ROHINI

COLLEGE OF ENGINEERING AND TECHNOLOGY

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DEPARTMENT OF AGRICULTURAL ENGINEERING

AI3402 SOIL AND WATER CONSERVATION ENGINEERING

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Methods of in Stream Sediment Measurements

There are different methods for stream sediment measurements: such as bed load, suspended load, wash load, dissolved load and saltation load measurements.

Bed Load-Measurements

Bed load gauging (also called bed load transport measurement) is often mixed up with bed material sampling. Bed load gauging is the measurement of the amount of sediment that is moving as "bed load", i.e. rolling, sliding and bouncing (in "saltation") on or over the stream bottom, while bed material sampling is the collection of the material comprising the stream bottom. Bed load is extremely difficult to measure directly because the measuring instrument (bed load sampler) invariably interferes with the flow. Most bed load movement occurs during periods of high discharge on steep gradients when the water level is high and the flow is extremely turbulent. Such conditions also cause problems for field measurements.

A commonly used type of bed-load sampler is shown in Fig. 20.1. In small streams where the sampler can often be placed on the bed so that it is appropriately oriented towards the flow, the sample collected may be meaningful although there is always some bed scour at the inlet that distorts the actual bed-load transport in the vicinity of the instrument. In large rivers where the sampler must be lowered from a boat by cable to an unseen bed, measurements can be highly inaccurate and must be repeated many times before reliable results can be obtained. The problems relate largely to the fact that the operator is unable to see the position of the sampler on the bed. If the sampler settles on a boulder or dune face, for example, it may push the sampler inlet into the bed and as a result the sampler may drastically over sample the rate of bed-load transport. At other times the sampler position and the bed morphology may be such that scouring of the bed at the sampler inlet could be severe leading to over sampling.

Fig. 20.1. A Commonly Used Type of Bed-load Sampler. (Source: http://www.sfu.ca/~hickin/RIVERS/Rivers4(Sediment transport).pdf)

When the bed-load sampler is appropriately oriented towards the flow direction, bed-load material enters the sampler through the inlet and the divergent flow within the sampler reduces the flow velocity, allowing the sediment to accumulate. A fine mesh provided at the rear of the sampler allows the incoming water but not the bed-load sediment to pass through. After an appropriate measured time-interval the sampler is taken out and the trapped sediment is removed for weighing.

A different problem during sampling occurs if the bed-load sampler settles on the back of a dune or perhaps the front of the sampler settles on an object that keeps the inlet from contacting the bed. For these reasons river scientists often prefer to rely on other methods to estimate bed-load transport rates in rivers. Methods other than direct measurement by bed-load sampler include:

1. Bed-load Pits or Traps

These are the installations that divert sediment from a channel and convey it to a measurement facility where it is weighed and then returned once again to the channel so that the sediment-transport system is not unduly disrupted. Obviously such a facility is expensive to build and operate and there are few of them. The main purpose of such a facility is to calibrate bed-load transport equations for se on other river channels.

2. Morphological Methods

a) Bed Form Surveys

Where bed-material is moving as bedforms such as dunes, bedform surveys can be used to track the downstream movement of sediment. This technique relies on high-resolution sonar imaging of the river bed to construct profiles that can be differenced to determine the volumetric bed-load sediment transport rate.

b) Channel Surveys

Channel surveys can be used to produce sequential morphologic maps of a reach of river that can be differenced (using GIS) to yield amounts of erosion and deposition over time. The principle here is the same as that for bedform surveys but in this case involves the entire three-dimensional channel morphology. Like the bedform-based calculation, differencing channel morphology as a basis for calculating bed-load sediment transport relies on the assumption that there is no sediment throughput. That is, all transported bed-load is involved in local deposition and erosion and not simply transported through the reach without contributing to the changing channel morphology

c) Sedimentation-zone Surveys

Sedimentation-zone surveys are one of the most reliable methods of determining representative long-term bed-load transport rates in rivers. This morphologic method relies on measuring the accumulating sediment in a feature such as a delta that a river is gradually building into a lake or embayment

Suspended Load-measurements

The simplest way of taking a sample of suspended sediment is to dip a bucket or other container into the stream, preferably at a point where the sediment is well mixed, such as downstream from a weir or rock bar. The sediment contained in a measured volume of water is filtered, dried and weighed. This gives a measure of the concentration of sediment and when combined with the rate of flow gives the rate of sediment discharge. For determining suspended sediment load, it is necessary to consider all particle sizes (sand + silt + clay). Therefore, a depth-integrating sampler must be used to ensure that the depth-dependent sand-sized fraction is correctly sampled. There are two generally accepted methods for measuring suspended sediment concentration for load determination as described below:

1. Equal-discharge-increment Method: This method requires that at first a complete flow measurement be carried out across the cross section of the river. Using the results, the cross-section should be divided into five (more on large or complex rivers) intervals (i.e. vertical sections) having almost equal discharge in each interval. The number *n* of the intervals is selected based on experience. Depth integrated suspended sediment sampling is carried out at one vertical within each of the equal-discharge-intervals, usually at a location most closely representing the centroid of flow for that interval. The sediment concentration for each equal-discharge- interval should be measured. The mean discharge-weighted suspended sediment concentration (SS_c) should be obtained by taking the average of the concentration values C obtained for each interval i.

$$SS_c = \frac{\sum_{i=1}^{n} C_i}{n} \qquad (20.1)$$

The discharge-weighted suspended sediment load (SS_L), in tonnes per day, for the river cross-section have to be obtained by multiplying the concentration, C in ppm (mg/l) by the discharge, Q, in m^3/s of each equal-discharge-interval, i and summing for all the intervals. This method is very time-consuming, but is the most used by the sediment recording agencies.

$$SS_L = \sum_{i=1}^{n}(C_i Q_i) \times 0.0864 \qquad (20.2)$$

2. Equal-width-increment Method: This method is used without making flow measurements and is usually used in small to medium rivers and especially rivers that are shallow enough for wading. The operator marks off 10-20 equal intervals across the river cross-section. At the deepest point, the operator takes a depth-integrated sample, noting the transit rate of the sampler (i.e. the uniform speed at which the sampler is lowered, then raised to the surface). Using that same transit rate, a suspended sediment sample is taken at each of the intervals. Because each vertical will have a different depth and velocity, the sample volume will vary with each vertical sampled. Care should be taken to see that the bottle is never over-filled. All samples are collected in a single container which is then agitated and sub-sampled, usually two or three times and analysed for suspended sediment concentration. The average of these values is the mean cross sectional suspended sediment concentration. In this method, the results are corrected for differences in discharge at each section caused due to the same transit rate (and the same nozzle diameter) used at all sections although a shallow section with less discharge produces a proportionally smaller suspended sediment sample than a deep section having a higher discharge.

For suspended sediment quality, where the primary interest is the chemistry associated with the silt + clay (< 0.63 μm) fraction, sampling can be greatly simplified because this fraction is not normally depth dependent. While there are no universally accepted rules for sampling, many scientists collect a grab sample from a depth of 0.5 m at the point of maximum flow in the cross-section. For larger rivers, or rivers where there is concern over cross-sectional variation, grab samples can be taken from several locations across the section. For more precise work where accurate loads are required, especially for micro-pollutants, sampling should be carried out using either of the methods mentioned above. It is particularly important to avoid sampling near river banks (or lake shores) where elevated concentrations of suspended matter occur and which are often contaminated by garbage and other anthropogenic materials.

Location of Measurement

When the question 'where to measure' comes to our mind the most obvious answer in a broader sense is where the data can be collected, however the answer is not so simple. It becomes quiet complex when sediment concentrations or loads of an entire large area need to be characterized which largely depends on the information wanted and the particular situation being studied. Generally, measurements should be made downstream as close as possible to the area of disturbance. The effect of a sediment-producing condition is attenuated and its effect is confounded with the effects of dilution and other sediment sources farther downstream. If the downstream effects of a disturbance are being studied, it is better to measure at the affected site.

The location of measuring station also depends on the hydraulic conditions in the stream. In some streams, control can be affected by geology or large organic debris. Bedrock cropping out at the crest of major riffles or falls can provide excellent control in natural channels. In some situations, well emplaced logs stabilize the channels and provide suitable locations to measure both the suspended sediment concentration and discharge. Along with location, depth is the other factor which affects the concentration of sediment in the streams i.e. near the stream bed it is more, in the middle relatively less, while on the top of the surface it is too less. Thus it is very difficult to select the sampling point, which can accurately define the sediment concentration in vertical cross-section of stream.

Frequency of Measurement

Frequency of sampling depends upon the sediment concentration in the stream flow. It is well known that the sediment concentration increases rapidly on the rising phase of the hydrograph than the falling phase. Therefore, sediment samples should be collected more frequently at the beginning of runoff and it should be continued up to the peak stage of runoff. The sample should be taken at every 15 minutes interval.

Number of Monitoring Stations

In most of the cases the entire runoff of the watershed is drained from a single point known as the outlet, the collection of the sediment sample should be carried out from the outlet point. The outlet is an ideal location of monitoring station for the entire watershed. Similarly, in case of drainage system, where flow is drained from more than one points, gauging station should be provided at each outlet point for sampling.

Observation and Collection of Sediment Samples

There are several methods which are used today for evaluation of sediment transport in rivers. The total number of sampling points (Table 21.1) to be considered for collecting the sediment samples depends on the width of the stream flow.

Table 21.1. Number of Sampling Points in the Stream.

Width of Stream (m)	No. of Sampling Points	Location of Point from Site
< 30	3	25, 50 and 75% of the stream width
30 - 300	5	25, 35, 50, 65 and 80% of the stream width
> 300	7	15, 30, 40, 50, 60,70 and 85% of the stream width

Apart from width-wise sediment sampling, the depth-wise sampling is also carried out using the following points:

1. In case of single point sampling, the sample should be collected from the depth of 0.6 d, measured from the surface (d = the depth of the stream).
2. In case of double point sampling, one sample should be collected from the point near the top of water surface i.e. at a depth of about 0.2 d and other near the stream bed at about 0.8 d. The concentration of sediment is weighted equally.
3. For three point sampling: one sample should be taken near the top of water surface, second from mid depth of stream and the third near the stream bed, and weighted equally.
4. Similarly, in case of multiple sampling, there should be several samples from several points of vertical section of the stream flow. This helps to elaborate the sediment distribution in the stream.

5. The sediment sampler should be kept in vertical position from the stream bed.

6. The mouth of the sampler should be opened after reaching the desired depth of stream flow.

7. Whenever it is expected that the distribution of sediment is uniform in the stream flow, sampling should be done only at 0.6d of the stream flow.