# Chapter 5

# Flow measurement

When the water available from a particular source is limited and must be used very carefully, it is useful, and even necessary, to measure the discharge at various points in the system and the flow at farmers' intakes. Also, where farmers have to pay for the water used, discharges should be measured. Flow measurements may also be useful for settling any disputes about the distribution of the water. In addition, measurement of the flows can provide important information about the functioning of the irrigation system.

Canal discharges can be measured without structures, as was shown in Manual 7, *Canals*, in this series. Discharges can also be measured with the use of discharge measurement structures, and such devices are discussed in this chapter, starting with weirs and followed by flumes.

## 5.1 WEIRS

Weirs are sharp-crested, overflow structures that are built across open canals. They are easy to construct and can measure the discharge accurately when correctly installed. However, it is important that the water level downstream is always below the weir crest, otherwise the discharge reading will be incorrect.

The water level upstream of the structure is measured using a measuring gauge, as shown in Figure 31, where the difference - the head - between the water level and the crest of the weir is marked 'H'. The discharge corresponding to that water level is then read from a table which is specific for the size and type of weir being used, or the gauge post can show the discharge directly, as will be discussed in Section 5.1.2.

### 5.1.1 Types of weirs

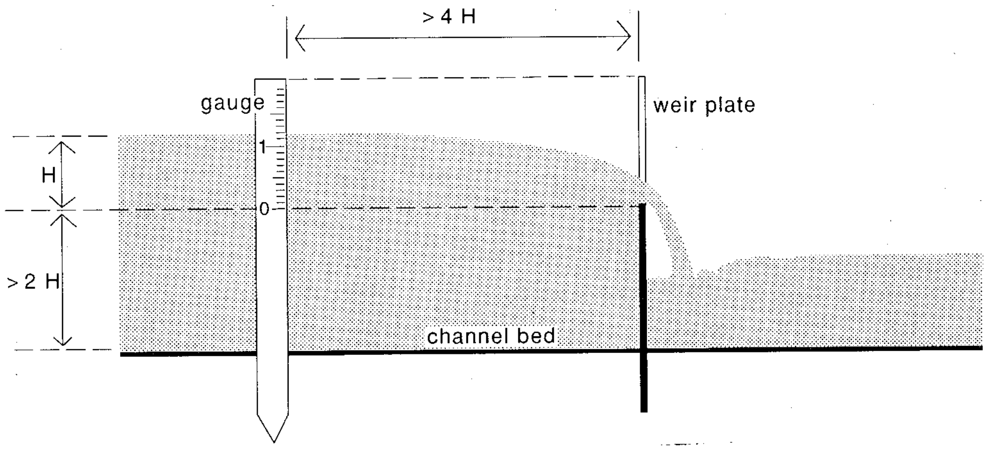
Examples of three well-known weir types are illustrated: the Rectangular weir (Figure 32), the Cipoletti trapezoidal weir (Figure 33) and the 90° V-notch weir (Figure 34).

As can be seen in the figure, the Rectangular weir has a rectangular opening.

The Cipoletti trapezoidal weir is in fact an improved rectangular weir, with a slightly higher capacity for the same crest length. Its opening is trapezoidal with the sides inclining at a slope of 4 (vertical) to 1 (horizontal).

The 90° V-notch weir has a triangular opening, and this type is well suited to measuring small flows with high accuracy.

FIGURE 31
**Weir used for discharge measurement**

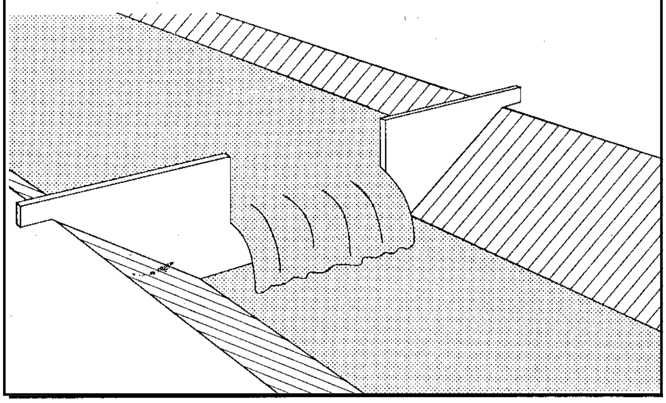



### 5.1.2 Measurement procedures using weirs

To obtain a true measurement of the flow over weirs, certain dimensions must be respected because they are critical to correct operation. These are indicated in Figure 31, and are

- the level of the weir crest relative to the channel bottom
- the horizontal distance between the measuring gauge and the weir, and
- the level of the gauge relative to the level of the crest of the weir.

FIGURE 32
**The rectangular weir: a standard sharp-crested weir for discharge measurement**



***Establishing the correct dimensions for the structure***

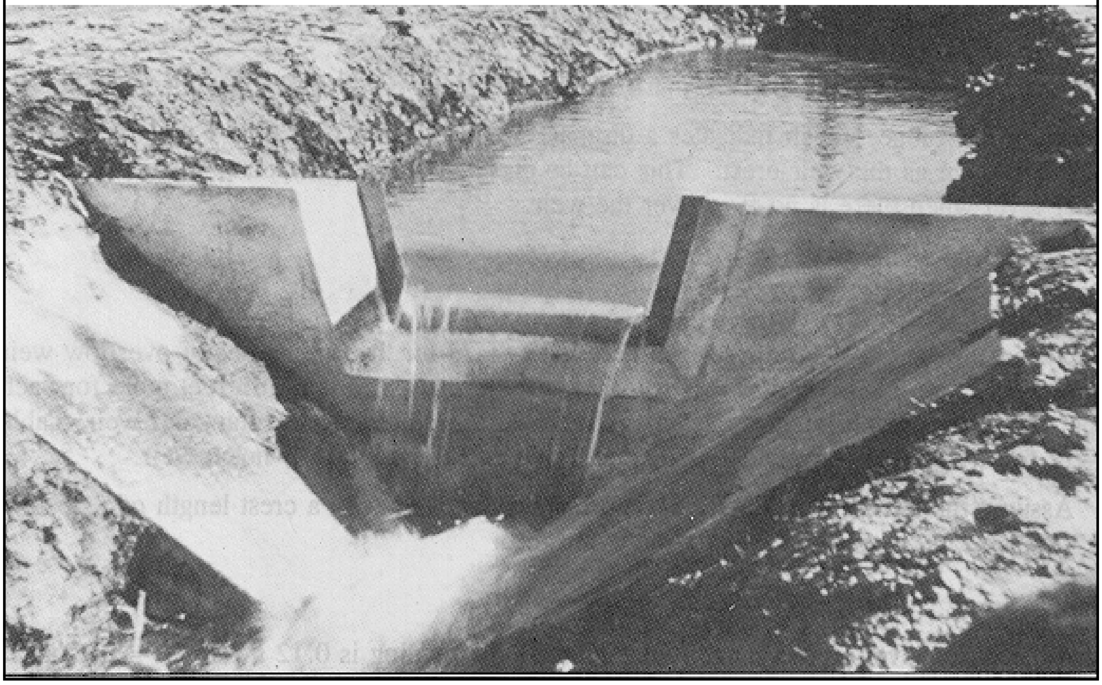
The procedure for getting the correct set up for the structure is given in the form of a practical example. The measurement structure in this example, illustrated in Figure 31, is assumed to be the overflow type, namely a rectangular weir with a crest length of 1 m.

**Step 1**

Estimate the maximum discharge that is likely in the canal to be measured. This defines the corresponding maximum head of water over the weir crest for the structure concerned.

The maximum discharge to be measured is estimated at 200 l/s.

FIGURE 33
**The Cipoletti trapezoidal weir: a standard sharp-crested weir for discharge measurement**



Using Table A-2.1 in Annex 2, one can see that for discharge of 200 l/s, the head, *H,* is a little less than 0.25 m. (Refer to the column for *L* = 1.0 m: when discharge *Q* is 219 l/s, *H* = 0.25 m.)

**Step 2**

Check the level of the weir crest.

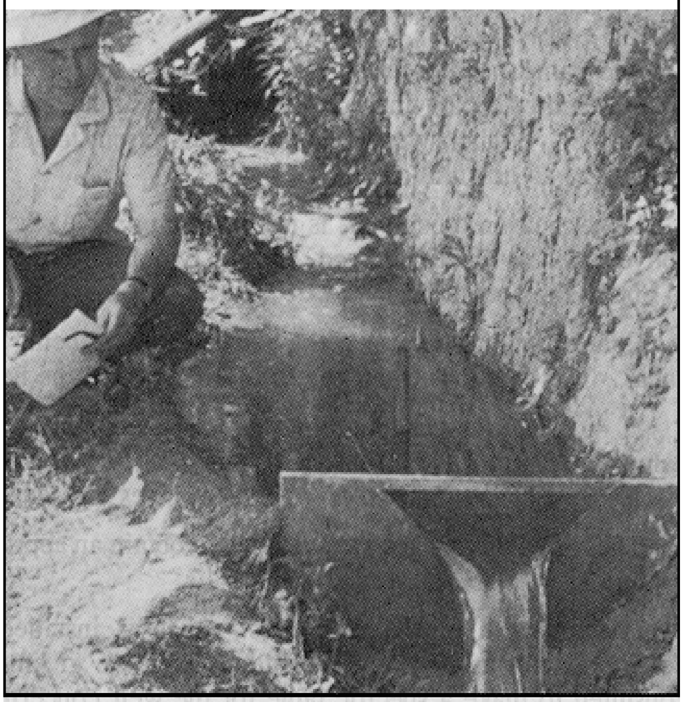
The level of the crest above the canal bed should be at least 2 times the maximum head, 2*H* in 31. In this case the weir should have a crest level which is at least 2 ´ 0.25 = 0.50 m higher than the canal bed.

**Step 3**

Check the distance between the gauge and the weir.

The distance between the gauge and the weir should be at least 4

FIGURE 34
**The 900 V-notch weir: a standard sharp-crested weir for discharge measurement**



times the maximum head, 4*H* in Figure 31. In this case the gauge should be located at least 4 x 0.25 = 1.00 m upstream of the weir.

**Step 4**

Check the elevation of the 0 (zero mark) on the gauge.

The 0 on the gauge, which indicates a discharge of 0 l/s - i.e., no flow - should have the same elevation as the weir crest. This can be checked using a carpenter's level or by the water level when there is no flow over the weir.

***Discharge measurement***

The measurement procedure described here is standard for the three types of overflow weir shown in Figure 32,Figure 33 & Figure 34, except that there is a different table for each type. These are given in Annex 2, where Table A-2.1 is used for a rectangular weir; Table A-2.2 for a Cipoletti trapezoidal weir; and Table A-2.3 for a 90$^{o}$ V-notch weir.

Assume the structure in Figure 31 is a rectangular weir with a crest length of 1.25 m.

**Step 1**

Read the water level on the gauge. In 31 the reading is 0.12 m, so *H* = 0.12 m.

**Step 2**

Go to Table A-2.1 in Annex 2, find the row corresponding to 0.12 m, and move across that row till it meets the column for the weir crest being used, 1.25 m. The value at the point where the column and row cross is 94, and that is the discharge in litres per second: *Q* = 94 l/s.

The same procedures + for establishing the proper dimensions for the set up of the structure and for carrying out discharge measurements + apply to Cipoletti trapezoidal weirs and to 900 V-notch weirs, except that different tables are used to obtain the value of the discharge, as noted above.

If the measured head, *H*, is not found in a table, the rows with the *H* values immediately above and below are followed, and the two discharge values found in the table are averaged to obtain the actual discharge.

For example, suppose a trapezoidal weir is being used to measure the discharge in a canal. The crest has a length, *L*, of 1.00 m and the head reading, *H*, is 0.17 m.

*H* = 0.17 m is not found in Table A-2.2 in Annex 2, so the nearest *H* values above and below are used. These are 0.16 and 0.18 m. *H* = 0.16 m gives, when *L* =1.00 m, a discharge, *Q*, 119 l/s, and *H* = 0.18 m gives a discharge of 142 l/s.

These two discharges are averaged to obtain an approximate value for the canal discharge, namely *Q* = (119 + 142) / 2 = 131 l/s.

If the length of the weir crest which is installed in an irrigation scheme does not correspond to the one of the lengths which are given in the tables, an engineer should be consulted to make a specific table for the weir concerned.

## 5.2 FLUMES

Other well-known structures for discharge measurement are flumes. Flumes consist of a narrowed canal section with a particular, well-defined shape.

The advantage of flumes over weirs is the small drop in water level (head loss), and so flumes can be used in relatively shallow canals with flat grades. The drop in water level is only one quarter of the drop needed to be able to use a weir, for the same discharge under similar conditions. Because of this, smaller flumes can easily be used as transportable measuring devices.

A disadvantage of flumes is that they are relatively expensive and they cannot easily be combined with other structures, whereas that is possible with weirs.

Like measurements with weirs, the water level upstream of the flume is a measure of the discharge through the flume, and when the head has been measured the discharge can be obtained by reading the value on a diagram which is specific for the flume being used. This will be discussed in Section 5.2.2.

### 5.2.1 Types of flumes

Three of the most common types of measuring flumes are illustrated. They are the Parshall flume (Figure 35), the Cut-throat flume (Figure 36), and the RBC flume (Figure 37).

The abbreviations used in the plan and longtitudinal section views of the three common flume types are as follows: *c.b.* + canal bed; $H_a$ - upstream water level, relative to the bottom of the structure; $H_b$ - downstream water level, relative to the bottom of the structure; $L$ - length of flume; *c.s.* - converging section; *t.(s.)* - throat (section); *d.s.* - diverging section; $W$ - throat width; and $B_c$ - throat bottom width.

A Parshall flume consists of three principal sections: a converging section at the upstream end, a constricted section or throat in the middle and a diverging section downstream. The floor of the throat slopes downwards and the diverging section has slopes upwards. It is shown in Figure 35, together with plan and longtitudinal section views.

Parshall flumes have standard dimensions which must be followed closely in order to obtain accurate measurements.

A Cut-throat flume (Figure 36) has two principal sections: a converging section at the upstream end and a diverging section at the downstream end, and has a flat bottom. The advantage of a Cut-throat flume over a Parshall flume is that its construction is made easier by the horizontal floor, the use of flat metal sheets and the absence of a throat section.

As for Parshall flumes, the standard dimensions must be followed carefully to obtain accurate measurements.

The RBC flume (Figure 37) has a short trapezoidal section with a contraction inserted in the flume bottom. When constructing an RBC flume, it is not absolutely necessary to follow the standard measures exactly, since for each RBC flume a flume-specific head-discharge table can be established. This is not possible for the Parshall or Cut-throat flumes.

### 5.2.2 Measurement procedures in flumes

When using a flume to measure discharge in a canal it is assumed that the flume has been made using standard dimensions, and that flume-specific tables are available. In the case of an RBC

FIGURE 35
**The Parshall flume**

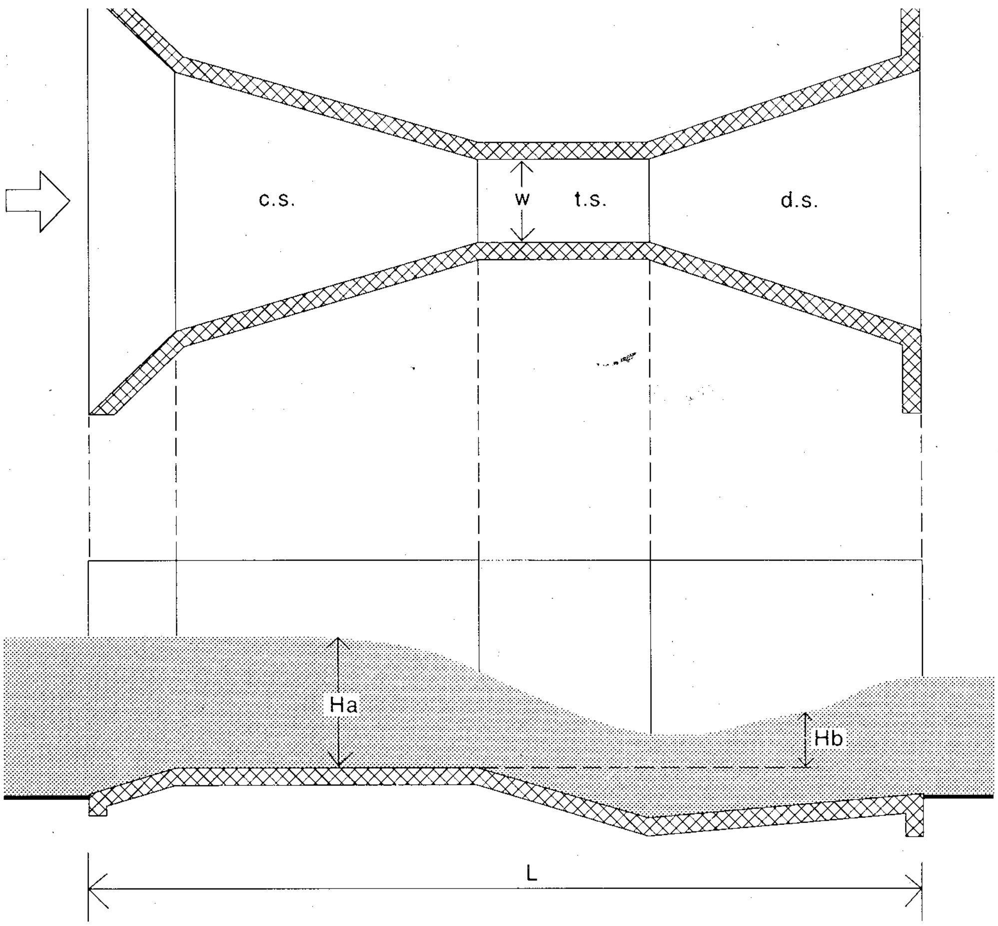
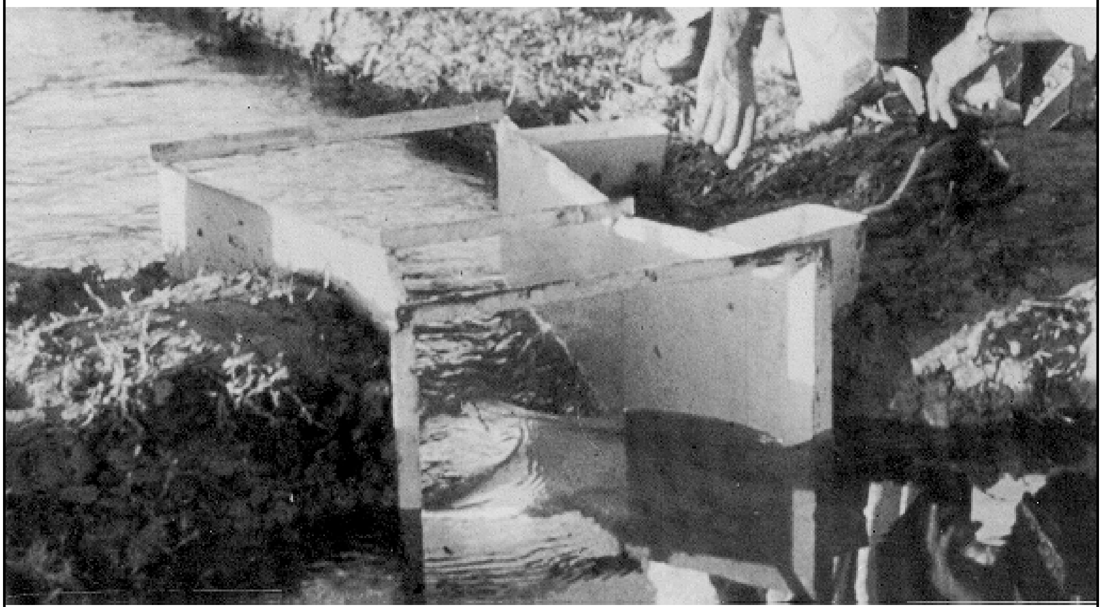


FIGURE 36
**Cut-throat flume**



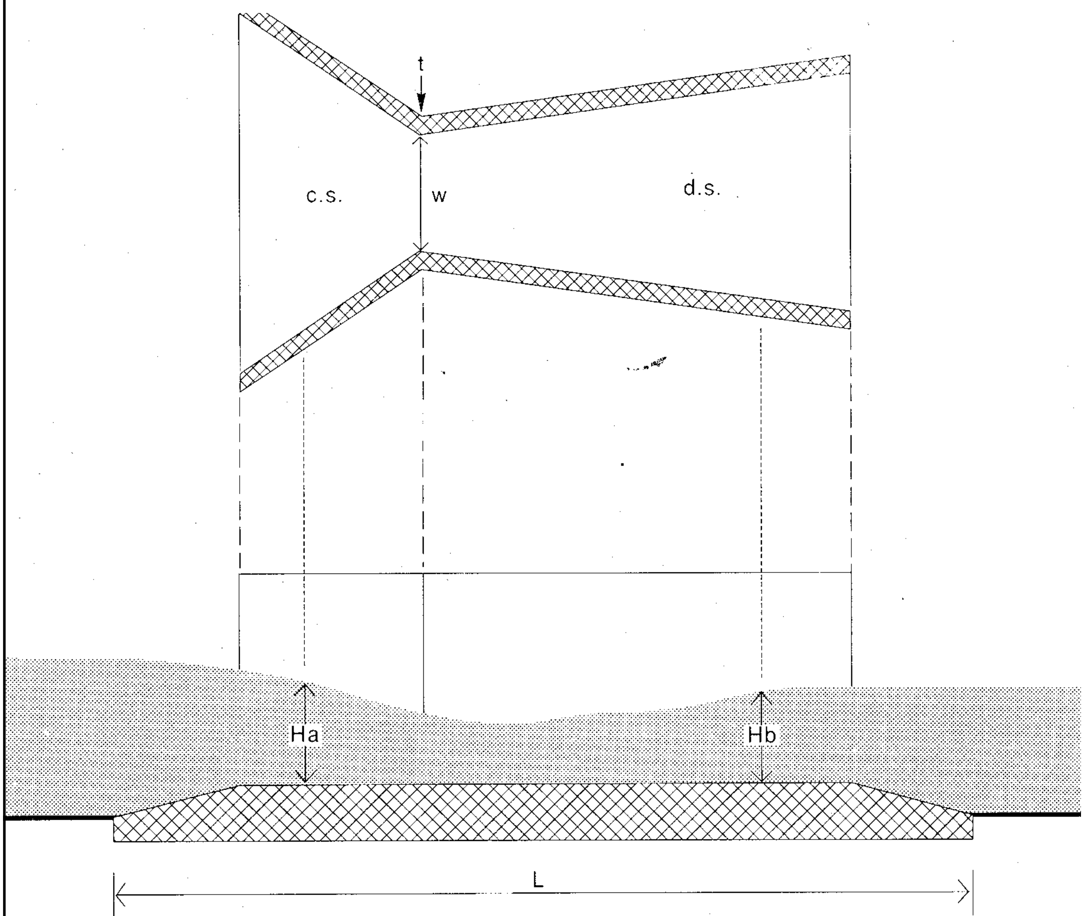
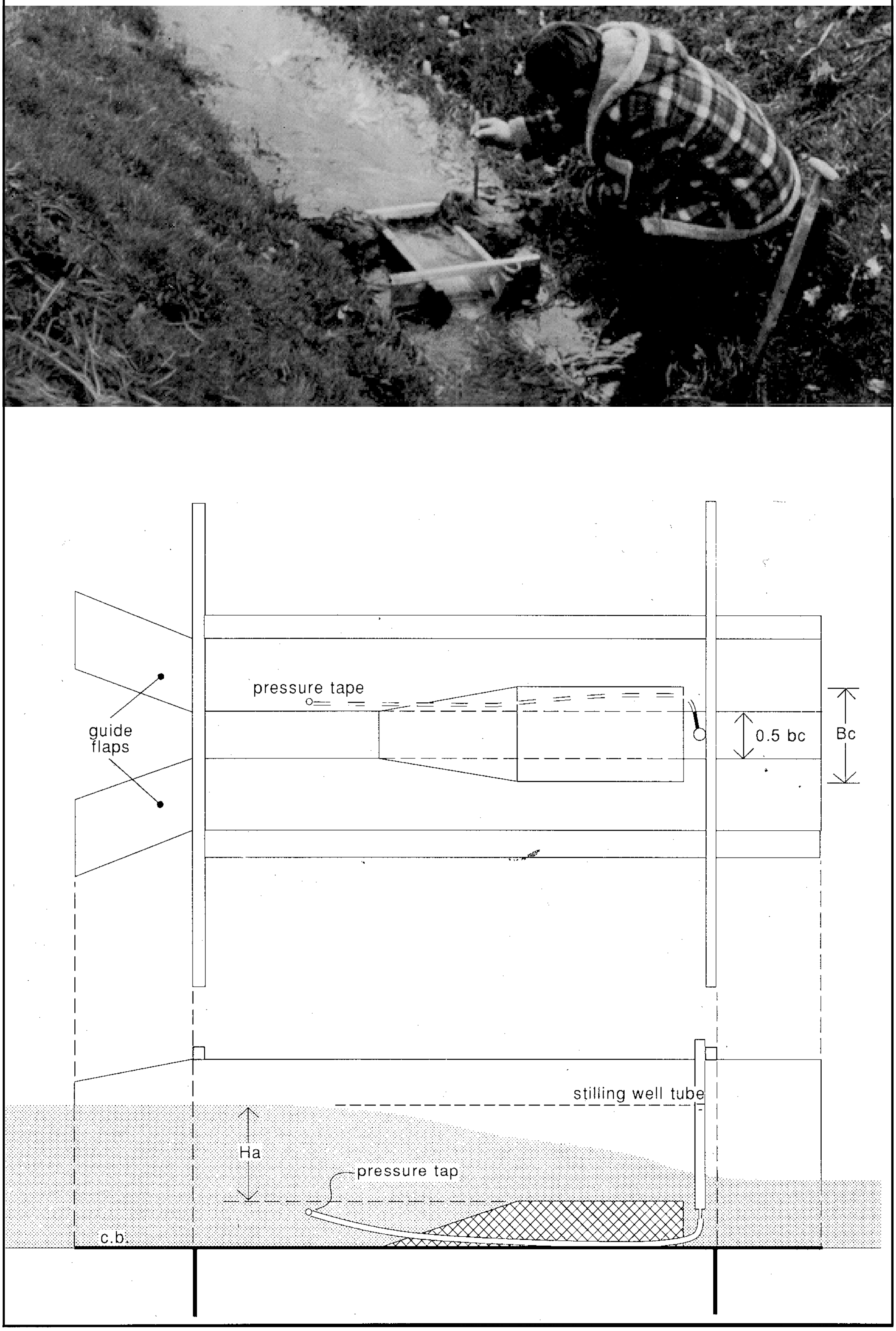


FIGURE 37
**RBC flume**



flume, the assumption is made that a table has been established especially for the flume being used.

Examples of tables for the three types of flumes can be found in Annex 2 of this manual. The tables are applicable for so-called 'free flow' conditions, which means that the upstream water level is not affected by the downstream water level.

For detailed information on free flow conditions and for more information on measuring flumes, the publications *Small Hydraulic Structures*[1] and *Discharge Measurement Structures*[2] can be consulted.

The method for measuring discharge using a flume is illustrated by Exercise 4.

**EXERCISE 4**

**QUESTION**: What is the discharge in a canal if:

- a Parshall flume with throat width $W$ = 0.46 m (1.5 ft) is used to measure the flow; and
- the reading, taken under free flow conditions, is 0.23 m?

**ANSWER**: $H_a$ = 0.23 m (read from the gauge).

Using Table A-2.4 in Annex 2 for a Parshall flume with a throat width of 0.46 m, read from the table the discharge when $H_a$ = 0.23 m. The discharge $Q$ = 110 l/s.

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1 *FAO Irrigation and Drainage Paper*, Nº **26/2**

2 Bos, M.G. (ed). 1989. *ILRI Paper*, Nº 20.