

Australian Standard[®]

Measurement of water flow in open channels

Method 4.11: Measurement using flow gauging structures—End-depth method for estimation of flow in non-rectangular channels with a free overfall (approximate method)



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- Association of Consulting Engineers, Australia
 - Australian Water and Wastewater Association
 - Board of Works, Melbourne
 - Department of Water Resources, N.S.W.
 - Engineering and Water Supply Department of South Australia
 - Forestry Commission, N.S.W.
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PREFACE

This Standard was prepared by the Standards Australia Committee on Measurement of Water Flow in Open Channels and Closed Conduits. It is identical with and has been reproduced from ISO 4371:1984, *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)*.

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This Standard is one of a series which deals with methods of measurement of water flow in open channels. The series when complete will consist of the following parts:

- Part 1: *Vocabulary and symbols*
- Part 2.1: *General—Guidelines for the selection of methods of measurement*
- Part 2.2: *General—Establishment and operation of a gauging station*
- Part 2.3: *General—Determination of the stage-discharge relation*
- Part 2.4: *General—Estimation of uncertainty of a flow-rate measurement*
- Part 2.5: *General—Guidelines for the selection of flow gauging structures*
- Part 3: *Velocity-area methods*
- Method 3.1: *Measurement by current-meters and floats*
- Method 3.2: *Measurement by moving-boat method*
- Method 3.3: *Measurement by slope-area method*
- Method 3.4: *Collection and processing of data for determination of errors in measurement*
- Method 3.5: *Investigation of total error*
- Method 3.6: *Measurement of flow in tidal channels*
- Method 3.7: *Measurement by ultrasonic (acoustic) method*
- Method 3.8: *Electromagnetic method using a full-channel-width coil*
- Part 4: *Measurement using flow gauging structures*
- Method 4.1: *Thin-plate weirs*
- Method 4.2: *Rectangular broad-crested weirs*
- Method 4.3: *Round-nose horizontal broad-crested weirs*
- Method 4.4: *V-shaped broad-crested weirs*
- Method 4.5: *Triangular profile weirs*
- Method 4.6: *Flat-V weirs*
- Method 4.7: *Rectangular, trapezoidal and U-shaped flumes*
- Method 4.8: *Trapezoidal profile weirs*
- Method 4.9: *Parshall and Saniiri flumes*
- Method 4.10: *End-depth method for estimation of flow in rectangular channels with a free overfall*
- Method 4.11: *End-depth method for estimation of flow in non-rectangular channels with a free overfall (approximate method) (this Standard)*
- Part 5: *Dilution methods*
- Method 5.1: *Constant-rate injection method for the measurement of steady flow*
- Method 5.2: *Integration method for the measurement of steady flow*
- Part 6.1: *Measuring devices, instruments and equipment—Rotating element current-meters*
- Part 6.2: *Measuring devices, instruments and equipment—Direct depth sounding and suspension equipment*
- Part 6.3: *Measuring devices, instruments and equipment—Calibration of rotating element current-meters in straight open tanks*
- Part 6.4: *Measuring devices, instruments and equipment—Echo sounders for water depth measurements*
- Part 6.5: *Measuring devices, instruments and equipment—Water level measuring devices*
- Part 6.6: *Measuring devices, instruments and equipment—Cableway system for stream gauging*
- Part 6.7: *Measuring devices, instruments and equipment—Ultrasonic (acoustic) velocity meters*
- Part 6.8: *Measuring devices, instruments and equipment—Position fixing equipment for hydrometric boats*

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- (i) Wherever the words 'International Standard' appear, referring to this Standard, they should be read as 'Australian Standard'.
- (ii) Wherever the word 'fluid' appears, it should be read as 'water'.
- (iii) Substitute a full point (.) for a comma (,) as a decimal marker.
- (iv) The references to other publications should be replaced by references to Australian Standards as follows:

<i>Reference to International Standard</i>	<i>Australian Standard</i>
ISO	AS 3778
772 Liquid flow measurement in open channels—Vocabulary and symbols	Measurement of water flow in open channels Part 1: Vocabulary and symbols
1438 Water flow measurement in open channels using weirs and venturi flumes	3778.1 3778.4.1
1438-1 Part 1: Thin-plate weirs	Method 4.1: Thin-plate weirs
3846 Liquid flow measurement in open channels by weirs and flumes—Rectangular broad-crested weirs	Part 4: Measurement using flow gauging structures Method 4.2: Rectangular broad-crested weirs
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	3778.4.2 3778.4.10
	Part 4: Measurement using flow gauging structures Method 4.10: End-depth method for estimation of flow in rectangular channels with a free overfall

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Measurement of water flow in open channels

Part 4: Measurement using flow gauging structures

Method 4.11: End-depth method for estimation of flow in non-rectangular channels with a free overfall (approximate method)

0 Introduction

Free overfall occurs in many hydraulic structures when the bottom of a horizontal channel (or gently sloping channel) is abruptly discontinued. Such an overfall forms a control section and offers an approximate means for the estimation of flow. The flow at the brink is curvilinear and, therefore, the depth at the drop is not equal to the critical depth as computed by the principle based on assumption of parallel flow. However, the ratio between the end depth and the critical depth (as in the case of the assumption of parallel flow) has an almost constant value. Therefore, from the depth measured at the drop, the discharge can be estimated.

1 Scope and field of application

This International Standard specifies a method for the estimation of subcritical flow of clear water in smooth, essentially horizontal, straight open channels with a vertical drop and discharging freely. Gentle positive slopes not greater than 1 in 2 000 are admissible. This International Standard covers channels with the following types of cross-section, the nappe being unconfined:

- a) trapezoidal;
- b) triangular;
- c) parabolic;
- d) circular.

Using the measured depth at the end, the flow can be estimated.

2 References

ISO 772, *Liquid flow measurement in open channels — 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 measurements in open channels by weirs and flumes — Free overfall weirs of finite crest width (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*.

3 Definitions

For the purpose of this International Standard, in addition to the definitions given in ISO 772, the following definition shall apply:

unconfined nappe: The jet formed by the flow where the guide walls of the structure end at the crest (or edge) and permit free lateral expansion of flow and where the nappe is sufficiently ventilated to ensure atmospheric pressure below the nappe.

4 Units of measurement

The units of measurement used in this International Standard are SI units.

5 Selection of site

A preliminary survey shall be made of the physical and hydraulic features of the proposed site to check that it conforms (or may be made to conform) to the requirements necessary for measurement by the end depth method.

Particular attention should be paid to the following features in selecting the site and ensuring the necessary flow conditions:

- a) an adequate straight length (at least $20 h_e$ where h_e is the end depth corresponding to the maximum discharge anticipated) of channel of regular cross-section should be available upstream of the drop;

b) velocity distribution seen by inspection or measurement should be normal;

c) the channel bottom should be horizontal. Gentle positive slopes not greater than 1 in 2 000 are admissible;

d) the side walls as well as the bottom should be smooth as far as possible (in this specification a smooth surface shall correspond to a neat cement finish);

NOTE — The finish of the structure shall be well maintained; changes in wall roughness due to erosion and various forms of deposition will change the discharge relationship.

e) the end of the channel shall be cut off normal to its centreline and the water shall be allowed to fall freely beyond this point;

f) the flow shall be sub-critical and normal upstream of the drop;

g) the nappe should be fully aerated and completely free at the sides to permit unrestricted spreading.

6 Measurement of depth

The depth shall be measured midstream exactly at the end (drop) with a point gauge or other suitable measuring device.

NOTE — The flow at the drop is fully curvilinear and any small error in the location of gauge will result in large errors in measurement of discharge.

7 Computation of discharge

7.1 Critical depth, h_c

From the measured value of the end depth h_e , using the relationship for the respective channel cross-section, the critical depth h_c is computed and the discharge in terms of the critical depth is given by the following equation (for a channel cross-section):

$$\frac{Q^2}{g} = \frac{A_c^3}{B_c} = \frac{f_1(h_c)}{f_2(h_c)} \quad \dots (1)$$

where

Q is the discharge;

g is the acceleration due to gravity;

A_c is the cross-sectional area at the critical section;

B_c is the surface width of flow at the critical section.

From a knowledge of the critical depth h_c and the geometry of the channel, A_c and B_c can be obtained and by using equation (1), the discharge can be computed.

7.2 Trapezoidal channels

7.2.1 The geometry of channel cross-section is shown in figure 1.

7.2.2 The ratio h_e/h_c (that is, end depth to critical depth) is a function of the parameter

$$\frac{mh_e}{B_o}$$

where

m is the side slope;

B_o is the bottom width;

h_e is the depth of flow at the end;

and the value of h_e/h_c can be obtained from figure 2. Knowing the value of h_e , the value of h_c can be computed and used to compute the discharge from equation (1).

7.2.3 As an alternative to equation (1), the discharge in terms of h_c is given by the following equation:

$$Q = \frac{\sqrt{g/2}}{m^{3/2}} \left(\frac{B_o}{2} \right)^{5/2} \frac{\left[\left\{ \frac{h_c^2}{\left(\frac{B_o}{2m} \right)^2} + \frac{2h_c}{\left(\frac{B_o}{2m} \right)} \right\}^{3/2}} \right]}{\left\{ 1 + \frac{h_c}{\left(\frac{B_o}{2m} \right)} \right\}^{1/2}} \quad \dots (2)$$

Figure 3 may be used directly for computing the discharge, based on equation (2), in view of the simplicity of calculations.

7.3 Triangular channels

7.3.1 The geometry of channel cross-section is shown in figure 4.

7.3.2 The ratio h_e/h_c (that is, end depth to critical depth) is 0,795.

7.3.3 With a triangular channel of semi-apex angle θ , as an alternative to equation (1), the discharge in terms of h_c is given by:

$$Q = \sqrt{g/2} \times h_c^{3/2} \times \tan \theta \quad \dots (3)$$

7.4 Parabolic channels

7.4.1 The geometry of channel cross-section is shown in figure 5.

7.4.2 The ratio h_e/h_c (that is, end depth to critical depth) is 0,772.