CONTINUOUS TURBIDITY MONITORING IN STREAMS OF NORTHWESTERN CALIFORNIA

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ABSTRACT

Overview. Redwood Sciences Laboratory, a field office of the USDA Forest Service, Pacific Southwest Research Station has developed and refined methods and instrumentation to monitor turbidity and suspended sediment in streams of northern California since 1996. Currently we operate 21 stations and have provided assistance in the installation of 6 gaging stations for agencies, municipalities, universities, and citizens groups.

These installations employ a method called Turbidity Threshold Sampling (TTS), an automated data collection and sampling system in which a data logger employs real-time turbidity to control a pumping sampler (Lewis and Eads, 2001; Lewis, 1996). It is common in streams and rivers for most of the annual suspended sediment to be transported during a few, large rainstorm events. Automated data collection is essential to effectively capture such events.

TTS was designed to permit accurate determination of suspended sediment loads by establishing a relation between suspended sediment concentration (SSC) and turbidity for each sampling period with significant sediment transport. It does so by collecting pumped suspended sediment samples when pre-selected turbidity conditions, or thresholds, are satisfied. During analysis the relations are applied to the nearly continuous turbidity data for the respective sampling periods to produce a continuous record of estimated SSC (Lewis, 2002). The product of discharge and estimated SSC is then integrated to obtain accurate suspended sediment yields. Additional benefits of TTS are (1) it provides samples that can be used to determine whether turbidity spikes resulted from fouling or actual sediment transport, and (2) the continuous record of turbidity is useful for revealing the timing of erosion events, assessing impacts on beneficial uses, and enforcing water quality regulations.

Installation, fouling, and maintenance. Key requirements for collecting good turbidity data are real-time data filtering, proper mounting and housing of the sensor, selecting a sensor with a reliable wiper, regular inspection of the data, and maintenance of the equipment.

Real-time data filtering replaces a series of values taken rapidly over a short time period with a measure of central tendency of the series. We record the median of 60 values taken at half-second intervals. Examination of individual values from such short-duration series' reveals that elevated values commonly occur with no change in SSC. These contribute to a noisy record if recorded without filtering. The arithmetic mean is sensitive to outliers and, as such, is not nearly as effective as the median in removing the influence of stray values.

We have experimented with several different types of sensor mounting configurations

1. fixed-bracket mounted to the streambed
2. depth-proportional boom anchored to the streambed
3. articulating boom mounted on the stream bank
4. articulating boom mounted on a bridge
5. articulated cable-mounted boom spanning the channel

The first two configurations are not recommended because (1) sensors mounted too close to a mobile bed produce erratic turbidity readings, and (2) the sensor is not accessible at high flows. Articulating booms are designed to keep the sensor out of the bedload zone but adequately submerged at all flows. The booms are retractable, permitting access to the sensor at all flows, and they pivot both longitudinally and laterally upon impact to release large woody debris. The boom swings downstream and the sensor rises in the water column as velocity and depth of flow increase, so the boom must be appropriately weighted to keep the sensor from hydroplaning at the highest flows.

We have deployed the OBS-3 probe, manufactured by D&A Instrument Co., at all of our sites. In recent comparisons with the DTS-12, manufactured by FTS, Inc., the self-cleaning wiper on the DTS-12 prevented most episodes of fouling experienced by an OBS-3 mounted beside it on the same boom. However, a wiper can only prevent fouling from small contaminants such as fine organics and sediment, algae, and macroinvertebrates. Larger debris must be manually removed.

We have experimented with flow-through housings but now deploy a design made from square aluminum tubing that is open on the downstream end, and cut on an angle, allowing the sensor's optics to look across the flow or downstream, depending on the optical configuration. The housings are fastened to the downstream side of the boom in approximate alignment with the flow. The flow-through housing was screened at the upstream end, and the sensor required an intercept offset to remove the bias of viewing the pipe wall during low turbidities. The velocity inside the housing was restricted by this design, especially when the screen was clogged with debris, and readings were often unresponsive at lower flows or elevated by sediment that had settled inside the pipe. The housings are designed to shed debris that could potentially interfere with the sensor's viewing area, but have been only partially successful in that respect. Further design modifications, such as increasing the distance from the boom to the optical viewing area, might reduce the amount of fouling. Additionally, a sensor with a small viewing volume is less likely to view trapped debris. The OBS-3 has a relatively large viewing volume and the manufacture recommends placing it at least 20 cm from the nearest object.

In shallow streams, it is difficult to keep the sensor submerged at all flows without placing it close to the stream bottom. Therefore, we have had the most success positioning sensors in natural or artificially created scour pools. However, pools that scour and fill with each event, or that have excessive turbulence, are poor choices for sensor deployment. Close proximity to the water surface is also to be avoided to prevent entrainment of air at high flows or saturation of the sensor's detector with solar radiation. In shallow streams we shield the sensor's optics with a visor that prevents direct exposure to sunlight.

Routine site maintenance related to the turbidity sensor includes

1. inspecting the sensor and removing debris or cleaning as necessary
2. downloading and plotting the data to ensure the sensor is functioning properly
3. recording detailed field notes, including the times of any disturbances or manipulations
4. comparing the in-stream turbidity readings to Hach 2100P manual samples and adjusting the calibration offset if necessary (see Calibration section below).

Calibration. We consider two types of calibration here: (1) the calibration of the turbidity sensor to formazin, and (2) the calibration of SSC to turbidity. The first should be relatively stable while the second varies substantially throughout the year. The first needs to be checked upon shipment and once or twice a year. The second should not be considered fixed except during individual episodes of sediment transport. It is also possible to directly calibrate SSC to electronic output. Such calibrations fall in the same category as (2) above, i.e. they are very dynamic and need to be adjusted frequently. The TTS method is designed specifically to provide SSC data for type (2) calibrations of each event.

In estimating sediment yields, the absolute accuracy of the turbidity record is secondary in importance to obtaining reliable relationships between turbidity and SSC. Nevertheless, because turbidity is used by regulatory agencies to determine impacts on the beneficial uses of water, we now regularly check the continuous turbidity data with readings from portable Hach 2100P manual samples taken under low turbidity conditions. If necessary, the turbidity offset (calibration intercept) in the data logger program can be adjusted to bring the readings into agreement. We do not consider manual samples taken under high turbidity conditions to be reliable enough for such purposes.

Data processing. Data recorded at 10- or 15-minute intervals from a network of gaging stations is very difficult to manage without custom programs for plotting and processing the data. Processing programs are needed for interpolation, reconstruction, adjustment, and for adding quality codes to the data.

Routine processing starts with plotting the raw data and annotating the plots using field notes that might aid in the interpretation of the data. Such notes are invaluable for identifying problems and explaining anomalies. Some types of fouling can be readily identified on the plots with experience. However, fouling that occurs during storm events can often be identified only by plotting the turbidity against SSC from corresponding field samples or by comparing the turbidity with independent readings from a second sensor.

Once problems have been identified, the data must be corrected, omitted, or coded as suspect. In cases of ephemeral fouling, simple linear interpolation may often be satisfactory. Extended fouling is usually not correctable unless conditions are changing very slowly, such as late on the recession limb of a hydrograph or during an extended dry period. In such cases, the reconstructed data must be clearly coded as questionable. We do not recommend that raw turbidity data be released for any purpose before being carefully examined and corrected or quality-coded. Even with the proper caveats, provisional raw turbidity data is likely to be misinterpreted and misused.

REFERENCES

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