INTERNATIONAL STANDARD

ISO 1088

Third edition
2007-07-01

Hydrometry — Velocity-area methods using current-meters — Collection and processing of data for determination of uncertainties in flow measurement

Hydrométrie — Méthodes d'exploration du champ des vitesses à l'aide de moulinets — Recueil et traitement des données pour la détermination des incertitudes de mesurage du débit

Reference number
ISO 1088:2007(E)

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.

iTeh STANDARD PREVIEW
(standards.iteh.ai)

ISO 1088:2007
https://standards.iteh.ai/catalog/standards/sist/d25e01e9-8fdf-4383-be5f-a5cd75fb3f5f/iso-1088-2007

COPYRIGHT PROTECTED DOCUMENT

© ISO 2007

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

Contents

Page

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.

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 1088 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 5, *Instruments, equipment and data management*.

This third edition cancels and replaces the second edition (ISO 1088:1985), which has been revised to incorporate ISO/TR 7178 (based on ISO/DATA No. 2) and edited in accordance with ISO/IEC Guide 98:1995, *Guide to the expression of uncertainty in measurement (GUM)*. This third edition of ISO 1088 also cancels and replaces ISO/TR 7178, all provisions of which have been incorporated into this edition.

Introduction

All measurements of physical quantities are subject to uncertainties, which can be due to biases (systematic errors) introduced in the manufacture, calibration, and maintenance of measurement instruments, or to random scatter caused by a lack of sensitivity of the instruments, and to other sources of error.

During the preparation of the first edition of ISO 748, much discussion was given to the question of the magnitude of errors in measurements, and it was concluded that recommendations could only be formulated on the basis of an analysis of sufficient data. Moreover, it was recognized that to be able to analyze such data statistically, it was essential that the data be collected and recorded on a standardized basis and in a systematic manner, and this recognition led to the preparation of ISO 1088 and ISO/TR 7178.

On the basis of the procedures given in the first editions of ISO 748 (1968) and ISO 1088 (1973), data were subsequently collected and processed from the following rivers (see Annex A for the characteristics of these rivers) and ISO/TR 7178 was accordingly published:

a) Rivers Ganga, Jalangi, Yamuna, and Visvesvaraya Canal, in India;

b) River IJssel, in the Netherlands;

c) Rivers Derwent, Eden, Lambourne, Ouse, Tyne, and Usk in the United Kingdom;

d) Rivers Columbia and Mississippi, in the United States.

Further data obtained on the Rivers Ganga and Krishna, in India, and the Spey,Tay, Tweed, Tyne, Gala Water, Yarrow Water, Ettrick Water, and the Clyde, in the United Kingdom, were received later, but could not be included in the processing.

The procedures for estimating the component uncertainties and the uncertainty in discharge in this International Standard conform to the ISO/IEC Guide 98, *Guide to the expression of uncertainty in measurement (GUM)*.

Hydrometry — Velocity-area methods using current-meters — Collection and processing of data for determination of uncertainties in flow measurement

1 Scope

This International Standard provides a standard basis for the collection and processing of data for the determination of the uncertainties in measurements of discharge in open channels by velocity-area methods using current-meters.

To determine the discharge in open channels by the velocity-area method, components of the flow (velocity, depth and breadth) need to be measured. The component measurements are combined to compute the total discharge. The total uncertainty in the computed discharge is a combination of the uncertainties in the measured components.

Clause 4 of this International Standard deals with the types of errors and uncertainties involved. Clauses 5 and 6 present a standard procedure to estimate the component uncertainties by the collection and processing of the necessary data.

This International Standard is intended to be applied to velocity-area methods that involve measurement of point velocities at a relatively small number of discrete depths and transverse positions in the flow cross-section, as described in ISO 748. This International Standard is not intended to be applied to measurements made by Acoustic Doppler Velocity Profilers (ADVP) or other instruments that produce essentially continuous velocity profiles of the flow field.

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 748, *Measurement of liquid flow in open channels — Velocity-area methods*

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

ISO 4364, *Measurement of liquid flow in open channels — Bed material sampling*

3 Symbols and abbreviated terms

a	coefficient of linear regression, slope of trend line
b_i	breadth (width) of segment i
d_i	depth at vertical in segment i
L	number of sets of measurements (error type ii)
J	number of measurements per set (error types ii and iii)
k'	time displacement in autocorrelation function (of time interval, etc.)
k	coverage factor for expanded uncertainty (taken as 2, corresponding to a level of confidence of approximately 95 %)
m	number of verticals or sections per measurement cross-section
n	multiple of basic exposure-time for velocity measurement (error type i)
n_i	number of depths in vertical i at which velocity measurements are made
Q	discharge
Q_j	discharge of measurement j in a set of measurements (error type iii)
S_{rel}	standard deviation of the relative mean velocities (error type ii)
S_{F}	mean standard deviation of all measurement sets together due to velocity fluctuations (error type ii)
$S_{\mathrm{F},i}$	standard deviation of sampling error in measurement set i (error type ii)
S_{s}	standard deviation of the sampling error due to the computation rule (error type ii)
S_i	stochastic sampling error of mean velocity in vertical i (error type ii)
$S_{\bar{v},i}$	unobservable random sampling error of mean velocity in vertical i (error type ii)
$S_{\mathrm{s},hd}(m)$	standard deviation of relative error when m verticals are applied (error type iii)
t_i	instant of time of observation i (error type i)
t_0	initial measuring time (basic time interval)
$\bar{t}$	mean of observation times t_i in a linear trend segment (error type i)
u_i	standard relative (percentage) uncertainty in uncertainty component i
u	standard relative (percentage) combined uncertainty of measurement
U	expanded relative (percentage) uncertainty with coverage factor k
u_{c}	standard relative (percentage) uncertainty due to responsiveness of current-meter
u_{b}	standard relative (percentage) uncertainty in width measurement
u_{d}	standard relative (percentage) uncertainty in depth measurement

u_e	standard relative (percentage) uncertainty due to velocity fluctuations
u_m	standard relative (percentage) uncertainty due to limited number of verticals
u_p	standard relative (percentage) uncertainty due to limited number of depths at which velocity is measured
u_s	standard relative (percentage) uncertainty due to instrument calibration errors
v_i	velocity at time t_i or in vertical i
V_i	actual velocity at time t_i or in vertical i
v_i'	corrected velocity from which trend has been removed (error type i)
$\hat{v}(t)$	trend-line velocity (error type i)
$\bar{v}_i$	mean velocity in vertical i or at point i;
$\bar{V}_\mathrm{rel}$	mean of the relative mean velocities (error type ii)
$\bar{V}_{\mathrm{rel},j}$	mean relative velocity in the j^th profile (error type ii)
$\hat{\mu}_\mathrm{s}$	mean sampling error for the entire series of measurement sets (error type ii)
$\mu_{\mathrm{s},i}$	mean sampling error in measurement set i (error type ii)
$\hat{\mu}(m)$	mean relative error when m verticals are applied (error type iii)
σ_F	standard deviation of velocity fluctuations (error type i)

Additional symbols are defined in the text.

Due to the statistical nature of this International Standard, it is necessary to have symbols representing observed values and true values of variables. The symbols therefore might not conform to ISO 772.

4 Types of errors and procedure for estimating the uncertainties in flow measurement

4.1 Principle

The principle of the velocity-area method consists in determining from measurements the distribution of the flow velocity in the cross-section and the area of the cross-section, and using these observations for the computation of the discharge.

The measurements of the velocity are made in a number of verticals. In each vertical the mean velocity is determined from measurements at a selected number of points. The discharge per unit width can be found by multiplying the mean velocity by the depth in the vertical considered.

Each vertical is assumed to be representative of a segment of the cross-sectional area. The selection of the number and location of the verticals determines the width of these segments. Recommendations on the number of verticals required are given in 4.4.3 c).

Assuming that the discharge has remained constant during the measurements, summation of the discharge in the various segments gives the total discharge through the section.

4.2 Occurrence of error

In general, the result of a measurement is only an estimate of the true value of the quantity subjected to measurement. The discrepancy between the true and measured values is the measurement error. The measurement error, which cannot be known, causes an uncertainty about the correctness of the measurement result.

The measurement error is a combination of component errors, which arise during the performance of various elementary operations during the measurement process. For measurements of composite quantities, which depend on several component quantities, the total error of the measurement is a combination of the errors in all component quantities. Determination of measurement uncertainty involves identification and characterization of all components of error, and the quantification and combination of the corresponding uncertainties.

ISO/IEC Guide 98 treats measurement uncertainty using concepts and formulas for probability distributions, expected values, standard deviations, and correlations of random variables. The standard deviation of the measurement error is taken as the quantitative measure of uncertainty.

ISO/IEC Guide 98 does not make use of the traditional categorization of errors as random and systematic. That categorization can be difficult to apply in practice. For example, an error that is systematic in one measurement process might become random in a different process. The essential characteristic of systematic errors is that they are not reduced by averaging of replicate measurements. The guide makes it clear that accurate description of the measurement process and correct mathematical formulation of the uncertainty equations are sufficient to account for the fact that some uncertainty sources are not reduced by averaging of replicate measurements whereas others are reduced, without reliance on the concepts of systematic and random error.

The components of uncertainty are characterized by estimates of standard deviations, which are termed standard uncertainty, with recommended symbol u_i, where i identifies the component in question, and which are equal to the positive square root of the estimated variance, u_i^2. The uncertainty components are combined using formulas for combination of standard deviations of possibly correlated random variables. The resultant uncertainty, which takes all sources and components of uncertainty into account, is called the combined uncertainty and is denoted as u.

ISO/IEC Guide 98 introduces the concepts of Type A and Type B methods of evaluation of uncertainty to make a distinction between uncertainty evaluation by statistical analysis of replicate measurements and uncertainty evaluation by other (perhaps subjective or judgmental) means. Type A evaluation of uncertainty is by statistical analysis of repeated observations to obtain statistical estimates of the standard deviations of the observations; this evaluation commonly can be carried out automatically during the measurement process by data loggers or other instrumentation. Type B evaluation is by calculation of the standard deviation of an assumed probability distribution based on scientific judgment and consideration of all available information, which might include previous measurement and calibration data and experience or general knowledge of the behaviour and properties of relevant instruments. By proper consideration of correlations, either Type A or Type B method of evaluation can be used for evaluation of either systematic or random uncertainty components.

In this International Standard, all uncertainties are expressed numerically as percentages. Standard uncertainty values thus correspond to percentage coefficients of variation (standard deviation divided by the mean). Expanded uncertainties are explicitly identified as such, and are taken with coverage factor 2, corresponding to a level of confidence of approximately 95 %.

4.3 Sources of error

Theoretically, the discharge can be expressed as

$$Q = \iint v(x,y)\,\mathrm{d}x\,\mathrm{d}y \tag{1}$$

where

Q is the true discharge;

$v(x,y)$ is the velocity field over the width, x, and depth, y, of the cross section.

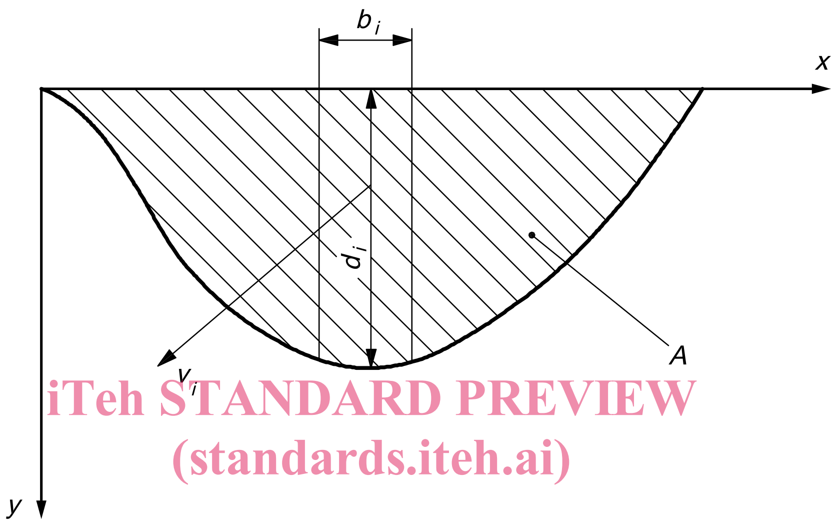

Figure 1 — Definition sketch

In practice, the integral is approximated by the summation

$$Q = \sum_{i=1}^{m} \left(b_i d_i \bar{v}_i \right) \cdot F \tag{2}$$

where

Q is the calculated discharge;

b_i is the width of the i^{th} section;

d_i is the depth of the i^{th} vertical;

$\bar{v}_i$ is the mean velocity in the i^{th} vertical;

F is a factor, conventionally assumed as unity, that relates the discrete sum of the finite number of verticals to the integral of the continuous function over the cross-section (see ISO 748);

m is the number of verticals.

Errors in Q are due to

a) errors in the measurement of quantities b_i and d_i and of the individual measurements of the velocity necessary for the determination of the average velocity, $\bar{v}_i$, and

b) errors in approximation of the integral equation [Equation (1)] by the summation equation [Equation (2)].

4.4 Determination of the individual components of the uncertainty

4.4.1 Uncertainties in width

The measurement of the width between verticals is normally made by measuring distances from a reference point on the bank. When a tape or tag-line is used, or the movement of the wire attached to a trolley is observed, the uncertainty depends on the distance but is usually negligible. Where optical means are used, the uncertainties also depend on the distance measured but can be greater.

Where the distance is measured by electronic means, a constant uncertainty and an uncertainty depending on the distance measured occurs.

The uncertainties result mainly from instrument errors.

4.4.2 Uncertainties in depth

Some uncertainties depend on the type and use of the instrument applied. Such uncertainties are not included in this International Standard.

Uncertainties also arise due to the interpolation of the depth between verticals at which depths are measured.

4.4.3 Uncertainties in the determination of the mean velocity

Apart from instrument calibration errors, the error in the mean flow velocity can be considered as consisting of three independent types of error.

a) **Error Type i — Pulsations:** The uncertainty due to the limited measuring time of the local point velocity in each vertical. Because of turbulence, the velocity fluctuates continuously over the wet cross-section. The mean velocity at any point, determined from measurement during a certain time interval, is an approximation of the true mean velocity at that particular point. In this International Standard, uncertainties of this nature are referred to as “error type i”. Pulsations in flow are not independent of each other. The velocity at time t_2 is influenced by the velocity at time t_1. This influence will decrease as the time interval $t_2 - t_1$ increases. The effect of increasing the measuring time on the uncertainty is given in Annex B.

b) **Error Type ii — Number of points in the vertical:** The uncertainty arising from the use of a limited number of sampling points in a vertical. Computation of the mean velocity in a vertical as an average or weighted average of a number of point velocities results in an approximation of the true mean velocity in the vertical considered. In this International Standard, uncertainties of this nature are referred to as “error type ii”.

c) **Error Type iii — Number of verticals:** The uncertainty from the limited number of verticals in which velocities are measured. The horizontal velocity profile and bed profile between two verticals have to be determined by interpolation, which introduces an uncertainty (see Annex F). In this International Standard, uncertainties of this nature are referred to as “error type iii”.

NOTE The types of errors referred to in this International Standard are not related to statistical Type i and Type ii errors.

To determine the influence of the distribution of horizontal velocity and depth between the verticals on the total uncertainty in discharge, it is necessary to make a detailed measurement of the cross-section and to locate the verticals for the velocity measurement at intervals of no more than 0,25 m or 1/50 of the total width, whichever is greater.

The values of depth d_i, breadth b_i, and mean velocity $\bar{v}_i$ in the vertical are used to determine the discharge per unit width and discharge through segment i. Summation of the discharges through each segment according to Equation (2) results in an approximation of the true total discharge.

4.5 Total uncertainty in discharge

The uncertainties in the individual components of discharge are expressed as relative standard uncertainties in percent, corresponding to percentage coefficients of variation (standard deviation of error divided by expected value of the measured quantity).

The relative (percentage) combined standard uncertainty in the measurement is given by the following equation (ISO 748):

$$u(Q)^2 = u_\mathrm{m}^2 + u_\mathrm{s}^2 + \frac{\sum_{i=1}^{m}\left(\left(b_i d_i \bar{v}_i\right)^2 \left(u_{\mathrm{b},i}^2 + u_{\mathrm{d},i}^2 + u_{\bar{v},i}^2\right)\right)}{\left(\sum_{i=1}^{m} b_i d_i \bar{v}_i\right)^2} \tag{3}$$

where

$u(Q)$	is the relative (percentage) combined standard uncertainty in discharge;
$u_{\mathrm{b},i}$, $u_{\mathrm{d},i}$, $u_{\bar{v},i}$	are the relative (percentage) standard uncertainties in the breadth, depth, and mean velocity measured at vertical i;
u_s	is the relative uncertainty due to calibration errors in the current-meter, breadth measurement instrument, and depth sounding instrument;
u_m	is the relative uncertainty due to the limited number of verticals;
m	is the number of verticals.

The relative uncertainty due to calibration errors, u_s, can be expressed as $u_\mathrm{s} = (u_\mathrm{cm}{}^2 + u_\mathrm{bm}{}^2 + u_\mathrm{ds}{}^2)^{1/2}$, where u_cm, u_bm, and u_ds are the relative uncertainties due to calibration errors in the current-meter, breadth measurement instrument, and depth sounding instrument, respectively. An estimated practical value of 1 % can be taken for the value of u_s.

The mean velocity $\bar{v}_i$ at vertical i is the average of point measurements of velocity made at several depths in the vertical. The uncertainty in $\bar{v}_i$ is computed as follows:

$$u\left(\bar{v}_i\right)^2 = u_{\mathrm{p},i}^2 + \left(\frac{1}{n_i}\right)\left(u_{\mathrm{c},i}^2 + u_{\mathrm{e},i}^2\right) \tag{4}$$

where

$u_{\mathrm{p},i}$	is the uncertainty in mean velocity $\bar{v}_i$ due to the limited number of depths at which velocity measurements are made at vertical i;
n_i	is the number of depths in the vertical i at which velocity measurements are made;
$u_{\mathrm{c},i}$	is the uncertainty in point velocity at a particular depth in vertical i due to variable responsiveness of current-meter;
$u_{\mathrm{e},i}$	is the uncertainty in point velocity at a particular depth in vertical i due to velocity fluctuations (pulsations) in the stream.

Combining Equations (3) and (4) yields:

$$u(Q)^2 = u_{\mathrm{m}}^2 + u_{\mathrm{s}}^2 + \frac{\sum_{i=1}^{m}\left((b_i d_i \bar{v}_i)^2\left(u_{\mathrm{b},i}^2 + u_{\mathrm{d},i}^2 + u_{\mathrm{p},i}^2 + \left(\frac{1}{n_i}\right)\left(u_{\mathrm{c},i}^2 + u_{\mathrm{e},i}^2\right)\right)\right)}{\left(\sum_{i=1}^{m} b_i d_i \bar{v}_i\right)^2} \tag{5}$$

If the measurement verticals are placed so that the segment discharges ($b_i\, d_i\, \bar{v}_i$) are approximately equal and if the component uncertainties are equal from vertical to vertical, then Equation (5) simplifies to:

$$u(Q) = \left[u_{\mathrm{m}}^2 + u_{\mathrm{s}}^2 + \left(\frac{1}{m}\right)\left(u_{\mathrm{b}}^2 + u_{\mathrm{d}}^2 + u_{\mathrm{p}}^2 + \left(\frac{1}{n}\right)\left(u_{\mathrm{c}}^2 + u_{\mathrm{e}}^2\right)\right)\right]^{\frac{1}{2}} \tag{6}$$

Equation (6) can be used for uncertainty computation for a particular measurement if the segment discharges ($b_i\, d_i\, \bar{v}_i$) and the component uncertainties are nearly equal from vertical to vertical. More generally, however, Equation (6) is useful for developing a qualitative understanding of how the various component uncertainties contribute to the total uncertainty discharge measurement. Equation (5) is needed to properly account for the effects of unequal distribution of flow among the segments.

From the above equations, it can be seen that the total standard uncertainty may be reduced by increasing the number of verticals, improving the measurement of the individual components, or both.

It is recommended that, whenever possible, the user shall determine independently the values of the component uncertainties in the above equations. However, for routine gauging, values are given in Annex E of ISO 748:1997 that are the result of many investigations carried out since the publication of the first edition of ISO 748 in 1968. These results are included in Annex G, re-expressed in terms of standard uncertainties (level of confidence approximately 68 %) for conformance with ISO/IEC Guide 98.

It should be noted that since the individual components of uncertainty presented in Annex G are based on statistical analyses of the spread of replicate measurements, on prior observations, rather than on repeated observations during the actual course of the measurement of discharge, they shall be considered as Type B evaluations of uncertainties (see 4.2).

A simplified example of the calculation of the uncertainty in a velocity-area gauging using Equation (6) and the relevant component uncertainties given in Annex G is presented in Annex H.

5 Collection and processing of data for the investigation of component uncertainties – type A evaluation of uncertainties

5.1 Data on the local point velocity

To judge the uncertainty of a single point velocity measurement, the following procedure is required at each of three verticals.

At each point of measurement on a vertical, an uninterrupted observation of the velocity over a period of 2 000 s, or for a period during which the discharge does not change by more than 5 % of the initial value, whichever is the less, shall be made with a current-meter. Every 10 s, a reading of the instrument should be taken, thus giving a total of 200 readings. When pulses are emitted by the current-meter, the number of pulses should be recorded every 10 s; or, when the time is measured at a fixed number of pulses, this time interval should average 10 s. When a continuous record is produced, the complete record should be given and the response characteristics of the electronic instrument stated.

The verticals to be taken for this measurement should be the vertical situated at the deepest point and the verticals situated at places where the depths are 0,6 and 0,3 times the maximum depth, both located on the side of the greater segment of the width from the deepest point.

In each vertical this procedure should be carried out at 0,2, 0,6, and 0,8 and, where possible, at 0,9 times the depth, all measured from the surface. The data shall be obtained, where possible, during the same 2 000 s period.

The data thus obtained shall be indicated in the report format as illustrated in Annex C. In the case of a continuous recorder, the values at intervals of 10 s shall be given, indicating the method of determination.

5.2 Data on the average velocity

5.2.1 General

The average velocity in a vertical can be obtained in various ways. The velocity distribution method, however, is taken as a basis for comparison with the results of other methods generally used or special methods adopted owing to special circumstances.

The following procedure is required for investigating the average velocity in each of the three verticals.

5.2.2 Location of the verticals

The location of the verticals for this measurement shall normally be determined from the known velocity distribution in the gauging cross-section, so as to give velocities which are representative of the whole cross-section.

When the velocity distributions in the gauging cross-section are not known, the verticals taken for this measurement shall be that at maximum depth in the cross-section and at places where the depths are 0,6 and 0,3 times the maximum depth respectively, at the side of the greater segment and not too close to the bank.

5.2.3 Distribution of measuring points in the vertical

Velocity measurements shall be made at the following depths in each vertical:

1) immediately below the surface

2) at 0,2 times the depth

3) at 0,3 times the depth

4) at 0,4 times the depth

5) at 0,5 times the depth

6) at 0,6 times the depth

7) at 0,7 times the depth

8) at 0,8 times the depth

9) at 0,9 times the depth

10) near the bed

In channels containing weed growth, great care shall be taken to ensure that measurements made in the vicinity of the bed are not affected by weed fouling the current-meter.