Sutron Suspended Sediment Monitor

White Paper

Overview

Sutron's Suspended Sediment Monitor, a special model of the Dual Orifice Constant Flow Bubbler, provides continuous measurement of suspended sediment concentrations in bodies of water. Using field proven techniques for measuring pressure, the device measures mass volume concentration to get the density and concentration results. Field tests confirm that the Suspended Sediment Monitor is robust and provides reliable measurements of concentrations over a wide range.

Features

- Exceeds USGS accuracy specifications for sediment concentrations greater than 10,000 mg/
- Direct measurement of mass per volume sediment concentrations via a density measurement using bubbler-pressure techniques
- Accuracy improves with increasing concentrations and continues to work with high sediment concentrations.
- Continuous monitor updates (as often as once a minute) eliminate the need to interpolate between sampler reading
- Robust pressure measuring technique is resistant to clogging and fouling, unlike other common techniques which are prone to fouling and debris..
- Easy to install since no electronics are in the water, only the orifice assembly.
- Easy to maintain because the monitor automatically purges the orifice lines to keep them free from sediment or clogging.
- Built-in display, logger, SDI-12 interface for stand-alone operation and/or connection to telemetry systems.
- Compatible with Sutron's Datalogger/Transmitters including SatLink , IridiumLink, GPRSLink, CDMALink & HSPALink telemetry systems

Operation Theory

The Suspended Sediment Monitor measures mass/volume concentration of suspended-sediment using a density measurement. The density is measured using a precision pressure sensor to measure the pressure incident on two orifices separated by a known vertical distance. The device can provide suspended sediment as long as both orifices are submerged. The overall accuracy depends, in part, on the vertical separation of the orifices and the unit is more accurate as the separation between the orifices increases.

Density is computed by the relation Dm = Pressure_in_kPa/9.8*separation_in_ meters.

The suspended sediment is computed from the relation SuspendedSediment = 1,000,000(Dm – Dt) where Dm is the measured density and Dt is the density of pure water at the temperature of the water. A separate water temperature sensor is provided with the Suspended Sediment monitor for making this temperature measurement. A built-in equation computes Dt from this temperature.

The Monitor includes a second precision sensor for making a reading of the water level (stage). The reported stage level is computed as stage = kPa/9.8/ density.

Dual Orifice Constant Flow Bubbler with Suspended Sediment Monitor

Dual Orifice Constant Flow Bubbler Connectors on Enclosure Bottom

Specifications

Suspended Sediment

- *Resolution*: <100mg/l
- *Accuracy*: 1000 mg/l (based on 2' separation of the orifices)
- *Range*: 0 to >1,000,000 mg/l

Stage

- *Resolution*: <0.001 ft
- *Accuracy*: 0.01 ft < 20ft, 0.01% reading > 20ft

Ancillary Equipment

- Sutron density assembly – specify desired separation at time of order
- Sutron density assembly with flow compensation.

Hasn't This Been Tried Before without Success?

Several attempts have been made in the past to use bubblers measuring pressure as a surrogate for making suspended sediment measurements. These attempts failed due to the following:

- **Poor accuracy in the measurement.** The equipment used in prior tests required two sensors to make the density measurement instead of one (i.e., Sutron's Suspended Sediment Monitor). The noise and errors from two sensors caused measurements to experience 2-4 times the error that a single sensor typically produces. Moreover, the two density-measurement stage sensors used in previous tests had inferior accuracy compared to the Suspended Sediment Monitor with measurement accuracy of 0.1%.
- **Imprecise measurement of the vertical separation of the orifices.** With a 2-foot spacing between orifices, an uncertainty of 0.1 ft. in the separation equates to an error of 6000mg/L. Sutron's simple calibration technique computes the exact separation distance thus eliminating this error.
- **Poor handling of temperature effects.** Previous experiments did not automatically factor in the temperature effects on fluid density and the resultant suspended sediment value. The Suspended Sediment Monitor measures temperature and density at the same time in order to factor in the temperature effects without any time lag.

The Dual Orifice Constant Flow Bubbler with its Suspended Sediment Monitor overcomes all of the above.

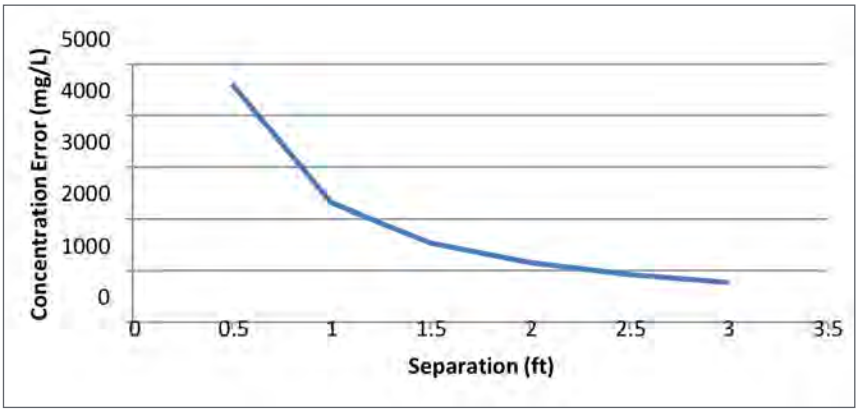
What About Other Techniques?

- Some studies using hydroacoustic techniques to measure suspended sediment show promising results for streams in the range of 0 to 20,000 mg/L. However, the technology is difficult to use, expensive, indirect and doesn't work at all >20,000mg/L.
- Similarly, optical techniques are difficult to use, indirect and don't work > 4,000mg/L.
- Laser techniques have the added problem that they tend to measure volume density, instead of the mass volume and cannot provide mass volumes without knowing the type of sediment in the water.
- The Sutron Suspended Sediment Monitor with its direct density measurement is easy to install and maintain, doesn't require complicated calibration and continues to work in high sediment loads.

Accuracy & Orifice Separation

When planning the location for an installation, **it is important to remember: Accuracy increases as the separation between the orifices increases.**

Suspended Sediment Concentration Error



Calibration

The calibration of the mass/volume measurement depends on three factors:

- the calibration of the pressure sensors
- the calibration of the temperature sensor
- the calibration of the separation of the orifice

These factors ensure that the measurement will be accurate at the point of measurement. (Note: overall accuracy/calibration of the concentration being measured to reflect the concentration of the entire stream is discussed in the Section titled "Factors Affecting Accuracy".)

Sutron's ultra-accurate Accubar sensors, long used by the USGS for precision pressure measurements, are used in the Suspended Sediment Monitor to measure pressure. Most Sutron sensors are manufactured and tested to maintain their calibration for more than three years. The sensors are calibrated by Sutron at the factory to be accurate over a wide range of temperatures and pressures. When sensor recalibration is necessary, the sensor can be removed from the system and sent to Sutron for recalibration. The calibration data resides with the sensor allowing a replacement sensor to be installed in the field without removing the entire unit.

The temperature sensor is a precision thermistor. There is no calibration needed for the thermistor temperature sensor. The separation of the orifices is the final factor affecting the calibration. The system must know the exact vertical separation of the orifices in order to accurately compute the density. Any error in this measurement will cause an offset or shift in the measurement. Because of the importance of this measurement, Sutron provides this simple procedure to ensure highly accurate results.

1. Create the orifice assembly in a workshop fixing the orifices so they do not move. (Or purchase a density assembly from Sutron)
2. Prepare a column of tap water tall enough to immerse both orifices vertically. Let the column stabilize to room temperature.
3. Immerse the assembly in a tube of water. Make sure the assembly is vertical. Insert the temperature sensor in the water.
4. Navigate to the "Density" display on the product. Press SET.
5. The product will prompt "Pure Water YES/NO"
6. Press SET since you have the assembly in pure water. The system will make measurements of the temperature and pressure and automatically compute the separation of the orifices.
7. The separation will be displayed and stored for future use. Write it down for your reference. (Navigate to the System Setup/Orifice Settings/ Separation if you need to see the separation value currently in use by the system).

Calibration continued

If you select NO at step 5, the system will prompt you to enter the current density from which the separation will be computed and stored. It follows that you would need to calculate the density using another measuring device. You may be able to make an educated guess about the density based on your knowledge of the temperature of the stream and the suspended sediment concentration in the stream.

If you are in the field and have to perform the density calibration, you can still follow the procedure answering YES to the prompt about pure water. The effect will be to introduce a small shift in the readings equal to the amount of sediment currently in the stream.

Factors Affecting Accuracy

The Suspended Sediment Monitor has been field proven in comparison tests with sediment samplers. These tests suggest several factors affecting the accuracy:

1. As with any field measurement, site selection is critical.
2. If the sediment is not uniformly mixed in the area of the orifices (causing a gradient in the suspended sediment), the Sediment Monitor will provide a value that is different than the actual value.
3. Streams exhibit both cross-sectional variances and vertical variances in concentrations. The Sutron Suspended Sediment Monitor cannot account for these variances. In normal USGS procedures, concentrations are sampled at multiple cross-sections and throughout the vertical profile. The resultant value represents the entire stream. Concentrations from the Sutron sensor can be adjusted to reflect the entire stream by comparing the Sutron results with the sampled values.
4. If the upper orifice is not completely covered during the entire time the measurement is made, the sediment monitor will report a value less than the actual value.
5. If samples are not taken from the same location as the orifices, the value from the sediment monitor may not match those of the samples simply because there were differences in the location at the time the measurements were taken.
6. The samplers may filter out some of the sediment due to their own filtration providing a value less than that of the sediment monitor.
7. Pressure measurements are affected by stream flow. A fast moving stream can cause a drop in the pressures being measured (Bernoulli effect). As long as the flow is uniform and equal on each orifice, there will be no effect on the suspended sediment concentration. (**Note**: there will be an effect on the overall stage being reported.) Stream turbulence effects can normally be minimized increasing the averaging time used for the measurement. However, the natural velocity profile of the stream suggests that the velocity at each orifice will be different and cannot be removed by averaging. The best way to eliminate stream flow effects is to use a flow compensation device. Sutron offers such a device as optional equipment.