Computing suspended-sediment concentrations and loads from in-stream turbidity-sensor and streamflow data

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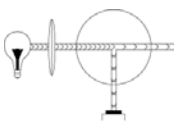
Introduction

The U.S. Geological Survey (USGS) recently (2009) approved Techniques and Methods report, "Guidelines and Procedures for Computing Time-Series Suspended-Sediment Concentrations and Loads from In-Stream Turbidity-Sensor and Streamflow Data," Rasmussen and others. These guidelines represent an alternative to the Porterfield (1972) methods for computing suspended-sediment concentrations (SSC) and loads (SSL).

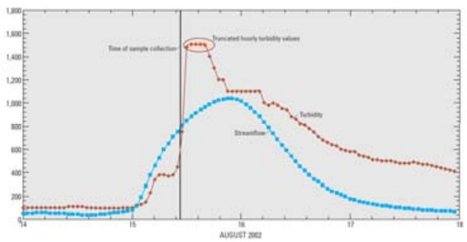
The method described in Rasmussen and others (2009) uses the turbidity time series calibrated with SSC samples based on linear-regression techniques to compute a SSC time series. The turbidity-based computational scheme to produce SSC data has a number of advantages over Porterfield (1972) which is streamflow based.

1. No subjective interpolation or estimation is required.
2. The computational procedure is precisely reproducible.
3. The scheme can substantially reduce the time and effort needed to compute SSL records.
4. Estimates of uncertainty can be computed for the SSC time series.

Continuous turbidity and streamflow datasets

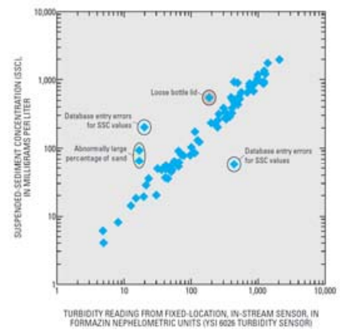


Turbidity is an expression of the optical properties of a sample that causes light rays to be scattered and absorbed rather than transmitted in straight lines through the sample (Anderson, 2005; ASTM International, 2007). Turbid water results from the presence of suspended and dissolved matter such as clay, silt, finely divided organic matter, plankton, other microscopic organisms, organic acids, and dyes. Continuous turbidity data can easily be collected using in-stream sensors designed for extended deployment.



Hourly values of turbidity, in formazin nephelometric units, and streamflow, in cubic feet per second at U.S. Geological Survey streamgage on Little Arkansas River near Sedgwick, Kansas.

Evaluating the sample dataset

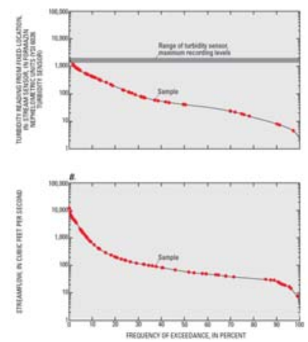


Comparison of turbidity to suspended-sediment concentration in water from U.S. Geological Survey streamgage on Little Arkansas near Sedgwick.

The of turbidity in streams, lakes, and estuaries is often proportional to SSC. The site-specific relation is illustrated when turbidity and SSC are plotted on a scatter plot. Potential outliers are identified for further analysis to determine if the data are indeed erroneous and then are corrected or removed from the dataset. Duration curves can be used to evaluate;

- the distribution of SSC data, and
- adapt subsequent sample-collection strategies.

Ideally, turbidity and streamflow associated with the SSC samples should span the ranges of the time-series turbidity and streamflow values for the site. Sample collection can be optimized by closely monitoring the real-time turbidity and streamflow time-series data and sampling the undefined duration-curve segments.



Duration curves for turbidity streamflow and corresponding values associated with suspended-sediment concentration samples.

Developing the regression model

A simple-linear regression (SLR) model relating turbidity to SSC is often sufficient for reliable computations of SSC. Criteria are provided for determining the sufficiency of a SLR model and for determining when a multiple linear regression (MLR) model relating both turbidity and streamflow to SSC results in a significant improvement over the SLR model that is based on turbidity alone. Typically, addition of a streamflow variable is more likely to improve the turbidity-SSC regression as the percentage of the SSC that is sand-size or larger material (coarser than 62 µm) increases.

Linear regression is not only used to derive a final model to compute SSC but also is used in the intermediate steps to determine the final model form.

Explanatory variables	n	R^2_a	RMSE	MSPE	p-value for streamflow	t-statistic for streamflow
Turbidity	68	0.975	0.101	+25.9, -20.6	n/a	n/a
Turbidity and streamflow	68	0.977	0.098	+25.3, -20.2	0.043314	2.06

[n, number of samples; R^2_a, adjusted coefficient of determination; RMSE, root-mean-squared error in log units; MSPE, model standard percentage error; n/a, not applicable]

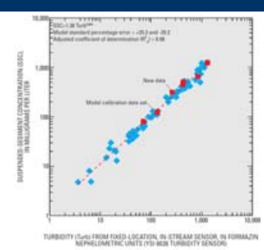
The hydrographer may need to evaluate the performance of more than one intermediate regression model before determining the optimal model for computing SSC. Regression results are an effective means for evaluating whether or not variables should be transformed and which variables are necessary to best estimate the variability in SSC.

Continued data collection

Regression models to compute SSC at a site should never be considered static but rather considered to represent a set period in a continually dynamic system in which additional data will help verify any change in SSC, type, and source. Once an acceptable regression model is developed, it can be used to compute SSC beyond the period of record used in model development with proper sample collection and analysis. Maintenance of a long-term SSC record requires;

- ongoing collection of turbidity and streamflow time-series data and sample collection,
- reanalysis and verification of the current SSC regression model with new turbidity-SSC data pairs, and
- a decision to use the new or keep the old model.

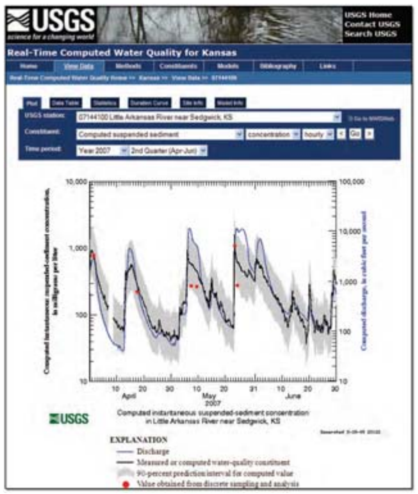
A fundamental shift in the turb-SSC relation probably reflects a major change in sediment source or transport processes in the watershed, such as those resulting from a substantial change in land use or land cover, construction or removal of an impoundment, wildfire, landslide, or a major flood. A more common occurrence is a gradual change over years that can be detected only by continued sample collection and analysis.



Model-calibration data set (water years 1999–2005) and new (water year 2006) turbidity and suspended-sediment concentration data.

National Real-Time Water Quality Webpage

The National Real-Time Water Quality website (http://nrtwq.usgs.gov) provides hourly computed concentrations and loads for sediment, nutrients, bacteria, and many additional constituents; uncertainty values and probabilities for exceeding drinking water or recreational criteria; frequency distribution curves; and all historical hourly in-stream sensor measurements.



Reference

Porterfield, George, 1972, Computation of fluvial-sediment discharge: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C3, 66 p.

Techniques and Methods Report

Rasmussen, P.P., Gray, J.R., Glysson, G.D., and Ziegler,A.C., 2009, Guidelines and procedures for computing time-series suspended-sediment concentrations and loads from in-stream turbidity-sensor and streamflow data: U.S. Geological Survey Techniques and Methods book 3, chap. C4, 53 p.

Available at:
http://pubs.usgs.gov/tm/tm3c4/