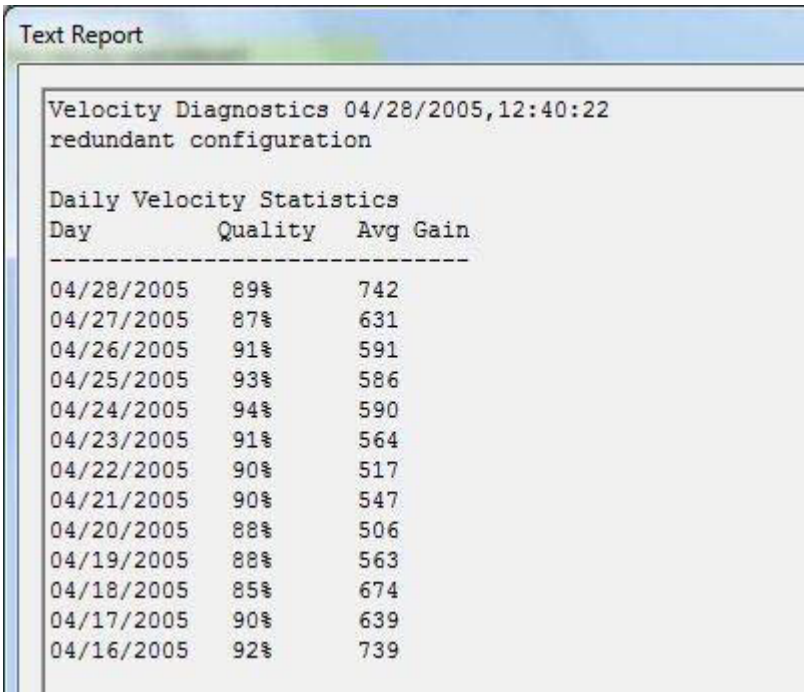


FIGURE 7. System performance overview

Triggers

The 2150 AV module operation can automatically change when triggered by a specified event or combination of events. Triggers are user-defined based on specific site conditions, and can be used to log data at secondary rates, conserve power by turning on equipment only when needed, and generate alarms.

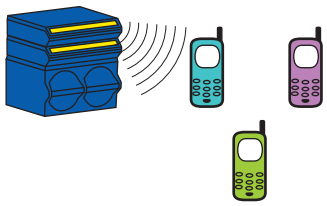
Variable Data Storage Rates

When the logger stores flow data at shorter intervals, the result is higher resolution, allowing more detailed examination of the flow data. This can be desirable during events such as heavy rainfall. However, frequent storage also uses more memory and power, and can significantly increase the time it takes to retrieve the data.

Area Velocity flow meters from Teledyne Isco are capable of having two data storage rates: a primary rate at a fixed interval for monitoring during normal conditions, and a faster secondary rate for collecting high resolution data when more detail is needed. The faster rate is automatically triggered when a defined condition occurs, based on threshold logic and/or an equation. For instance, the flow meter can be programmed to store data more frequently if the flow rate becomes greater than or equal to 100 gpm. The secondary rate continues until the condition stops being true. Data storage intervals for the 2150 AV module are selectable between 15 seconds and 24 hours.

This ability to store data at variable rates according to conditions results in increased battery life and available memory, as well as shorter data retrieval times.

Alarms



As discussed earlier, different site issues usually call for different courses of action. Field communication devices, as well as Flowlink software, can send an alarm to a selected list of contacts, depending on user-defined conditions. The nature of the alarm(s) needed is dictated by characteristics of a particular site, which will become well established over time. The alarm can take the form of SMS, text, or email.

For instance, if the velocity signal strength falls below 30% for over two hours, the flow meter can notify a selected team to clear the debris from the site. Or, if the water level rises above two feet, the alarm may notify a person or select team to open a relief valve or activate a pump station.

Alarms can be transmitted using a selection of communication protocols, including 1xRTT or GSM cellular technology.

Conclusion

Flow measurement accuracy is vital to meeting the growing demands of sewer system management, and wastewater monitoring and control regulations. Invalid flow data, or delayed/inaccurate diagnosis of site issues, can result in heavy penalties, costly repairs and modifications, or incorrect design projects. In the past, analysis for flow data validity and site evaluation had to be performed through special analysis of data.

Today, the diagnostic data from Isco's area velocity flow meters adds an extra layer of protection against errors and undetected site issues. Flow and diagnostic data can be remotely monitored in real time for quick site checks, as well as stored over time for historical performance analysis alongside correspondent flow data. The result is an advanced early warning system against data loss, as well as more time for actual flow data analysis.

A variety of communication options for remote data retrieval and user-defined alarm notifications is available from Teledyne Isco. Application specialists are available for a consultation to assist in determining the best technology for particular monitoring sites.