INTERNATIONAL STANDARD

ISO 8368

Second edition
1999-04-01

Hydrometric determinations — Flow measurements in open channels using structures — Guidelines for selection of structure

Déterminations hydrométriques — Mesure de débit dans les canaux découverts au moyen de structures — Lignes directrices pour le choix des structures

Reference number
ISO 8368:1999(E)

Contents

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Printed in Switzerland

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 3.

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.

International Standard ISO 8368 was prepared by Technical Committee ISO/TC 113, *Hydrometric determinations*, Subcommittee SC 2, *Notches, weirs and flumes*.

This second edition cancels and replaces the first edition (ISO 8368:1985). This second edition of ISO 8368 was prepared in order to bring the techniques described up to date. The format has been improved to make the information easier to interpret.

Hydrometric determinations — Flow measurements in open channels using structures — Guidelines for selection of structure

1 Scope

This International Standard gives guidelines for selection of a particular type of flow-gauging structure for measurement of liquid flow in open channels. It sets out the factors, and summarizes the parameters which may influence such a selection.

NOTE In general, a flow-gauging structure is used when high accuracy is required for continuous records of flow.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents listed below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 772, *Hydrometric determinations — Vocabulary and symbols.*

ISO 1438-1, *Water flow measurement in open channels using weirs and Venturi flumes — Part 1: Thin-plate weirs.*

ISO 3846, *Liquid flow measurement in open channels by weirs and flumes — Rectangular broad-crested weirs.*

ISO 3847, *Liquid flow measurement in open channels by weirs and flumes — End-depth method for estimation of flow in rectangular channels with a free overfall.*

ISO 4359, *Liquid flow measurement in open channels — Rectangular, trapezoidal and U-shaped flumes.*

ISO 4360, *Liquid flow measurement in open channels by weirs and flumes — Triangular-profile weirs.*

ISO 4362, *Measurement of liquid flow in open channels — Trapezoidal profile weirs.*

ISO 4371, *Measurement of liquid flow in open channels by weirs and flumes — End depth method for estimation of flow in non-rectangular channels with a free overfall (approximate method).*

ISO 4374, *Liquid flow measurement in open channels — Round-nose horizontal broad-crested weirs.*

ISO 4377, *Liquid flow measurement in open channels — Flat-V weirs.*

ISO 8333, *Liquid flow measurement in open channels by weirs and flumes — V-shaped broad-crested weirs.*

ISO 9826:1992, *Measurement of liquid flow in open channels — Parshall and SANIIRI flumes.*

ISO 9827, *Measurement of liquid flow in open channels by weirs and flumes — Streamlined triangular-profile weirs.*

ISO 13550 , *Hydrometric determinations — Flow measurements in open channels using structures — Use of vertical underflow gates and radial gates.*

ISO 14139, *Hydrometric determinations — Flow measurements in open channels using structures — Compound gauging structures.*

3 Terms, definitions and symbols

For the purposes of this International Standard, the terms, definitions and symbols together with the corresponding units of measurement given in ISO 772 apply.

4 Types of structure

The following types of structure can be used for the purpose of liquid flow measurement:

a) thin-plate weirs:

   1) rectangular;

   2) V-notch.

b) broad-crested weirs:

   1) round-nose horizontal;

   2) rectangular horizontal;

   3) V-shaped.

c) triangular-profile weirs.

d) streamlined triangular-profile weirs.

e) flat-V weirs.

f) flumes:

   1) rectangular;

   2) trapezoidal;

   3) U-throated;

   4) Parshall and SANIIRI.

g) end-depth method:

   1) rectangular channel;

   2) non-rectangular channel (approximate method).

h) trapezoidal-profile weirs.

i) compound gauging structures.

j) vertical underflow gates and radial gates.

Diagrams showing the construction of a particular type of flow-gauging structure are given in the appropriate International Standard listed in clause 2.

5 Factors affecting choice

5.1 General

The factors which affect choice can be considered under the following headings:

a) purpose;

b) range of flow;

c) afflux;

d) size and nature of channel;

e) channel slope and sediment load;

f) operation and maintenance;

g) environmental impact;

h) passage of fish;

i) cost.

5.2 Purpose

Table 1 tabulates the various structures and indicates some of the purposes for which they may be applicable, together with guidelines to their limitations.

The purpose for which the structure is required will determine the range of flows and accuracies which is necessary. The accuracy in a single determination of discharge depends upon the estimation of the component uncertainties involved.

In broad terms, thin-plate weirs will have a range of uncertainties from 1 % to 4 %, flumes and certain types of weirs will have a range from 2 % to 5 % and end methods and other weirs will have a range from 4 % to 10 %. Deviations from the construction, installation or use as laid down in the appropriate International Standard will result in measurement errors.

5.3 Range of flow

It is necessary to consider the relation between maximum flow and minimum flow when deciding which type of structure to use, and an indication of the range of some typical structures is given in Table 2. For the best overall accuracy over a wide range of small discharges, a thin-plate V-notch weir should be used in preference to a thin-plate rectangular notch or rectangular full-width weir. For a wide range of larger discharges, a trapezoidal flume, a flat-V weir or a triangular-profile weir should be used in preference to a broad-crested weir, free overfall or rectangular-throat flume.

5.4 Afflux

The rise in level immediately upstream of, and due to, a structure may interfere with the flow system and cause drainage problems, or limit the effectiveness of irrigation systems, or cause extra pumping costs. In addition, the aquatic habitat upstream of the structure may be adversely affected. A number of structures have been developed with high coefficients of discharge and whose accuracy is relatively unimpaired by high submergence ratios. The triangular-profile and flat-V weirs, and flumes are examples of this type of structure.

Table 1 — Applications and limitations of structures

Type	International Standard	Typical uncertainties in computed discharge, %	Modular[1)] limit	Limitations	Typical application
Thin-plate weirs	ISO 1438-1	1 to 4	[2)]	2 [3)]	Laboratory, pump tests, sediment free water, small streams, and for use in hydraulics laboratories.
Broad-crested weirs a) rectangular profile b) round-nose horizontal crest c) V-shaped	 ISO 3846 ISO 4374 ISO 8333	3 to 5	 66 % 80 % 80 %	 1,5 [3)] 1,5 [3)] 1,5 3,0 [3)]	Broad-crested weirs are best used in rectangular channels, but they can be used with good accuracy in non-rectangular channels if a smooth, rectangular approach channel extends upstream of the weir for a distance not less than twice the maximum head. Irrigation channels with little fall available and wide range of flow.
Triangular-profile weirs	ISO 4360	2 to 5	75 %	3,5 [3)]	Hydrometric networks and principal irrigation channels
Streamlined triangular-profile weirs	ISO 9827	2 to 5	?	?	Irrigation works and minor channels
Flat-V weirs	ISO 4377	2 to 5	70 %	2,5 [3)]	Hydrometric works with wide range of flow
Compound gauging structures	ISO 14139	2 to 5	Varies	Vary	Hydrometric works with wide range of flow
Trapezoidal-profile weirs	ISO 4362	4 to 8	65 % to 85 %[4)]	1,3 [3)]	Where ease of construction is an important factor. Irrigation works and minor channels.
Vertical underflow gates and radial gates	ISO 13550	4 to 8	[2)]	See ISO 13550	Situations where a near constant upstream water level is required.
End-depth method a) rectangular b) non-rectangular	 ISO 3847 ISO 4371	 5 to 10	[2)]	[6)]	Where accuracy may be relaxed for simplicity and economy.
Long-throated flumes	ISO 4359	2 to 5	74 %	0,7 [5)]	Flumes can be used in channels of any shape if flow conditions in the approach channel are reasonably uniform and steady. Sediment-laden channels, flow with debris, flow with migratory fish, conduits and partially filled pipes, flow in sewers.
Parshall and SANIIRI flumes	ISO 9826	4 to 8	60 % to 80 %	See ISO 9826	Flumes can be used in channels of any shape if flow conditions in the approach channel are reasonably uniform and steady. Hydrometric networks and water distribution channels.

1) The modular limit of each device requires careful consideration. The submergence ratio should be checked for the whole range of flows to be measured and compared with values for the modular limit given in Table 1.

2) Nappe to be fully aerated.

3) Maximum H/p, where H is the total upstream head and p is the height of the weir.

4) Depends on geometry.

5) Maximum A_t/A_u, where A_t and A_u are the cross-sectional areas of the throat and approach channel, respectively.

6) Not applicable.

Table 2 — Comparative discharges for various weirs and flumes

Structure	*D*[1)] m	*p*[1)] m	*b*[1)] m	*m*[1)] (slope)	*L*[1)] m	Discharge m^3/s min.	max.
Weirs							
Thin-plate, full width	- -	0,2 1,0	1,0 1,0	- -	- -	0,005 0,005	0,67 7,70
Thin-plate, contracted	- -	0,2 1,0	1,0 1,0	- -	- -	0,009 0,009	0,45 4,90
Thin-plate, V-notch	-	-	θ = 90°	-	-	0,001	1,80
Round-nose broad-crest	- -	0,15 1,0	1,0 1,0	- -	0,6 5,00	0,030 0,100	0,18 3,13
Rectangular broad-crested	- -	0,2 1,0	1,0 1,0	- -	0,8 2,0	0,030 0,130	0,26 3,07
V-shaped broad-crested	- -	0,30 0,15	θ = 90° θ = 150°		1,50 1,50	0,002 0,007	0,45 1,68
Triangular profile	- -	0,2 1,0	1,0 1,0	- -	- -	0,010 0,010	1,17 13,00
Flat-V	- -	0,2 1,0	4 80	1 : 10 1 : 40	- -	0,014 0,055	5,00 630
Flumes							
Rectangular	-	0,0	1,0	-	2,0	0,033	1,70
Trapezoidal	-	0,0	1,0	5 : 1	4,0	0,270	41,00
U-throated	0,3 1,0	0,0 0,0	0,3 1,0	- -	0,6 2,0	0,002 0,019	0,07 1,40

NOTE Dimensions are given as examples for comparison purposes only.

1) *D*: diameter of U-shaped throat; *p*: height of weir; *b*: breadth of weir or flume throat; *m*: side slopes: 1 vertical; *m* horizontal; *L*: length of flume throat or weir crest.

5.5 Size and nature of channel

The shape and size of the channel have a bearing on the practicality of selecting any particular type of structure. The material forming the bed and sides of the channel will influence the acceptable head loss through the structure without introducing appreciable leakage through the bed and banks. It will also determine the degree of protection necessary to alleviate scour downstream of the structure.

5.6 Channel slope and sediment load

For flows with suspended load, the use of thin-plate weirs should be avoided because the crest edge may be damaged or worn by the suspended materials. In addition, the rating of weirs can be affected by deposition and scour of sediment in the approach section to the weir. In streams with bed load, the use of structures which significantly reduce the stream velocity is not recommended, as it may result in fluctuations of the bed level as the flow varies. Flumes will generally perform better than weirs in streams with sediment load.

For gradients less than 0,1 % and Froude numbers less than 0,25, there is no restriction on the type of structure.

For gradients between 0,1 % and 0,4 % and Froude numbers between 0,25 and 0,5, flumes have an advantage over weirs with regard to the transport of sediment.

For gradients greater than 0,4 % and Froude numbers greater than about 0,5, standard weirs and flumes are not usually suitable, unless there is no transport of sediment.

5.7 Operation and maintenance

The accuracy of any device is very dependent upon the degree of maintenance it receives. However, flumes are particularly susceptible to errors of calibration due to algal growths in the throat.

Triangular and flat-V weirs are also susceptible to algal growth. Algal preventatives can be used, but this needs care to avoid environmental damage. Due regard to safety should be given attention during construction and maintenance operations. The achievement of ultra-smooth finishes to the weir crest is in itself considered to be the most effective way to minimize algal growth and corresponding maintenance.

When structures operate at temperatures below freezing point, consideration should also be given to the effect of the accumulation of ice on the calibration. In general, weirs, and thin-plate weirs in particular, are less affected by ice than flumes. In some cases, the problem of calibration errors can be overcome by heating the air space over a structure.

The calibration of thin-plate weirs can be affected by damage to the crest and corners and failure to clean the upstream face where algal growths will introduce errors into the calibration. The choice of structure, therefore, will be influenced by the regularity with which maintenance can be carried out. Broad-crested weirs, triangular-profile weirs, long-throated flumes and free overfall structures will normally pass floating debris more effectively than thin-plate weirs. The use of the thin-plate V-notch weir, in particular, should be avoided unless a debris trap is installed upstream.

5.8 Passage of fish

The movement of fish upstream for spawning may be restricted if a structure fails to make proper provision for their passage.

The principal factors which affect their movement past such an obstruction are the afflux at the obstruction and its overall length, and the depth of water below the obstruction and over its crest.

If a thin-plate or broad-crested weir is to be installed, there should be a sufficient depth of water from which the fish can take off to clear the weir. Flumes constitute a minimal obstruction, depending upon the velocities through the throat and the overall length. Triangular-profile weirs need careful consideration, as they may form a serious obstruction, particularly where energy dissipators are incorporated in the stilling basin.

The flat-V weir can be designed to minimize the obstruction by concentrating the flow in the appropriate flow range. This will give a relatively greater depth of flow over a section of the crest for a given discharge than will be obtained using a weir with a horizontal crest.

5.9 Cost

The financial value of the flow passing through the device and the benefit in terms of improved accuracy against the cost of the structure will have a direct bearing on the relative investment values of different types of structure. The total construction and long-term maintenance costs should be considered.

Triangular-profile weirs offer a low-cost option for flow-gauging when designed for operation close to their modular limit. Such designs are structurally smaller than other designs and have reduced afflux. Hence upstream and foundation works are minimized. If the channel has an appropriate concrete section, for example a culvert, then the weirs may, subject to size, be prefabricated and subsequently fixed to the floor of the channel. If drowned-flow conditions are anticipated, then a crest tapping will be required.

6 Recommendations

6.1 Thin-plate weirs

6.1.1 General

Thin-plate weirs are dependent on the full development of the contraction below the nappe but are relatively inexpensive to construct, although the manufacture of the crest requires particular care. Aeration of the nappe is required, by vents if necessary. Also the downstream water level shall not be allowed to interfere with this aeration process — a requirement which limits their applicability. They are recommended where high accuracy is required and are particularly suitable for laboratory work and use in artificial channels and other circumstances where good maintenance can be assured and there is little risk of damage to, or deterioration of, the crest. Particular applications include the gauging of compensation flows, flow measurement in water supply pumping tests and flow measurement in many industrial situations. Thin-plate weirs of both rectangular and V-notch types are well suited for temporary installations.

6.1.2 Rectangular weirs

These weirs may be full width, partially or fully contracted, the selection depending on the range of flow to be measured. The fully contracted weir has the advantage of having automatic aeration and may be installed, subject to certain conditions, in non-rectangular channels.

6.1.3 V-notch weirs

Thin-plate V-notch weirs are particularly suitable where the ratio of high to low flow is large and where the accuracy at low flow is important, owing to their greater sensitivity.

They also have the advantage that aeration of the nappe is automatic.

6.2 Broad-crested weirs

6.2.1 General

Broad-crested weirs are relatively inexpensive to construct and robust, and thus insensitive to minor damage. They are best used in rectangular channels where regular maintenance permits clearance of any deposition upstream and of algae from the crest.

These structures would normally have a fixed crest for flow measurement but if used to regulate and measure flow, as is the case for irrigation applications, a hand or mechanically movable crest can be provided.

6.2.2 Round-nose weirs

Round-nose broad-crested weirs have a good discharge range and submergence ratio, and are appropriate for use in smaller and medium-size installations.

6.2.3 Rectangular horizontal weirs

Rectangular horizontal weirs are simple to construct and have applications in both laboratory and field conditions. There are strict limitations on geometry if accurate flow measurement is required.

6.2.4 V-shaped weirs

V-shaped broad-crested weirs are suitable for flow measurement over a large discharge range. As they remain modular up to a submergence ratio of 80 %, they are particularly suitable for watercourses with little available fall.

6.3 Triangular-profile weirs

Triangular-profile weirs are particularly appropriate for the measurement of flow in natural watercourses where minimum head losses are sought and where relatively high accuracy is required. They have a good discharge range and modular limit, are robust, insensitive to minor damage and will operate even when the flow is silt-laden.

The triangular profile has a constant coefficient of discharge over a wide range of heads. The weir can also be used under submerged flow conditions; in this case, a second head measurement is necessary and can be achieved by means of tapping points at the crest.

The accuracy obtained over a wide range of flows and heads makes them excellent structures for hydrometric work.

6.4 Streamlined triangular-profile weirs

Most of the comments regarding triangular-profile weirs also apply to the streamlined structures. For drowned flow operation, however, a separate downstream gauge should be used rather than the crest tappings required for the triangular profile. They are, however, more difficult to construct and accurate pre-cast sections would be necessary if satisfactory results are to be achieved.

6.5 Flat-V weirs

Flat-V weirs are extremely sensitive and are recommended in situations where low flows would introduce unacceptable inaccuracies if a horizontal crest were to be considered. They are relatively expensive structures, particularly if erosion is liable to occur downstream, and protective works are required. If, however, high accuracy is required and instrumentation giving continuous records is installed, the additional costs, compared to those of other gauging devices, are marginal.

6.6 Compound gauging structures

Compound structures have many of the characteristics of flat-V weirs. They can be designed to give high sensitivity at low flows by introducing one or more relatively narrow low-level sections, and high afflux at high flows can be avoided by introducing wide high-level sections. The versatility of compound weirs is further enhanced by the permitted use of different types of weirs or flumes for the individual sections within the compound structure.

6.7 Trapezoidal-profile weirs

The trapezoidal-profile weir may be used in a modular and/or drowned-flow range. It is of simple geometry, but it must comply with a set of standard upstream and downstream slopes for the empirically derived characteristics to be applicable.

6.8 Vertical underflow gates and radial gates

Vertical underflow gates and radial gates can be operated with variable openings and hence can be used to measure a range of flows within a relatively narrow band of upstream water levels. The accuracy of this type of device is less than that of conventional 'overflow' structures.

6.9 End-depth method

The method, utilizing existing falls, is convenient for approximate measurement where accuracy is not of paramount importance. The method demands a free fall from the end of a pipe or culvert and may be rectangular or non-rectangular in section.

6.10 Flumes

6.10.1 General

Flumes are recommended where material is being transported along the channel, particularly where there is bed movement. Protective works downstream of the throat to contain the hydraulic jump are easily incorporated into the main structure.

6.10.2 Rectangular flumes

The dimensions of rectangular flumes are easily adapted to the size of the channel. Such flumes readily fit into rectangular channels and are almost universally used in measuring the inflow to sewage treatment works. They are suitable where the afflux needs to be kept to a minimum.

6.10.3 Trapezoidal flumes

Trapezoidal flumes are used for purposes similar to those employing rectangular flumes, but are particularly recommended if it is necessary to accommodate the gauging station in a trapezoidal channel and skilled labour is available for the construction work. They are suitable where relatively high accuracy is required over a wide range of flows.

6.10.4 U-throated flumes

U-throated flumes are well suited to the measurement of flows in sewers and other conduits running partly full.

6.10.5 Parshall and SANIIRI flumes

These flumes, designed to operate under both free-flow and submergence conditions, can be used in open channels and irrigation canals when there are steady or slowly varying flows. The criteria for considering the selection of either of these flumes are given in clause 4 of ISO 9826:1992, to which the user is referred for guidance.

7 Parameters governing choice of structures

Tables 1 and 2 set out the broad parameters which may be considered in the choice of a structure. Limitations and values of coefficients are set out in the appropriate International Standard, to which reference should be made for detailed design purposes.

Figure 1 shows a flow chart for the selection of structures; Table 3 gives a listing of the complete set of standardized structures. The flow chart enables the selection of the most appropriate flow-gauging structure, taking into account the following:

— function of the structure;
— field of application;
— presence of high sediment content;
— range of flow.

In addition, a number of non-technical aspects, such as familiarity with the structure, sensitivity to alterations by unauthorized people, and costs will play a part in the choice of the structure.

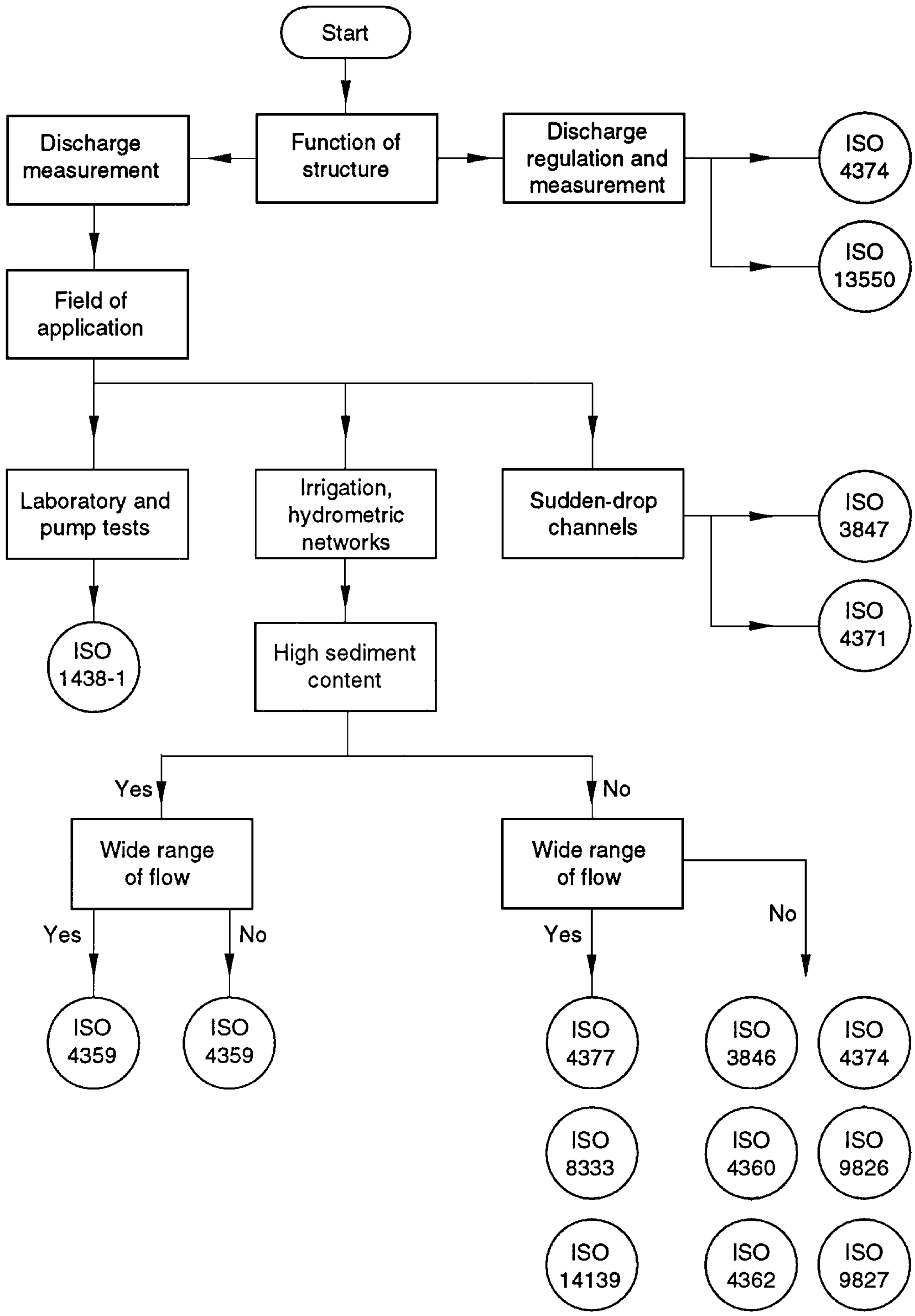

Figure 1 — Flow chart for the selection of structures (see also Table 3)

Table 3 — The complete set of International Standards on structures, for the selection of structures
(see also Figure 1)

ISO 1438-1	Thin-plate weirs	ISO 9827	Streamlined triangular-profile weirs
ISO 3847	Rectangular end-depth method	ISO 14139	Compound gauging structures
ISO 4360	Triangular-profile weirs	ISO 13550	Vertical underflow gates and radial gates
ISO 4371	Non-rectangular end-depth method	ISO 3846	Rectangular broad-crested weirs
ISO 4374	Round-nose horizontal broad-crested weirs	ISO 4359	Long-throated flumes
ISO 4377	Flat-V weirs	ISO 4362	Trapezoidal-profile weirs
ISO 9826	Parshall and SANIIRI flumes	ISO 8333	V-shaped broad-crested weirs

ICS 13.080.30

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