TECHNICAL
REPORT

ISO/TR
9212

Second edition
2006-08-01

Hydrometry — Measurement of liquid flow in open channels — Methods of measurement of bedload discharge

Hydrométrie — Mesurage du débit des liquides dans les canaux découverts — Méthodes de mesurage du débit des matériaux charriés sur le fond

Reference number
ISO/TR 9212:2006(E)

© ISO 2006

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS

Not for Resale

PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

© ISO 2006

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Contents

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 9212 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 6, *Sediment transport*.

This second edition cancels and replaces the first edition (ISO/TR 9212:1992), of which it constitutes a technical revision.

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Introduction

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). 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. 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 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.

--`,,```,,,,````-`-`,,`,,`,`,,`---

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

TECHNICAL REPORT **ISO/TR 9212:2006(E)**

Hydrometry — Measurement of liquid flow in open channels — 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,

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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 772, *Hydrometric determinations — Vocabulary and symbols*

ISO 4363, *Measurement of liquid flow in open channels — Methods for measurement of characteristics of suspended sediment*

--`,,```,,,,````-`-`,,`,,`,`,,`---

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 and ISO 4363 and the following apply.

3.1
bedload
material transported on or near the bed by rolling, sliding and bouncing

3.2
bedload transport rate
quantity of bedload passing through a section of the stream per unit width in unit time

NOTE The bedload transport rate is expressed in kilograms per metre (of width) per second.

3.3
bedload transport model
mathematical relation of hydraulic and sediment variables which can be used to estimate the bedload transport rates of sediment

3.4
bedload sampler efficiency
ratio of the amount of bedload collected by the sampler to the amount of bedload that would have passed through the sampler width in the same time in the absence of the sampler

4 Measurement of bedload

4.1 General

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

a) Direct measuring 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, or beneath the channel bed 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) Indirect measurement of bedload:

All other methods of bedload measurement in which no mechanical device, or bedload-sampler is used, are indirect methods.

4.2 Principle

4.2.1 Measurement using bedload samplers

4.2.1.1 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, 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 assures 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.

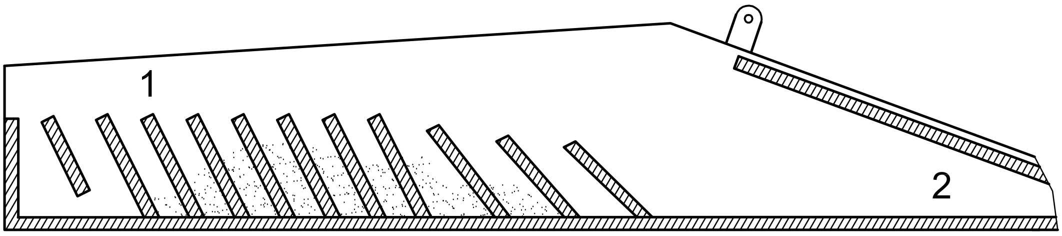
© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Since a part of the bedload is dropped in front of the sampler, the efficiency of basket type samplers is only of the order of 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.

4.2.1.2 Pressure-difference sampler

This type of sampler (see Figures 1 to 6) 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.



Key

1 transverse partitions

2 entrance

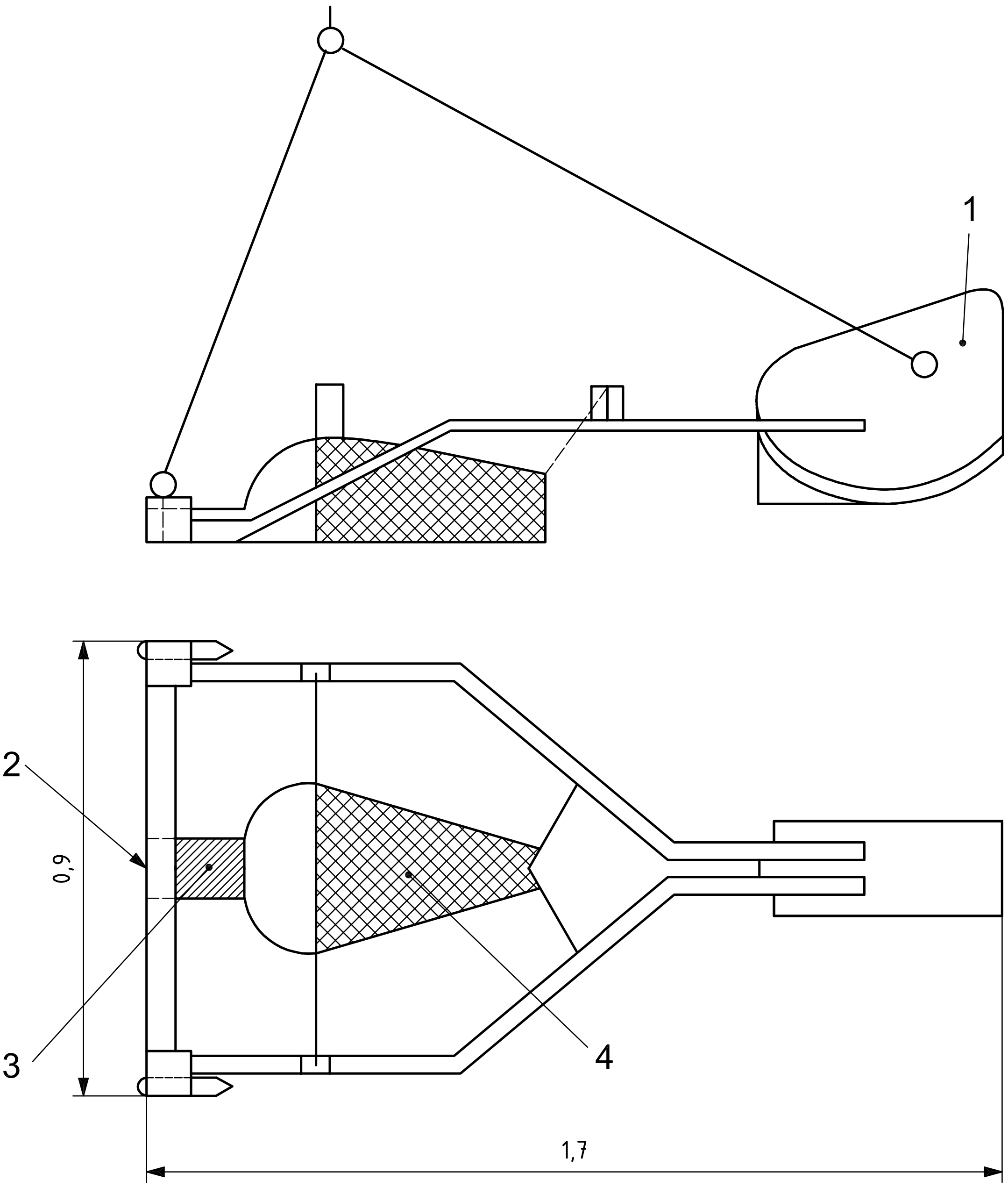
NOTE This is a pressure-difference bedload sampler. The SRIH sampler was the first of this type to be developed. Such samplers can sample particles as small as fine sand to as large as 200 mm. Efficiencies are extremely variable.

Figure 1 — Scientific Research Institute of Hydrotechnics (SRIH) sampler

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Dimensions in metres



Key

1 steering fin

2 entrance

3 rubber connection

4 mesh bag

NOTE This is a pressure-difference bedload sampler. The Arnhem, or Dutch, sampler is comprised of a rigid rectangular entrance connected by a diverging rubber-neck to a basket of 0,2 mm to 0,3 mm mesh. Efficiencies are variable, but generally about 70 %. It is suitable for collection of fine bedload material. The fine net of the sampler can get clogged leading to a drop in efficiency of the sampler.

Figure 2 — Arnhem sampler

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Dimensions in millimetres

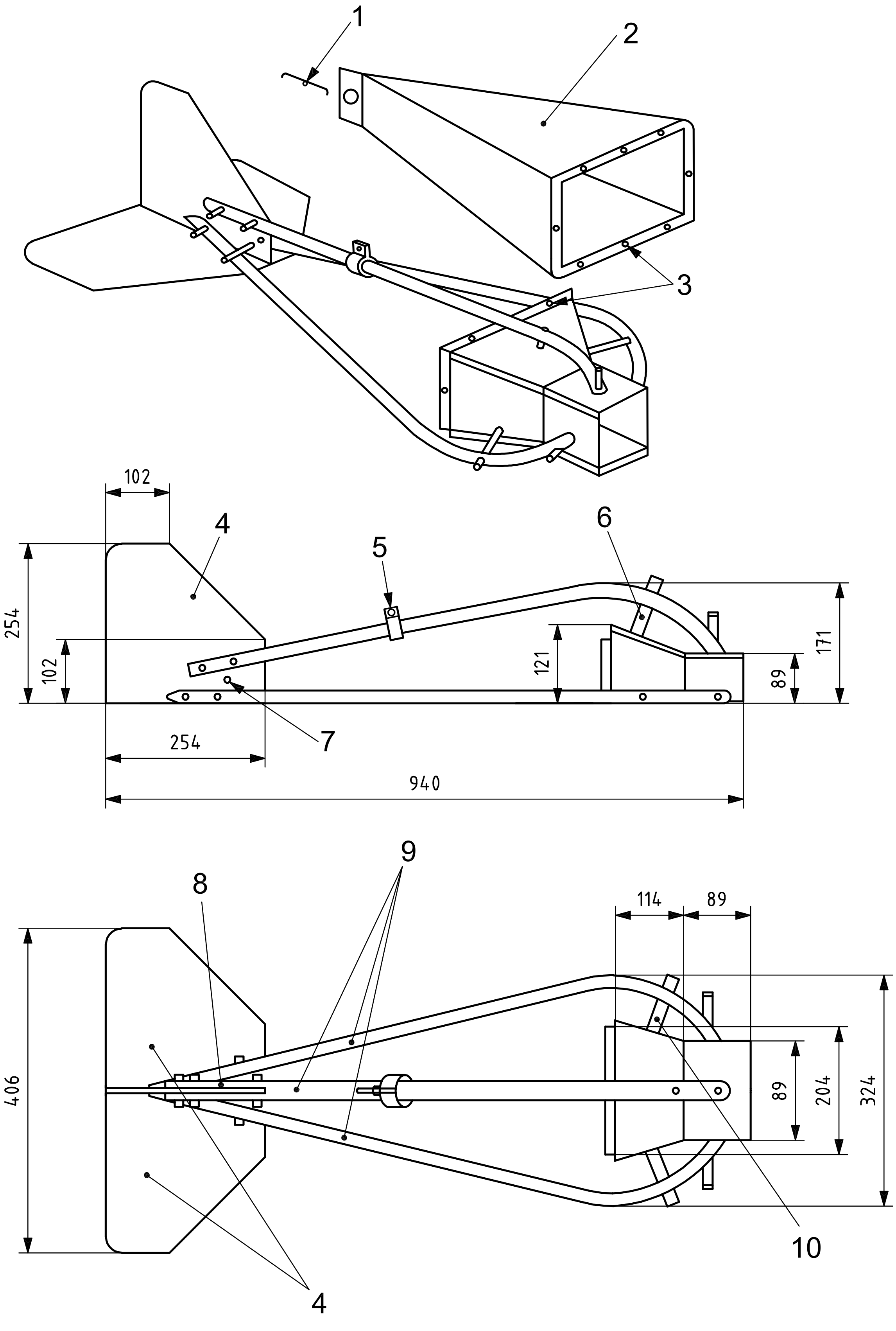


Figure 3 — Helley-Smith bedload sampler

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

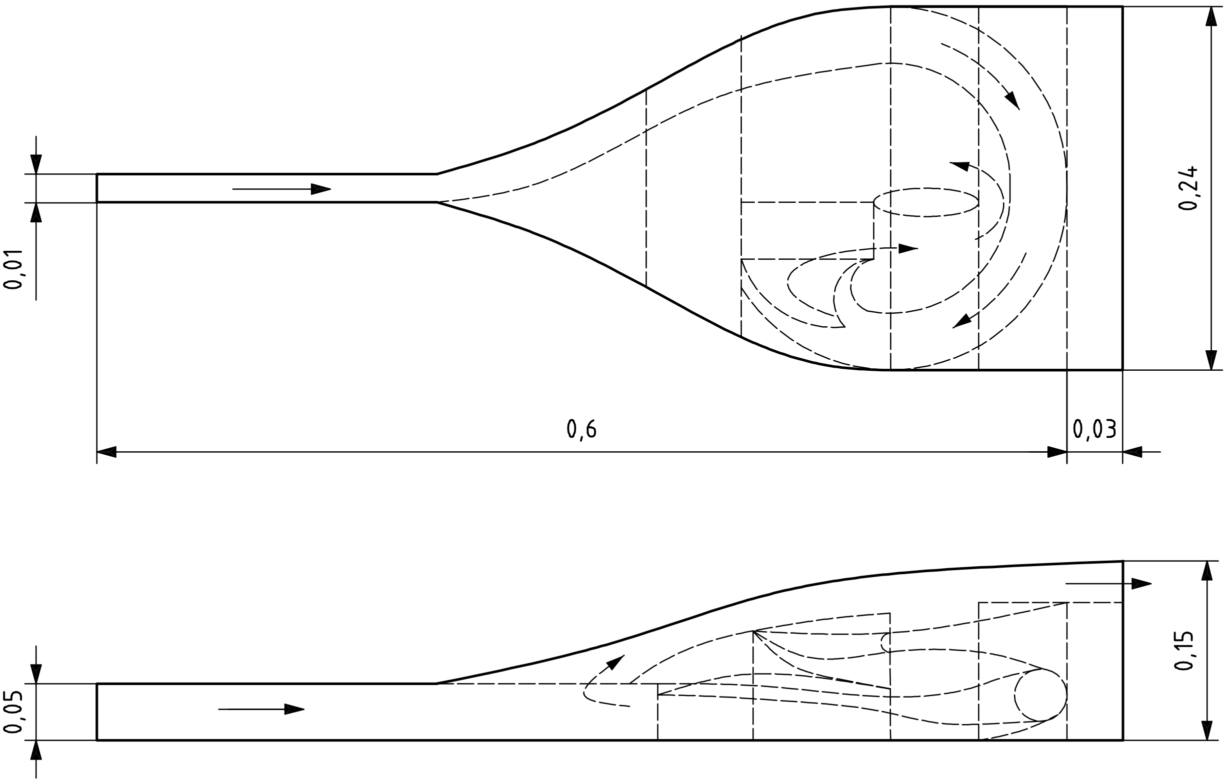
Key

1 bag to tail attachment spring
2 mesh polyester monofilament, 0,2 mm
3 dot fastener
4 aluminium alloy weld tail pieces except where side rails join tail
5 sliding collar
6 rail attachment bolt
7 hole for bag attachment spring
8 slot top rail to fit tail
9 aluminium tubing filled with lead after farming
10 tubing spacers where necessary

NOTE This is a pressure-difference bedload sampler. Field experiments indicate a nearly 100 % sampling efficiency for sizes from about 0,5 mm to 16 mm. Laboratory studies indicate that sampling efficiencies vary widely with particle size and transport rate.

Figure 3 (*continued*)

Dimensions in metres



NOTE This is a direct measurement sampler developed by Vinckers, Bijker and Schijft. The hydraulic efficiency varies from about 1,09 for clear flow, to about 1,0 for extreme conditions. Sampling efficiency varies from about 93 % for particle sizes finer than 0,2 mm to about 85 % for sizes finer than about 0,09 mm.

Figure 4 — Sphinx sampler

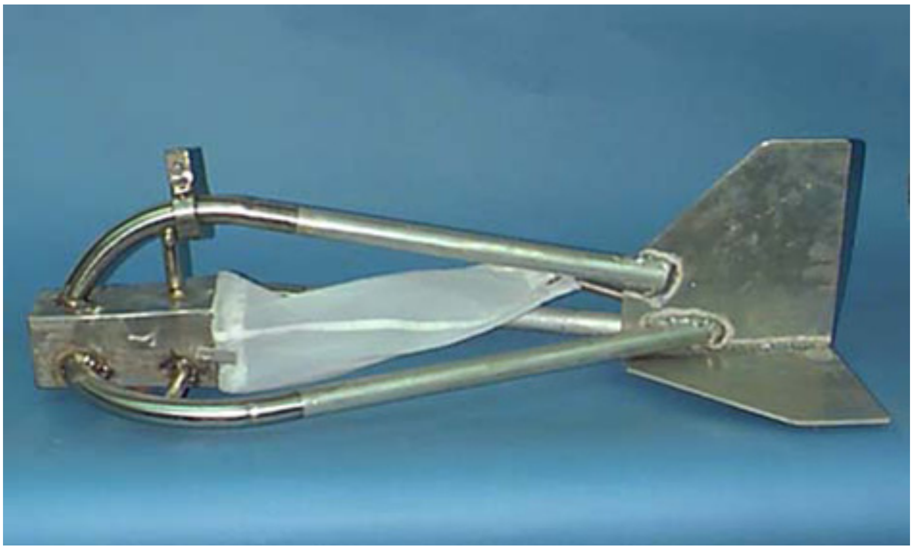
© ISO 2006 – All rights reserved

--`,,```,,,,````-`-`,,`,,`,`,,`---

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

NOTE The US BLH-84 is a hand-held 4,5 kg, wading type sampler used to collect bedload samples from a stream of wading depth. The sampler consists of an expanding nozzle, a sampler bag, and a wading rod assembly. Particle sizes less than 38 mm at mean velocities up to 3 m/s can be measured with this sampler. It was developed by the Federal Interagency Sedimentation Project, USA. Size of sampler: Length: 711 mm, Width: 140 mm, Mass: 4,5 kg.

Figure 5 — US BLH-84 Wading type bedload sampler



NOTE The US BL-84 is a cable suspended 14,4 kg, sampler to collect bedload samples from a stream of any depth. The sampler consists of an expanding nozzle mated to a frame, and a sampler bag. Particle sizes less than 38 mm at mean velocities up to 3 m/s can be measured with this sampler. It is developed by the Federal Interagency Sedimentation Project, USA [3]. Size of sampler: Length: 921 mm, Width: 381 mm, Mass: 14,4 kg.

Figure 6 — US BL-84 Cable suspended bedload sampler

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS Not for Resale

4.2.2 Indirect measurement of bedload transport

4.2.2.1 Differential measurements

Such measurements may be used if three conditions exist simultaneously in a stream: namely,

a) the bedload particles are sand-size or smaller,

b) an artificial or natural turbulence section exists in which all moving sediment is in suspension, and

c) there is a normal section nearby where bedload material is moving along the bed.

Suspended-sediment samples may be collected from both the turbulent and normal sections by standard suspended-sediment sampling techniques. The difference between the total sediment discharge measured in the turbulent section and the suspended-sediment discharge measured in the normal section, should be considered a good estimate of the bedload discharge in the normal section.

4.2.2.2 Volumetric method

Periodic volumetric measurements of changes in shape of deltoid deposits at river mouths may be used to estimate bedload discharge. Periodic volumetric measurements of the accumulation of deposited sediment behind dams or diversion structures may be used to estimate bedload discharge over longer periods of time.

4.2.2.3 Dune-tracking

Dune-tracking is a hydrographic survey method used when the bed forms are dune shaped. This method involves the mapping of a relatively short, straight reach of a channel under steady-flow conditions. The average parameters of the dune shapes are measured, and the average velocity of dune movement is determined.

4.2.2.4 Tracers

Easily identifiable tracer particles of known mass and size can be injected in the channel bed and the rate of their movement monitored for a specified time period.

4.2.2.5 Remote sensing

Where the channel bed is clearly visible through the water, time-lapse photography techniques can be used to track the movement of bedload particles. Acoustical sensing and recording devices can also be used to track the movement of very large bedload material, based on the theory that the noise created by particles hitting each other can be correlated with bedload discharge.

4.2.2.6 Acoustic instruments

For streams with relatively coarse bed material, a base plate or fork-shaped rod with a microphone attachment is lowered onto the stream bed. The sound of particle impact on the plate and inter particle collisions, picked up by the microphone, is transmitted to a recording device or an oscilloscope or a headphone. The instrument is useful in determining only the relative bedload transport in the cross-section and the relative variation with time. Such information about the relative variation in the cross-section is useful in the choice of the number and location of sampling points.

--`,,```,,,,````-`-`,,`,,`,`,,`---

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS

Not for Resale

4.3 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.

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 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.

5 Site selection

5.1 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.

5.2 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. The length of the straight reach should be approximately 10 to 20 channel widths (see 7.4)

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

5.3 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.

5.4 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 a bridge site, or at an excessively wide section.

6 Procedures for measurement of bedload discharge using bedload samplers

6.1 General

Many problems in determining bedload discharge over the wide range of sediment and hydraulic conditions found in nature have yet to be resolved. Among these problems, it should be noted that

a) quantification of physical relations is not complete enough to estimate the bedload discharge,

b) quantitative measurements are applicable only to specific site studies at the time of measurement and

c) direct-measurement devices are useful for only a very limited range of sediment size and hydraulic conditions.

As a result, no single apparatus or procedure has been universally accepted as completely adequate for the determination of the bedload discharge over the wide range of sediment and hydraulic conditions found in nature.

The type of sampler and the technique of sampling used will depend on a large number of factors: namely, stream velocity, depth, width, particle size, transport rate, channel stability and bed configuration. The transport rate of bedload not only changes from point to point in a cross-section but also exhibits widely variable short-term and long-term fluctuations at a fixed point. These variations in the measurement of bedload discharge mean that short-term measurements at a point are very likely to be non-representative of the mean bedload discharge at that point. Therefore, each sampling point should be sampled many times over an adequately long period in order to achieve any reasonable accuracy. The number of sampling points in a cross-section is usually dependent on funding and manpower available. However, it should be noted that the more points are sampled, the greater is the degree of accuracy.

The sampling time interval will be determined by the volume of bedload material in transport and the capacity of the sampler used. Generally, the quantity of material collected should not exceed two-thirds of the sampler capacity.

--`,,```,,,,````-`-`,,`,,`,`,,`---

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

6.2 Calculations

The computation of bedload discharge from measurements made by direct methods employs the following general formula which is applicable for all conditions for determining the total sediment discharge of a given particle size range:

$$T = (D/e) + Q_{\mathrm{sM}} + Q_{\mathrm{usM1}} - FQ_{\mathrm{sM1}} + (1 - E/e)\,Q_{\mathrm{ts2}}$$

where

T	is the total sediment discharge of the size range considered;
D	is the discharge of the size range as measured with the bedload sampler; if the sampler measures more than the bedload discharge, D includes some of the suspended-sediment discharge; if the sampler measures only the bedload discharge, $D = B$ (B being the bedload transport rate);
e	is the efficiency of the bedload sampler in measuring the bedload discharge of the size range;
Q_{sM}	is the measured suspended-sediment discharge of the size range. It equals the product of the total water discharge, a units-conversion constant, and the velocity-weighted mean concentration in the sampled zone;
Q_{usM1}	is the unmeasured suspended-sediment discharge of the size range at the depth between the lowest point measured by the suspended-sediment sampler and the highest point measured by the bedload sampler. It equals the product of the water discharge at this depth, a units-conversion constant, and the difference between the velocity-weighted mean concentrations in the sampled zone and at this depth;
F	is the fraction of flow at the depth measured by the bedload sampler with respect to total flow;
E	is the efficiency of the bedload sampler in measuring the suspended-sediment discharge of the size range that passes at the depth measured by the sampler;
Q_{ts2}	is the total suspended-sediment discharge of the size range that passes at the depth measured by the bedload sampler.

Simplifications of the general formula can be made for different combinations of particle size ranges (expressed as bedload or suspended load), vertical distribution of the suspended-sediment concentration and type of bedload measuring apparatus. Table 1 shows, for each combination, the equivalent of each factor in the general equation of the simplified formula.

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Table 1 — Simplified formulae for computing the total sediment discharge of a size range

Particle size range transported as [a]	Type of bedload measuring apparatus [b]	Equivalent					Simplified formula
		D/e	Q_{sM}	Q_{usM1}	F	Q_{ts2}	
s	W	0	Q_{sM}	0	0	0	$T = Q_{\mathrm{sM}}$
s	Y	$(E/e)\ Q_{\mathrm{ts2}}$	Q_{sM}	0	F	FQ_{sM}	$T = Q_{\mathrm{sM}}$
s	Z	$(E/e)\ Q_{\mathrm{ts2}}$	Q_{sM}	0	F	FQ_{sM}	$T = Q_{\mathrm{sM}}$
σ	W	0	Q_{sM}	Q_{usM1}	0	0	$T = Q_{\mathrm{sM}} + Q_{\mathrm{usM1}}$
σ	Y	$(E/e)\ Q_{\mathrm{ts2}}$	Q_{sM}	0	F	Q_{ts2}	$T = (D/e) + Q_{\mathrm{sM}} - FQ_{\mathrm{sM}} + (1 - E/e)\ Q_{\mathrm{ts2}}$ [c]
σ	Z	$(E/e)\ Q_{\mathrm{ts2}}$	Q_{sM}	Q_{usM1}	F	Q_{ts2}	$T = (D/e) + Q_{\mathrm{sM}} + Q_{\mathrm{usM1}} - FQ_{\mathrm{sM}} + (1 - E/e)\ Q_{\mathrm{ts2}}$ [c]
β	W	B/e	0	0	0	0	$T = (D/e)$
β	Y	B/e	0	0	F	0	$T = (D/e)$
β	Z	B/e	0	0	F	0	$T = (D/e)$
β, s	W	B/e	Q_{sM}	0	0	0	$T = (D/e) + Q_{\mathrm{sM}}$
β, s	Y	$(B/e) + (E/e)\ Q_{\mathrm{ts2}}$	Q_{sM}	0	F	FQ_{sM}	$T = (D/e) + Q_{\mathrm{sM}} - (E/e)\ Q_{\mathrm{ts2}}$
β, s	Z	$(B/e) + (E/e)\ Q_{\mathrm{ts2}}$	Q_{sM}	0	F	FQ_{sM}	$T = (D/e) + Q_{\mathrm{sM}} - (E/e)\ Q_{\mathrm{ts2}}$
β, σ	W	B/e	Q_{sM}	Q_{usM1}	0	0	$T = (D/e) + Q_{\mathrm{sM}} + Q_{\mathrm{usM1}}$
β, σ	Y	$(B/e) + (E/e)\ Q_{\mathrm{ts2}}$	Q_{sM}	0	F	Q_{ts2}	$T = (D/e) + Q_{\mathrm{sM}} - FQ_{\mathrm{sM}} + (1 - E/e)\ Q_{\mathrm{ts2}}$
β, σ	Z	$(B/e) + (E/e)\ Q_{\mathrm{ts2}}$	Q_{sM}	Q_{usM1}	F	Q_{ts2}	$T = (D/e) + Q_{\mathrm{sM}} + Q_{\mathrm{usM1}} - FQ_{\mathrm{sM}} + (1 - E/e)\ Q_{\mathrm{ts2}}$

[a] β: bedload; s: suspended-sediment having a uniform vertical distribution; σ: suspended-sediment having a non-uniform vertical distribution.

[b] W: measures only bedload; Y: measures bedload plus suspended sediment in all of unsampled depth; Z: measures bedload plus suspended sediment in part of unsampled depth.

[c] Or $Q_{\mathrm{sM}} + Q_{\mathrm{usM}}$ where Q_{usM} is unmeasured suspended-sediment discharge in unsampled depth.

6.3 Characteristics of bedload samplers

Because the sampling conditions encountered in streams vary widely, a single sampler for all conditions cannot be recommended. Factors such as cost, availability and specific requirements of the sampling also influence the choice of the sampler to a great extent. Table 2, which summarizes the characteristics of some commonly used samplers, can assist in the selection of a sampler in given conditions.

As the data obtained is affected by the sampling action and the mechanism of the sampler, any change in the sampler would itself introduce a variable. Therefore, the results obtained from different samplers might not be comparable.

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Table 2 — Samplers commonly used for bedload measurement

Type	Description	Disturbance of flow characteristics	Hydraulic stability	Sampler efficiency	Acceptability to various field conditions
Arnhem	Consists of a rigid rectangular entrance connected by a diverging rubber neck to a basket of 0,2 mm to 0,3 mm mesh fixed to a large framework by springs in such a way that the entrance is in contact with the bottom when the sampler is lowered onto the bed.	Variable	Variable	About 70 %	Generally restricted to collection of fine bedload material (2,0 mm); portable.
Helley-Smith	Tear-drop shaped, aluminium tubing frame connecting expanding brass entrance to aluminium tailfins; aluminium tubing filled with lead for mass (weight); bedload particles are trapped in a polyester mesh bag attached to exit.	Intake velocities are consistently higher than ambient velocities.	Stable in velocities up to 3,048 m/s (10 ft/s)	Variable from about 100 % for gravel to more than 150 % for sand	Varying sizes, from hand-held wading sampler to heavy sampler suspended from cables; fairly streamlined; portable.
US BLH-84 wading type sampler	The sampler is constructed of aluminium and is 711 mm long. Consists of an expanding nozzle, a sampler bag, and a wading rod assembly. The sampler has a 3 in 2 entrance nozzle and an area expansion ratio (ration of nozzle exit area to entrance area) of 1:40. A polyester mesh bag with mesh openings of 0,25 mm is attached to the rear of the nozzle assembly with a rubber “O” ring.		Mean velocities up to 2,987 m/s (9,8 ft/s). (This velocity is higher than safe wading velocities.)		The sampler design enables collection of particle sizes less than 38 mm at mean velocities up to 2,987 m/s (9,8 ft/s).

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Table 2 (*continued*)

Type	Description	Disturbance of flow characteristics	Hydraulic stability	Sampler efficiency	Acceptability to various field conditions
US BL-84 cable suspended sampler	The sampler consists of an expanding nozzle mated to a frame, and a sampler bag. The sampler has a 76,2 mm × 76,2 mm entrance nozzle and an area expansion ratio of 1,40. The US BL-84 is constructed of stainless steel and aluminium, is equipped with tail fins, and is 921 mm long by 381 mm wide. The sampler should be supported by a steel cable and reel to be lowered into a river or stream for taking a bedload sample.		Mean velocities up to 3,048 m/s (10 ft/s).		The sampler design enables collection of particle sizes up to 38 mm at mean velocities up to 3,048 m/s (10 ft/s).

6.4 Errors

The error in the bedload transport rate measured in a stream is caused by many factors: namely, efficiency of the bedload sampler, variable bedload movement, and the restricted number of verticals sampled in a cross-section, as well as operator error.

6.5 Sample identification

In order to properly evaluate the bedload samples, the following items should be recorded on the individual sampler container:

a) river name and location;

b) date of collection;

c) time of collection;

d) cross-section location;

e) depth of water;

f) length of sampling time;

g) water discharge;

h) type of sampler used.

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

7 Indirect measurement of bedload

7.1 General

Some methods (based on collection of samples) do not involve the measurement of the mass rate of transport of bedload. They mostly measure related parameters from which estimates of the volume rate of movement of bedload can be made. The one exception is the differential measurement method which can be utilized at some sites if the bedload material consists mostly of particles finer than about 2 mm.

7.2 Differential measurement method

The differential method for measuring bedload requires the measurement of suspended-sediment discharge at two sites within a river reach. The two sites should meet the following criteria:

a) particles no larger than about 2 mm are being transported;

b) the short-term time averaged bedload transport rates are similar at the two sites;

c) the upstream site represents a normal cross-section, i.e. a normal distribution of the total sediment load between bedload and suspended load, assumed to be representative of the reach in which bedload is being measured;

d) the downstream site is one at which the total sediment load is transported in suspension; this can be an artificially constructed section where turbulence is developed and maintained by a system of baffles;

e) representative cross-section samples can be collected at both sites using accepted suspended-sediment samplers.

7.3 Volumetric methods

Based on periodic measurement of the increased volume of sediment deposited in ponds, lakes, reservoirs and delta formations, volumetric measurements can sometimes be used to estimate average rates of bedload movement. These methods involve the use of capacity survey methods. Techniques for the measurement of elevations of the deposited sediments vary from use of sounding weights in small ponds to echo sounders in large lakes, reservoirs and deltas.

Periodic volumetric measurements of deposited sediments will be indicative of bedload-transport rates if the volume attributable to the sediment deposited from suspension can be determined. Generally, if suspended-sediment loads entering the area of deposition are measured on a continuing basis during the period of study, the deposited volume of the suspended portion of the total load can be estimated.

In order to accurately determine the bedload-transport rate of a river entering a well-defined area of deposition, the following factors should be taken into account.

a) The river being studied should be the major contributor of sediment to the deposition area; if it is not, the relative contributions of all other sources of sediment should be determined.

b) A unit mass of deposited sediment should be determined in order to translate volumetric measurements into mass measurements.

c) The period of time between surveys should be long enough to detect statistically significant measurable differences in elevations of the deposition area; generally, this means a minimum of 1 to 5 years between surveys, depending upon the sizes of the retention basin and the drainage basin.

d) The rate of compaction of deposited material between surveys should be estimated.

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS Not for Resale

7.4 Dune-tracking method

The dune-tracking method involves the monitoring of the rate of movement of dune-shaped forms in the downstream direction. Two techniques can be used: namely,

a) moving boat

An echo sounder mounted on a boat makes repetitive passes along well-defined longitudinal lines in a straight reach. The length of reach traversed should be long enough to include 20 to 25 well-defined dune forms.

b) *in situ* echo sounder

An echo sounder is mounted at a point in the cross-section of flow. The time rate of movement of at least 20 to 25 dunes past this point should be monitored.

For the moving-boat technique, a straight reach should be selected. The length of reach can be determined by first making a longitudinal pass along the approximate centreline of the channel to determine the length necessary to include 20 to 25 dune forms. For instance, if the dunes are approximately 3 m long, a 75 m to 100 m reach should be established to ensure inclusion of 20 to 25 dunes. Five to seven longitudinal lines should be established parallel to each other in the active bed zone of the reach. The sounding boat is moved along each line at a slow uniform speed so that the bed profile is accurately recorded on an analog strip-chart recorder. Each line should be sounded 2 to 4 times to determine the mean travel time of each identifiable dune form. Accurate records of times and distances along each line should be maintained. The second run should be maintained within 30 min to 40 min after the initial run to determine the approximate rate of movement of the dunes. The last run should be timed so that the first and last runs include most of the dune forms from crest to trough.

Similar criteria should be followed if the *in situ* technique is used. The sounder can be placed at 5 to 7 points in the cross-section in order to include a larger number of dune forms. Five to 7 separate echo sounders can also be set up to operate simultaneously.

The accuracy of the dune-tracking methods depends upon the

- ability of the sounding equipment to record the distance from transducer to the bed,
- accuracy of the determination of the boat position at any increment of time, and
- accuracy of the recording of all data, including the strip-chart recorder.

7.5 Tracers

A number of studies report the use of radioactive tracers to monitor the bedload movement. The technique is to insert into the stream a radioactive tracer in a form similar to the bedload, that is, it should have the same shape, size and mass as the natural sediment. The movement downstream can then be monitored using portable detectors. Alternatively, the tracer can be applied to the surface of naturally-occurring sediment, or it can be incorporated into artificial materials which can be made radioactive by irradiation (Tazioli, 1981) [5].

--`,,```,,,,````-`-`,,`,,`,`,,`---

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

Bibliography

[1] ISO/TS 3716:—1), *Hydrometry — Functional requirements and characteristics of suspended-sediment samplers*

[2] HUBALL, D.W. *Apparatus and Techniques for Measuring Bedload*, US Geological Survey of Water Supply Paper, **1748**, 1964, p. 10

[3] The Federal Interagency Sedimentation Project, Vicksburg, USA, Report on "Sampling with the US BL-84 sampler"

[4] Food and Agricultural Organisation of the United Nations, Rome, NW Hudson, Chapter V, *Field measurement of soil erosion and runoff*, 1993

[5] TAZIOLI, G.S. Nuclear techniques for measuring sediment transport in natural streams: examples from instrumental basins. In: *Erosion and Sediment Transport Measurement, Proceedings of the Florence Symposium*, IAHS Publ. no. 133, 1981, pp. 63-81

---

1) To be published. (Revision of ISO 3716:1977)

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale

ICS 17.120.20

Price based on 17 pages

© ISO 2006 – All rights reserved

Copyright International Organization for Standardization
Provided by IHS under license with ISO
No reproduction or networking permitted without license from IHS
Not for Resale