MEANS AND METHOD OF SAMPLING FLOW RELATED VARIABLES FROM A WATERWAY IN AN ACCURATE MANNER USING A PROGRAMMABLE CALCULATOR

TECHNICAL FIELD

The present invention relates generally to determining the amount of sediment in a river or stream. More particularly, the present invention relates to a method of sediment sampling that produces statistically accurate results.

BACKGROUND ART

Knowledge of sediment levels in rivers and streams as well as knowledge of stage height is necessary to accurately determine the effects of logging, industry, land development, or the like on rivers and streams. However, measuring and estimating suspended sediment yields in rivers has long been subject to confusion and uncertainty. Many methods have been developed for collecting data and estimating yields, a fact that suggests the lack of a compelling measurement methodology. The main reason for this situation is the lack of a theoretical framework that defines when discrete samples of suspended sediment should be taken.

The ideal way to estimate the suspended sediment yield of rivers would be to measure suspended sediment discharge continuously. Such data could be integrated over the monitoring period in a way similar to that used to obtain water yield from a discharge hydrograph. There is no technique, however, to monitor suspended sediment discharge directly. A second approach is to measure suspended sediment concentration and water discharge continuously, and use the product function as an estimate of suspended sediment discharge.

Obtaining continuous records of concentration, however, is subject to numerous problems. Such measurements are necessarily indirect; turbidity and water/sediment density are two quantities that can be related to suspended sediment concentration. Calibration of these qualities is a continuing problem, the instrumentation is expensive and subject to breakdown, and 120 volt A.C. electrical power is usually required.

When cost, remoteness of sites, and technical difficulties preclude collecting continuous concentration data, the usual course is to measure water discharge continuously and to take occasional discrete water samples for gravimetric analysis of suspended sediment concentration. The samples are taken manually, or, more commonly in recent years, with automatic sampling equipment.

Automatically pumping samples can facilitate the collection of suspended sediment samples. Most commercial samplers have two operational modes—fixed time intervals and flow-proportional sampling. In most instances, flow-proportional sampling requires an external controller with fixed time intervals handled internally by the sampler.

Pumped suspended sediment samples are often collected at equal intervals of time. This practice produces many samples during low flow conditions and few samples during infrequent high flow conditions. But, reducing the time interval increases the size of the data set with no assurance that high flows will be adequately represented. The need to sample more frequently is often hampered by difficulty of access to remote areas coupled with runoff events of short duration. When

dealing with such conditions, long periods of calibration are required, and analyzing streamflow information is delayed because of missing records.

Although numerous methods are available to improve automatic sampling, most rely on a "controller" to skew sampling toward high states or significant events. Several investigators have developed or modified instruments that control the collection of suspended sediment samples. One such instrument is known as a Proportional Frequency Controller and is an electronic device that produces a pulse frequency proportional to water discharge. Sampling frequency is controlled by **34** different stage positions of a float-pulley system. Each position is actuated with a magnetic switch and is adjusted with a fixed and a variable resistor. Consequently, to update a rating equation or move the device to a new location may require a substantial amount of rewiring and calibration. Besides these constraints, moisture and temperature can cause reliability problems. A second system uses a standard water level recorder modified so that the sampling frequency is controlled by switches wired to a timing circuit. Four intervals of stage can be set to five different fixed time intervals ($1\frac{1}{2}$ to 24 hours). Changing time intervals or stage settings requires electronic or mechanical manipulation of the recorder. Another sampling system was developed on the basis of the relationship between rainfall and discharge. Electric pulses from a tipping-bucket rain gauge activated a pumping sampler whenever the rainfall reached a threshold intensity. Sampling continued at regular increments of rainfall until the intensity dropped below the threshold. Thereafter, samples were collected at fixed time intervals.

These methods, although an improvement over fixed time intervals, do not provide for the flexibility to easily change sampling frequencies nor do they produce statistically acceptable data. Therefore, data sets are collected that contain little statistically useful information.

All of these sampling methods are based on the assumption that water height can be related accurately to sediment flow since sampling frequency is altered according to stage height. This assumption is based on prior data concerning a particular waterway. While such assumptions are accurate in a broad sense, they are not accurate enough and therefore affect any data gathered which is based on these data or assumptions.

Therefore, regardless of how the samples are collected, there remain the questions of when the measurements of concentration should be made, how they should be used to estimate the total yield, and what the properties of the estimates are.

In order to overcome these problems, a variety of methods for estimating total suspended yield have been investigated. The tested combinations of estimation technique have ranged from 70% below to 40% above the true value. Most of the estimates were less than 60% of the correct value. The variance of the estimators tended to increase as the accuracy improved, thus cancelling the benefits, and no approach emerged as the ideal choice for all conditions.

These techniques can be termed nonstatistical because the sampling probabilities are not known. The estimators, therefore, cannot take the probability structure into account, resulting in bias (i.e., systematic over- or underestimation of true values) that depends on unknown and variable factors in the data collection process and on specific site conditions. Bias is particularly