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Hydrometry — Methods of measurement of bedload discharge

Hydrométrie — Méthodes de mesurage du débit des matériaux charriés sur le fond

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Foreword

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The committee responsible for this document is ISO/TC 113, *Hydrometry*, Subcommittee SC 6, *Sediment transport*.

This third edition cancels and replaces the second edition (ISO/TR 9212:2006), which has been technically revised.

Introduction

The knowledge of the rate of sediment transport in a stream is essential in the solution of practically all problems associated with the flow in alluvial channels. The problems include river management, such as design and operation of flood control works, navigation channels and harbours, irrigation reservoirs and canals, and hydroelectric installations. The bedload and suspended load broadly constitute total sediment load. The bedload is the material transported on or near the bed by rolling or sliding (contact load) and the material bouncing along the bed, or moving directly or indirectly by the impact of bouncing particles (saltation load). Knowledge of the bedload-transport rate is necessary in designing reservoir capacity because virtually 100 % of all bedload entering a reservoir accumulates there. Bedload should not enter canals and distributaries and diversion structures should be designed to minimize the transfer of bedload from rivers to canals.

The bedload-transport rate can be measured either as mass per unit time or volume per unit time. Volume measurements should be converted to a mass rate. Measurements of mass rate of movement are made during short time periods (seconds, minutes), whereas measurements of volume rates of movement are measured over longer periods of time (hours, days). Regardless of whether the mass or volume rate is measured, the average particle-size distribution of moving material should be determined. Knowledge of particle-size distribution is needed to estimate the volume that the bedload material will occupy after it has been deposited. Knowledge of particle-size distribution also assists in the estimation of bedload-transport rates in other rivers transporting sediment.

The movement of bedload material is seldom uniform across the bed of a river. Depending upon the river, hydraulic, and sediment properties (size and gradation), the bedload may move in various forms, such as ripples, dunes, or narrow ribbons. Its downstream rate of movement is also extremely variable. It is difficult to actually sample the rate of movement in a river cross-section or to determine and verify theoretical methods of estimation.

Hydrometry — Methods of measurement of bedload discharge

1 Scope

This Technical Report reviews the current status of direct and indirect bedload-measurement techniques. The methods are mainly based on grain size distribution of the bedload, channel width, depth, and velocity of flow. This Technical Report outlines and explains several methods for direct and indirect measurement of bedload in streams, including various types of sampling devices.

The purposes of measuring bedload-transport rates are to

a) increase the accuracy of estimating total sediment load in rivers and deposition in reservoirs,

b) gain knowledge of bedload transport that cannot be completely measured by conventional suspended-sediment collection methods,

c) provide data to calibrate or verify theoretical transport models, and

d) provide information needed in the design of river diversion and entrainment structures.

NOTE The units of measurement used in this Technical Report are SI units.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 772, *Hydrometry — Vocabulary and symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 apply.

4 Measurement of bedload

4.1 General

Bedload can be measured by direct measuring bedload samplers or by indirect methods.

4.2 Direct measurement methods

a) Bedload samplers

In this method, a mechanical device or sampler is required for measuring the bedload-transport rate. The bedload sampler is designed so that it can be placed directly on the channel bed in the flow, to collect a sample of the bedload over a specific time interval. A sample thus obtained represents a time-averaged mass per unit width per unit time.

b) Bedload trap

The best measurement of bedload would occur when all of the bedload moving through the river cross was measured. Slot or pit samplers or traps meet this goal with near 100 % efficiencies.

4.3 Indirect measurement methods

All other methods of bedload measurement in which no mechanical device or bedload sampler is used, are indirect methods. These include differential measurements of total and suspended-sediment loads, periodic volumetric measurements of accumulated sediment depositions, dune tracking, tracers, remote sensing, and acoustic measurements of moving sediment.

5 Design and strategy of measurement of bedload discharge

Measurement of bedload is difficult because it is highly variable in both space and time. Bedload generally varies greatly both longitudinally along the channel and transversely across a cross section. These variations are caused by several factors and are difficult to predict. The design of bedload sampling needs to account for the spatial and temporal variability inherent in the processes of bedload transport.

Pit, vortex-tube, or other samplers that sample for long periods of time and encompass a significant portion of the width of a stream cross section integrate the fluctuations in bedload-transport rate in a cross section. In many instances, time, monetary constraints, or logistics precludes the use of these types of samplers.

The use of portable samplers that essentially only collect samples at a point for short periods of time is often the only practical way to collect samples of bedload. To effectively use portable samplers, the number and location of the samples collected shall be carefully designed. Sufficient information about the temporal and spatial variability is collected. To accomplish this task, information on the scales of spatial and temporal variability is needed. To design an adequate sampling strategy, these time and length scales shall be known at least approximately before the sampling procedure is defined.

Flow in many streams and rivers are not steady for periods of hours to days. For streams in which variable flow is the norm, portable samplers will not be practical unless many flow events can be sampled. No single sampling design can be used at all stations. A sampling design should be derived for each site where bedload is to be sampled. Initial samples collected can provide information to serve as a basis for developing the sampling plan.

6 Site selection

a) Depending upon the method of measurement, the site for conducting bedload measurements can be either a river reach or a cross-section. The site should be relatively close to the geographical location where bedload-transport rate information is needed. There should be no inflow or outflow from the river between the measuring site and the site where bedload transport estimates will be used.

b) When using a method such as dune-tracking, a straight reach where the channel width and depth are fairly uniform throughout the reach is desirable. Flow through the reach should be uniform and steady during the bedload-measurement period (see 9.4).

c) A single cross-section site should be selected if the method of measurement is by bedload sampler. The channel width and mean depth of the cross-section site should be representative of the average channel width and depth upstream and downstream. Ideally, a cross-section used for bedload measurement by bedload sampler should be at the centre of a straight reach selected for measurement of bedload by the dune-tracking method.

d) If it is not possible to place the cross-section site in the centre of an ideal straight, uniform reach, then the cross-section should be located at least 10 to 20 channel widths downstream from any bend in the channel. It should not be located at an excessively narrow section, such as might be present at a bridge site, or at an excessively wide section.

7 Bedload samplers and traps

7.1 Bedload samplers

7.1.1 Requirements of an ideal bedload sampler

In order that the samples taken are truly representative of the bedload material of a river at the point of sampling, the ideal bedload sampler should fulfil the following technical requirements.

a) It should be calibrated for bedload-sampler efficiency of specific sediment particle sizes.

b) It should be designed to minimize disturbances to normal bedload movement. In particular, local erosion near the sampler mouth should be avoided so as to not form scour holes.

c) The lower edge of the sampler and nozzle should be in contact with the river bed.

d) The velocity of inflow at the mouth of the sampler should be as close as possible to the ambient velocity of the stream at the sampling point, irrespective of what this velocity may be. This aspect is very important if large sampling errors are to be avoided.

e) The mouth of the sampler should always face into the current and the sample should be taken parallel to flow direction at the sampling point, into a specially designed chamber.

f) The mouth of the sampler should be outside the zone of the disturbances of the flow set up by the body of the sampler and its operating gear and the flow lines should be as little disturbed as possible, especially near the mouth.

g) The sampler should be able to collect only those particles moving as bedload, without contamination by suspended sediment.

h) The sampler should be portable, yet sufficiently heavy to minimize deflection of the supporting cable from the vertical due to current drag. A separate anchor is recommended for the sampler, wherever possible.

i) The sampler should be simple in design and robust in construction and should require minimum maintenance and care in operation.

j) It should be capable of collecting representative bedload samples under varying bed configurations.

k) The sampler should be designed for easy removal of the sampled material into a container for transfer to a laboratory.

l) The volume of the sample collected should be sufficient for the determination of mass and particle-size distribution.

m) The efficiency of the sampler should be independent of length of sampling over a reasonable time.

n) The efficiency of the sampler should be independent of the size of bedload particles and flow velocity.

7.1.2 Basket or box type sampler

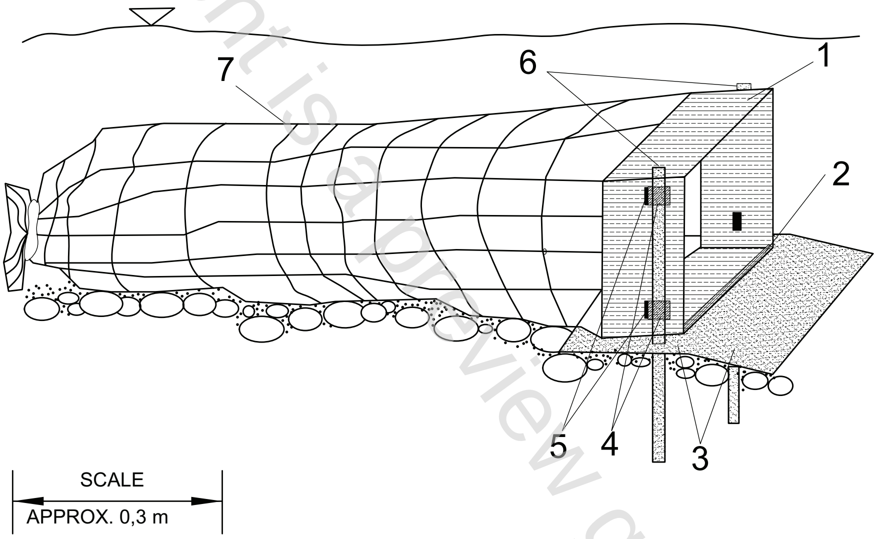
This type of sampler consists of a basket or box, usually made of mesh material on all sides except the front and bottom. The bottom may be solid or of loosely woven iron rings or steel mesh, to enable it to conform to the irregular shape of the stream bed. The sampler is placed on the channel bed with the help of a supporting frame and cables. A steering fin or vane(s) attached to the basket ensures positioning of the instrument in the direction of the flow. The sediment is collected in the basket by causing a reduction of the flow velocity and/or screening the sediment from flow for a measured time period.

Since a part of the bedload is dropped in front of the sampler, the efficiency of basket type samplers is only about 45 %, for average sediment sizes varying from 10 mm to 50 mm. However, due to their large capacity, basket type samplers are well suited for measuring of transport rate of large-sized sediment [7].

7.1.3 Frame and net sampler

These are portable samplers consisting of a steel or aluminium frame and a trailing net for collecting the sediment. The samplers can be used in small wadable streams. The samplers are anchored to the streambed with steel rods driven through the frames. These samplers can be deployed for 1 h or more, depending on the transport rate, so they can average out short-term temporal variations in transport rates.

The sampler shown in Figure 1 was designed for use in small mountain streams. The frame, which was fabricated from aluminium, 0,3 m wide, 0,2 m high, and 0,1 m deep. The netting, which extends about 1 m downstream from the frame, is sturdy nylon mesh with 3,5 mm openings. The sampler is able to trap gravel particles as small as 4 mm and cobbles particles as large as 128 mm.



Key

1 aluminium frame
2 bottom piece, bevelled
3 aluminium ground plate, inclined in front, with holes
4 adjustable nylon straps
5 slits at top and bottom on each side of the frame
6 smooth stakes, rolled steel
7 nylon netting

Figure 1 — Schematic diagram of a portable frame and net sampler[2]

7.1.4 Pressure-difference sampler

This type of sampler is designed so that the velocity of water entering the sampler and the stream velocity is approximately equal. Equalization of velocity is accomplished through creation of a pressure drop at the exit due to a diverging configuration between the entrance and the exit. These are flow-through samplers that trap coarse material behind baffles or in a mesh bag attached to the exit side or in a specially designed chamber. The Scientific Research Institute of Hydrotechnics (SRIH) and Sphinx samplers (see Figure 2 and Figure 5) are examples of samplers with internal baffles. The Arnhem, Helley-Smith, US BLH-84, and US BL-84 are examples of mesh bag samplers (see Figure 3, Figure 4, Figure 6, and Figure 7)

