# Chapter 4

# Water distribution within the canal network

Water flowing in a secondary irrigation canal can be divided over the tertiary canal network in several ways. One way is to divide the flow proportionally over these tertiary canals; another is to divide the time of supply and thus to divert the flow to each tertiary canal in turn; and a third way is to supply a tertiary canal with water upon request.

The same three options apply to the flow in the main irrigation canal regarding its distribution over the secondary canals of the system: proportional distribution; rotational distribution; or delivery on demand. The different methods of water distribution require different structures, and these structures are described here. The last sections of this chapter deal with the problem of how to deliver a fixed discharge to a canal, and what types of offtakes are commonly used for water supply to a branch canal.

## 4.1 PROPORTIONAL DISTRIBUTION

Proportional distribution of irrigation water means that flow in a canal is divided equally between two or more smaller canals. The flows in these canals are proportional to the areas to be irrigated by each of them.

### 4.1.1 Division of the flow

Each canal is given a portion of the flow. These portions correspond to the portion of the total area which is irrigated by that canal. This is considered in Exercise 1, in which the flow in a main canal is divided among three secondary canals. Figure 13 illustrates the problem.

**EXERCISE 1**

**QUESTION**: What discharges should be given to the secondary canals under the following conditions? See Figure 13.

- The discharge in the main canal is 170 l/s.
- It is to be divided among the three secondary canals in proportion to their command areas.
- The command areas of the secondary canals are 60 ha, 45 ha and 30 ha.

**ANSWER**: The total area commanded by the secondary canals is 60 + 45 + 30 = 135 ha.

- The first canal will receive 60/135 of the 170 l/s flow, i.e., (60/135) x 170 = 75 l/s.
- The second will get (45/135) x 170 = 57 l/s.
- The third will get (30/135) x 170 = 38 l/s.

**NOTE**: The discharges in the three secondary canals are proportional to the three command areas, i.e., 75:57:38 = 60:45:30. However, these theoretical values for the discharges in the three canals will be difficult to obtain in practice, and the actual discharges would be rounded to 70, 60 and 40 l/s.

**FIGURE 13**
**Flow is divided proportionally**

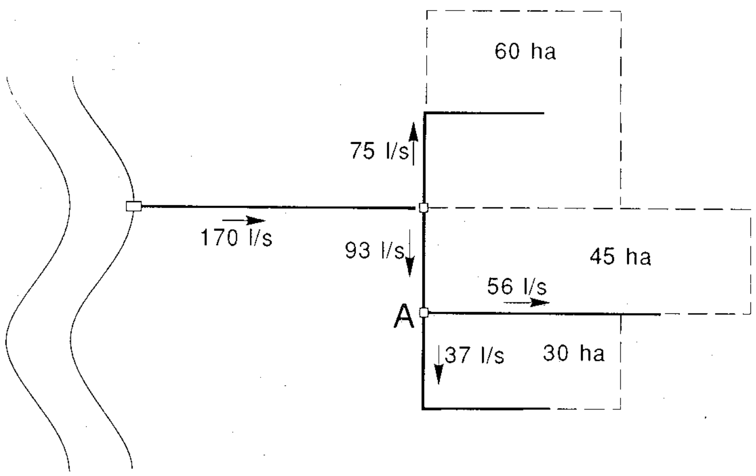



**FIGURE 14**
**Two-way proportional flow division structure**

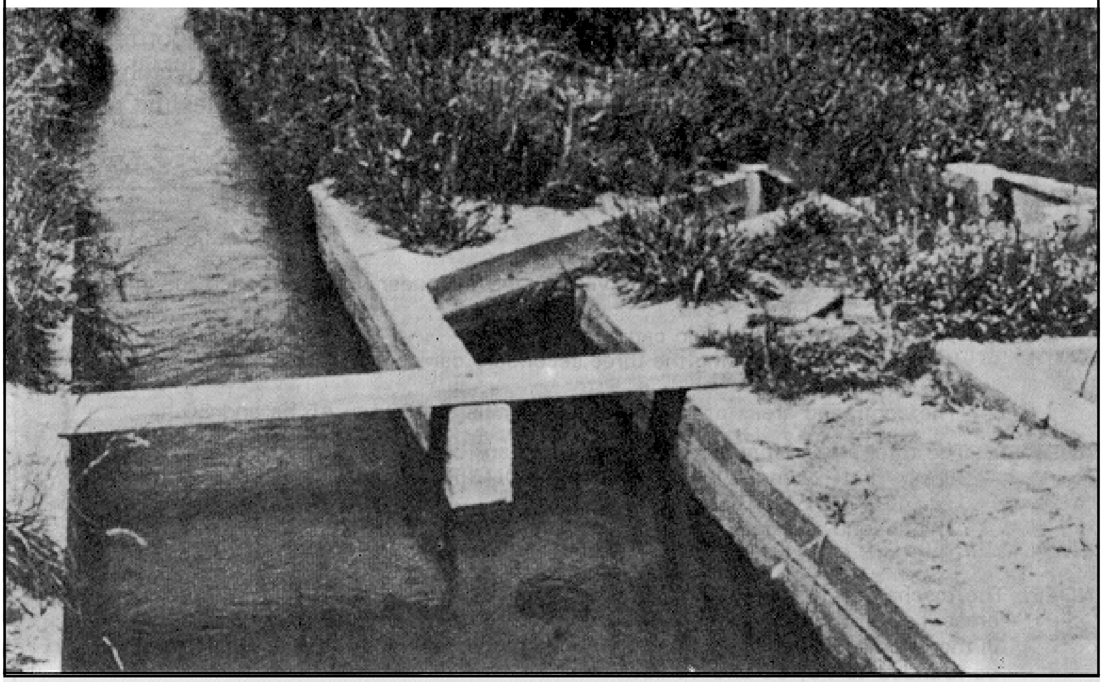
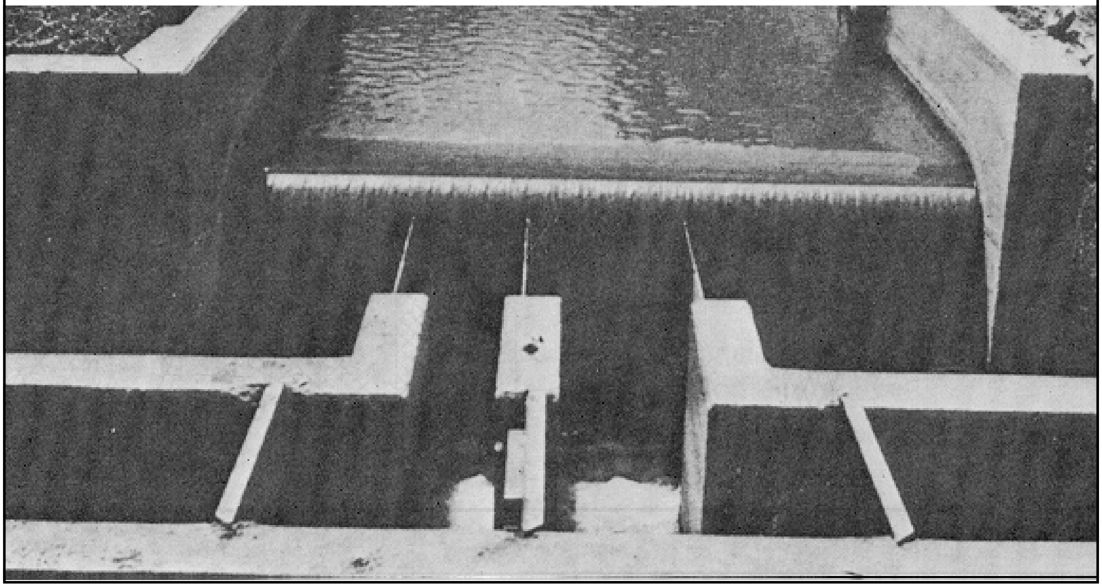


**FIGURE 15**
**Accurate proportional flow division structure**



### 4.1.2 Proportional flow division structures

The type of structure chosen to obtain proportional flow division depends on the accuracy that is required, on the number of offtake canals at the same distribution point, and on the local topography. Three common types are illustrated in Figure 14, Figure 15 and Figure 16.

The division of the flow in the structures in Figure 14 and Figure 15 is fixed and cannot be changed. This means that if the flow in the source canal changes, the flow in the branch canals will also change, but the flows remain proportional to the respective command areas of the branch canals. The flow division in the structure in Figure 16 can be adjusted according to changes in either water supply in the source canal or water demand in the branch canals.

The accuracy of flow division in the structure in Figure 14 is low, and the division can easily be manipulated - by farmers who want a larger share - by blocking off one of the canals with stones or sand.

The accuracy in the structure in Figure 15 is high, but, to obtain such accuracy, a drop in water level is required. The costs of such an accurate structure are higher than for a structure like the one in Figure 14.

Proportional flow division structures frequently used in small scale irrigation schemes are shown in Figure 17. The flows to the branch canals are proportional to the widths of the respective openings.

These boxes are sometimes combined with other structures, such as with a drop structure (Figure 17-B) or a culvert (Figure 17-C). These structures are discussed later, in Chapter 6.

**FIGURE 16**
**Variable proportional flow division structure**

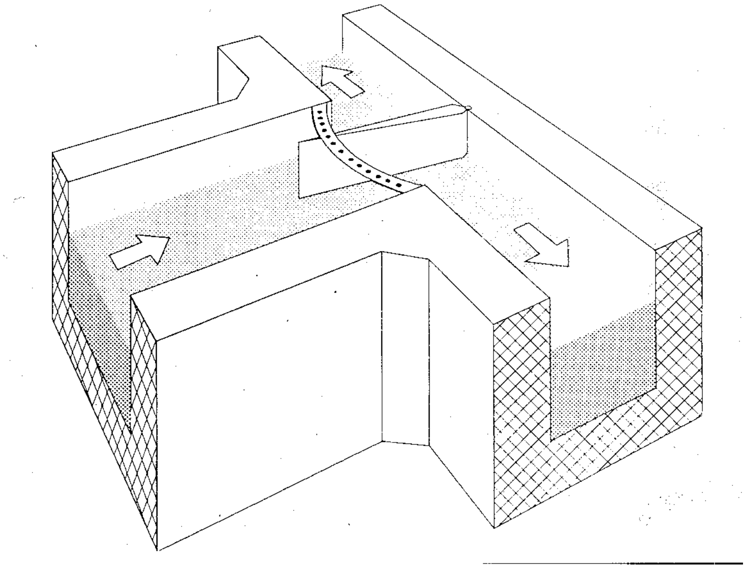


**FIGURE 17**
**Proportional flow division structures**

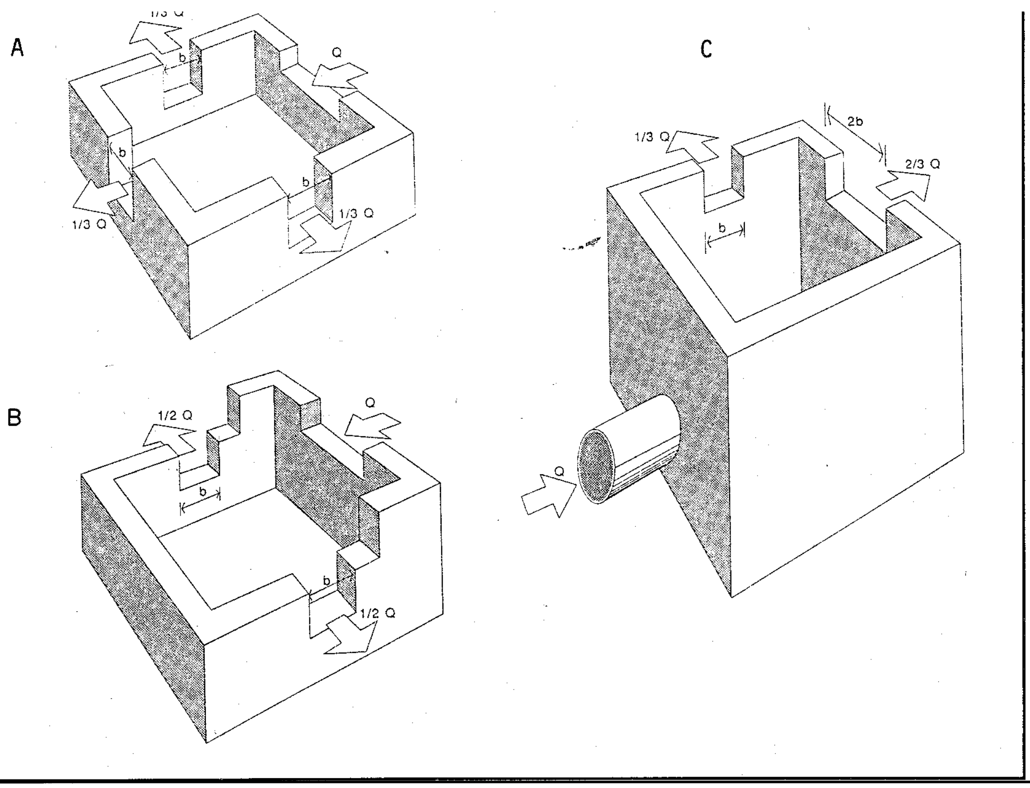
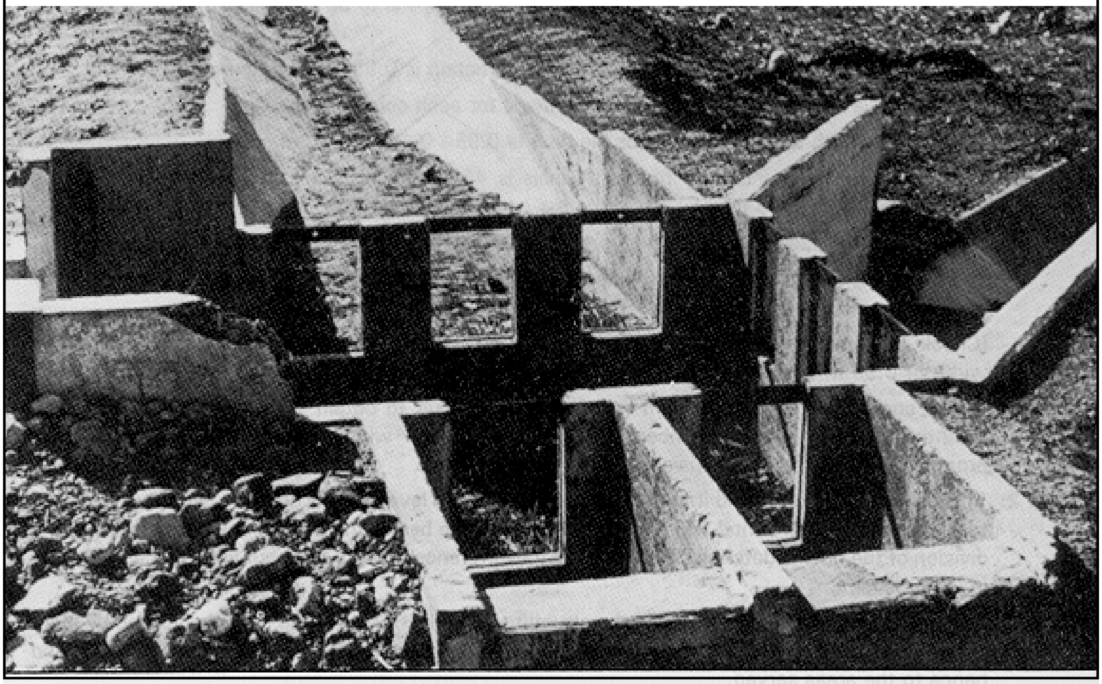


**FIGURE 18**
**Overflow division box**



Another common proportional flow division structure is shown in Figure 18. This can supply the two branch canals with portions of the flow. The flow comes from an inverted syphon and enters the box through the two gates in front. The flow is then divided between the main canal and the two branches, in proportion to the number of gates that are opened.

The proportionality of the flow division in the structures shown in Figure 15 to Figure 18 is related not only to the widths of the openings, but even more so to the elevations of the crests of the openings. A change in elevation of one of these crests has a more important effect on the flow division than a change of one of the widths: a 10% change in crest elevation will give a 15% change in discharge over that crest, whereas a 10% change in width of an opening gives a 10% change in discharge through that opening.

## 4.2 ROTATIONAL DISTRIBUTION

Rotational distribution of irrigation water means that the whole flow in an irrigation canal is diverted to the branch canal in turn. For instance, in the case of primary and secondary canals, it means that each secondary canal is without water for part of the time and, when supplied, it transports the whole "primary" flow. The same can apply to the distribution of the flow of secondary canals into tertiary canals, and rotational distribution can be carried out within the tertiary canals.

**EXERCISE 2**

**PROBLEM**: A proportional division structure has to be designed for site A in the scheme shown in Figure 13. This structure should divide the available flow between the two canals in proportion to their respective command areas.

One canal commands an area of 45 ha, the other an area of 30 ha.

A two-way flow division structure like the one in Figure 14 is to be used, and the separation wall will have to have a width of 0.15 m.

The total available canal width at the site of construction is 0.95 m. See Figure 19.

**QUESTION**: How large should the canal openings be made for each command area?

**ANSWER**: The total width that is available for the flow is 0.95 - 0.15 = 0.80 m.

The total area commanded by the two canals is 45 + 30 = 75 ha. The larger canal should therefore receive 45/75 of the total; the other canal should get the other 30/75.

The openings of each canal should be proportional to their command areas.

Therefore the larger canal opening should be (45/75) x 0.80 = 0.48 m wide, while the other opening should have a width of (30/75) x 0.80 = 0.32 m.

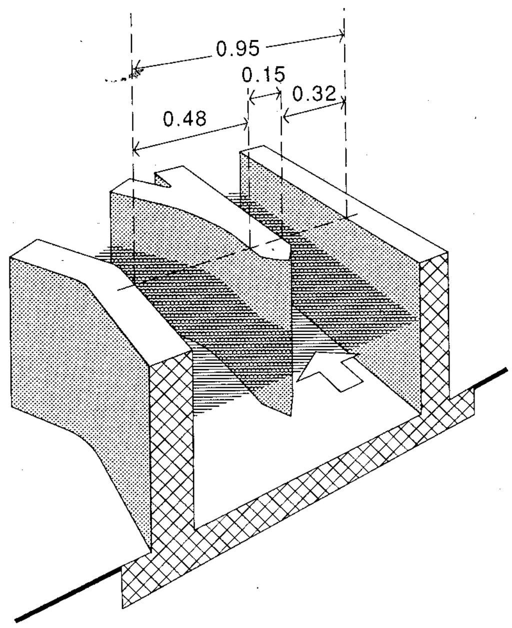
[Check: Do larger and smaller canal widths, plus separation wall thickness add up the available canal width of 0.95 m ? 0.48 + 0.32 + 0.15 = 0.95 m , correct!]

**NOTE 1**: When constructing the separation wall it will be difficult to obtain widths of exactly 0.48 and 0.32 m, but one should remember that smaller or greater widths have a direct impact on the proportionality of the flow division.

**NOTE 2**: This calculation is only valid if the structure has a flat and level floor. Therefore care must be taken to make the floor horizontal when constructing it. If the bed of the structure is not horizontal, the division of the flow is determined not only by the difference in bed width, but also by the difference in water level.

**NOTE 3**: Care must also be taken to maintain the structure properly. If one of the flows is blocked by plant growth, silt or rubbish, the division will no longer be proportional to the width of the openings and hence to the areas served.

**FIGURE 19**
**Diagram for calculation of proportional flow division**



### 4.2.1 Division of the time

The portion of the time during which a branch canal carries water is proportional to the area served by that canal. This is illustrated in Exercise 3, which should be considered together with Exercise 1.

**EXERCISE 3**

**QUESTION**: How many days during each period of 7 days will each secondary canal receive water under the following conditions? (See Figure 20)

- The continuous flow in the main canal is to be diverted in turn to three secondary canals.
- The command areas of the secondary canals are 60 ha, 45 ha and 30 ha.

**ANSWER**: The flow in the main canal is given to the whole scheme, which has a total area of 60 + 45 + 30 = 135 ha.

Each secondary block will receive the entire flow for a period within the 7 days that is proportional to its command area.

The first secondary canal serves an area of 60 ha. It will carry the full flow for (60/135) x 7 □3 days in every period of 7 days.

Similarly, the other canals will carry water for 45/135 x 7 □2½ days, and (30/135) x 7 □1½ days respectively in each period of 7 days.

**NOTE**: In this example the portions of a period that a branch canal carries the whole flow have been calculated. The first secondary canal carries the full flow for 3 days in every 7 days, but this does not mean that the irrigation interval in the fields is 7 days. This interval depends on soil type, crop, stage of growth and rate of evapotranspiration.

If the irrigation interval is 7 days, then the canal can be given the whole flow for 3 consecutive days. If the interval is 14 days, then the first secondary canal may carry water for 6 consecutive days, and then be dry for the other 8 days of the 2-week period.

**FIGURE 20**
**Supply time divided proportionally**

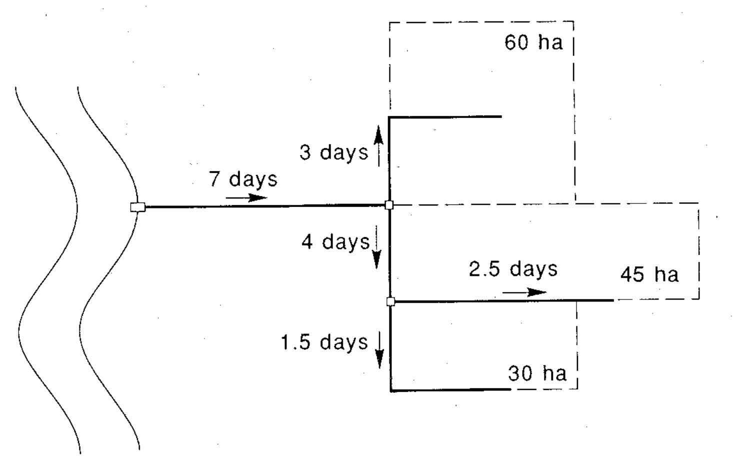


**FIGURE 21**
**Gated canal offtake**

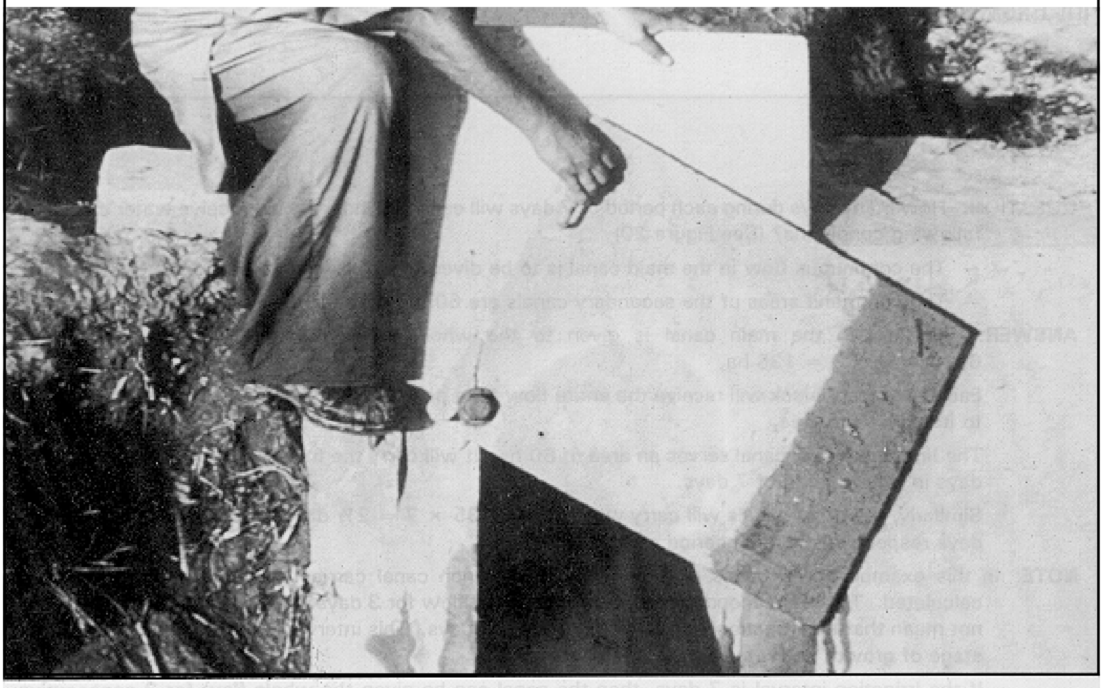


**FIGURE 22**
**Canal with simple division boxes**

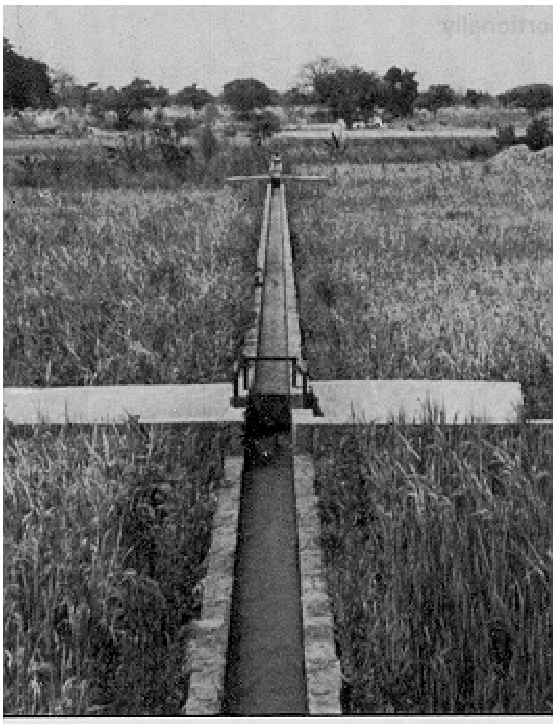
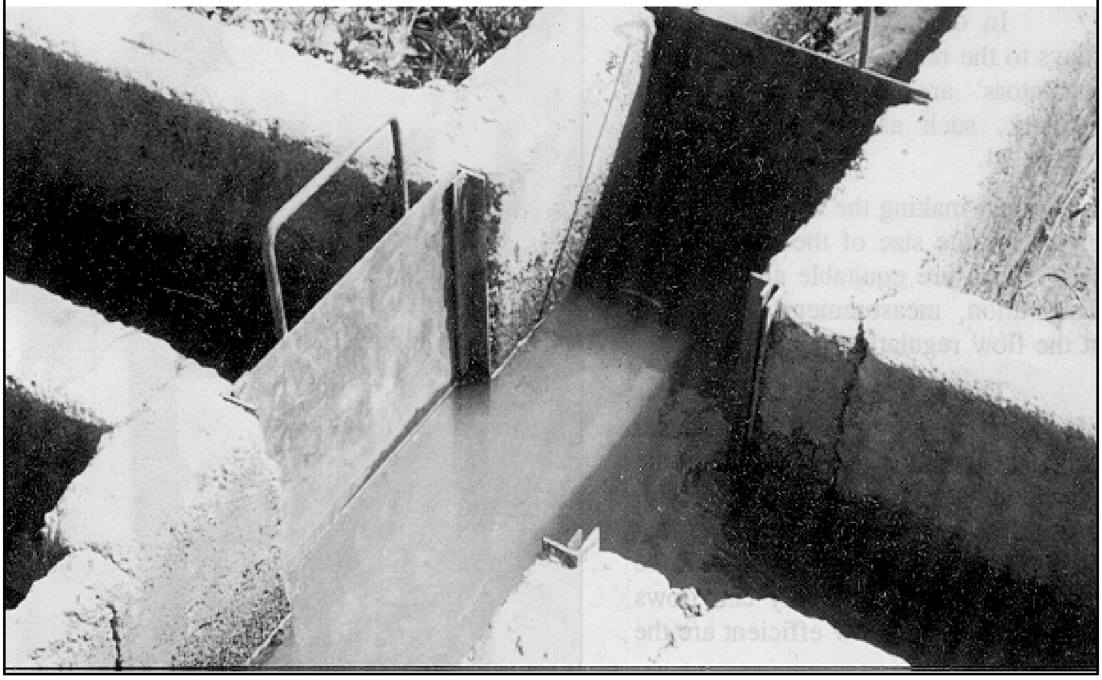


**FIGURE 23**
**Close up view of a division box**



### 4.2.2 Flow diversion structures

Canals that are supplied with water according to a rotation schedule or on an 'on demand' basis must be equipped with gates at the offtake. (Delivery 'on demand' is discussed later, in Section 4.3). Sand bags can also be used instead of gates in small tertiary canals.

Figure 21 shows a canal offtake which can be closed by a gate, and Figure 22 shows a canal equipped with division boxes. A close-up of such a division box is presented in Figure 23, and, as can be seen, the whole flow can either be directed to a branch canal at the division box, or the flow continues down the main canal for diversion at a subsequent point. Therefore, under rotational distribution, a canal which receives water should have the same capacity as the supply canal, as flow is not divided. In Exercise 3, each secondary canal should have a capacity of 170 l/s, which is equal to that of the main canal.

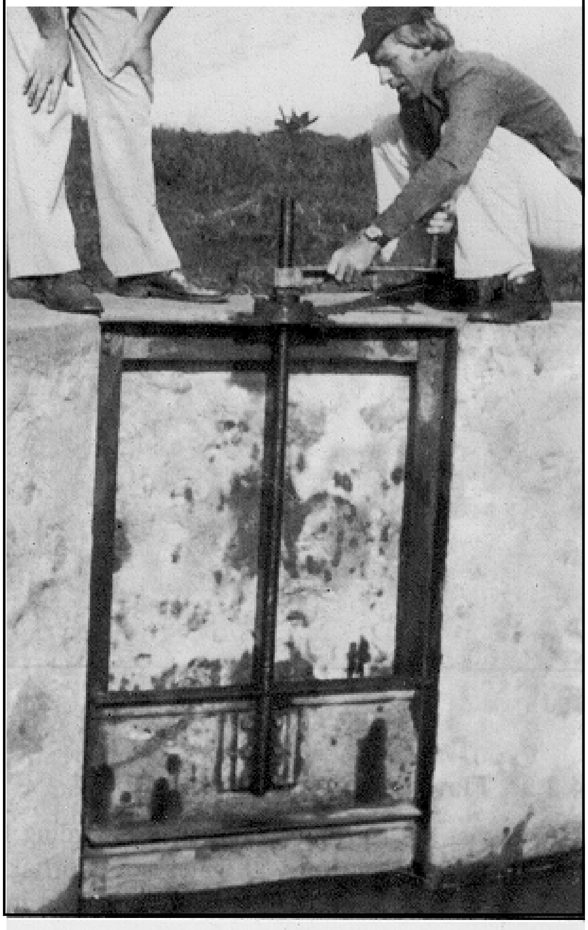
## 4.3 DELIVERY ON DEMAND

Instead of water delivery based on areas, as in proportional or rotational supply, delivery can be based on requests from farmers or a group of farmers. In such a delivery system, water is directed only to those canals where farmers have announced that they need water.

Because the demand varies, the duration or the size of flow, or both, need to be controlled to accommodate this variation.

In simple and small schemes it may only be possible to control the duration of irrigation, with no flow control. Note that the possibility of water losses increases when demand is relatively small compared to the canal capacity. In more sophisticated schemes it may also be possible to adjust the quantity of water flowing so that the flow can also be subject to request.

FIGURE 24
Cross-regulator



In order to be able to adapt flows to the requests, so-called 'cross-regulators' are needed in the canal network, such as that illustrated in Figure 24.

By making the opening smaller or larger, the size of the flow can be set. To ensure equitable and efficient distribution, measurement is required at the flow regulating point.

The accuracy and effectiveness of water delivery with respect to demand depend on the flexibility of the system: how much water is available, taking into account other requests that have been made; what capacities have the canals; how accurately can flows be regulated; and how efficient are the operators?

For such a system to work efficiently two things are needed:

- good structures in which gate settings can be easily and accurately adjusted; and
- a team of well-trained operators.

## 4.4 DELIVERY OF A FIXED DISCHARGE TO A TERTIARY CANAL

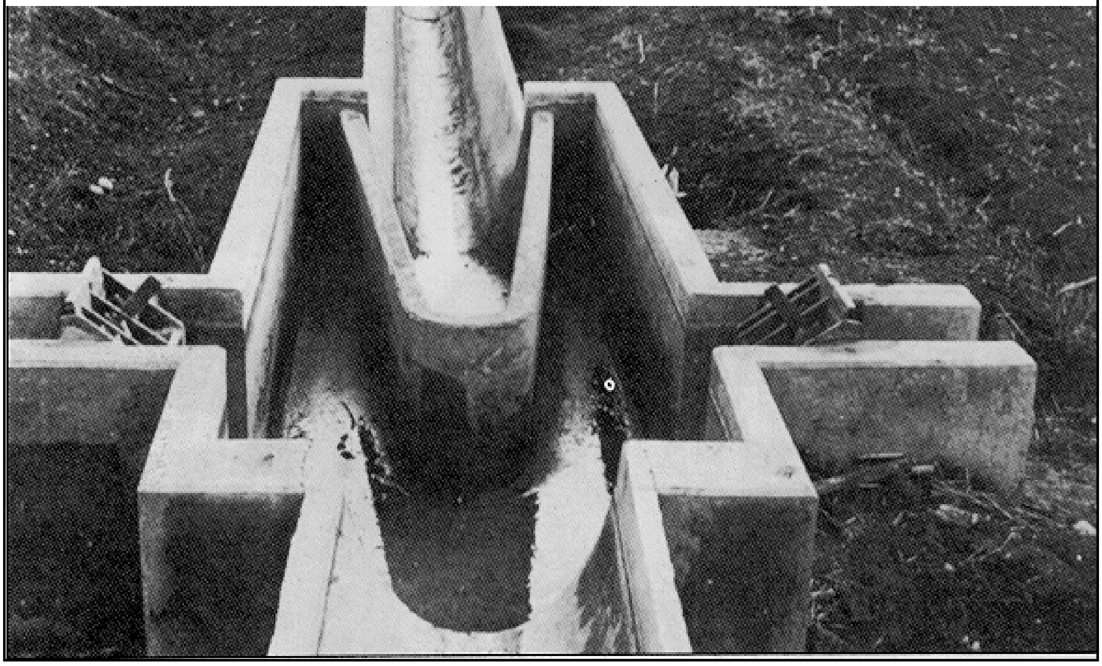
Main canals and secondary canals in an irrigation scheme may carry variable flows. This can be caused by fluctuations in water supply from the water source, or by the flows being adjusted to meet varying needs within the scheme.

Obviously the discharges in tertiary canals will also vary as a result of these fluctuations if no precautions are taken.

If the water level in a tertiary canal rises to above its design level there is a risk of overtopping, and if the level drops the discharges to the fields could be too small for proper irrigation. Therefore the water levels in tertiary canals should be kept constant as far as is possible.

One factor that is very important in maintaining a constant water level in any canal is the discharge that enters that canal. The smaller the fluctuation in the incoming flow, the less will be the fluctuation in water level in the canal. There are other factors that also play a role, such as canal maintenance, gate settings in field turnouts, installation of checks, etc., and these will be discussed later in this manual.

**FIGURE 25**
**A duckbill weir**



The type of tertiary offtake + whether it is an overflow gate (open device) or an underflow gate (closed device) + and the water level in the secondary canal determine to a great extent the discharge delivered to the tertiary canal. The water level in the secondary canal is more important when offtake is by an overflow structure than when an underflow structure is used, as discussed earlier, in Section 3.1 of this manual.

Therefore, in order to obtain a constant discharge in a tertiary canal, attention should be paid to controlling the water level in the secondary canal.

Water in a secondary canal can easily be maintained at a more-or-less constant level by installing a long-crested weir, such as the duckbill weir illustrated in Figure 25. Such a weir blocks the flow. Being blocked, water rises and spills over the weir.

A small flow gives a small water layer over a weir; a larger flow causes a thicker water layer. The advantage of a long-crested weir is that this water layer is very thin, a few centimetres only. The longer the crest of the weir, the thinner the water layer and thus the smaller the variation in water level upstream of the weir.

A duckbill weir has two important functions:

- under normal flow conditions it blocks a canal and maintains the water level upstream; and,
- in the event of large flows it helps to maintain the level within a certain range immediately upstream of the weir.

Thanks to the length of the crest of the weir, the level of the water that spills over will be only a little higher than the level of the crest.

FIGURE 26
**Long-crested weir in a small canal**

For smaller canals, other forms of weirs may be used, such as the type illustrated in Figure 26, where the weir is placed parallel to the long axis of the canal and can thus have a long crest.

The water level upstream of the long-crested weir is almost constant, and, as was explained above, a constant water level at the offtake is maintained in order to obtain a constant discharge into a tertiary canal. As can be seen in Figures 25 and 26, the canal offtakes are situated immediately upstream of the long-crested weirs. In this situation one can say that the diverted discharges are constant.

## 4.5 SMALL CANAL OFFTAKES

Canal offtakes are usually sited just upstream of a structure for water-level control, and the Figures 27 to 30 show four different types that are commonly used as offtakes for smaller, tertiary canals.

Figure 27 shows a concrete or masonry structure equipped with wooden flash boards. This type is easy to construct but is difficult to make leakproof.

The structures in Figure 28 and Figure 29 can be quite leakproof, but they are more expensive than the one in Figure 27, and they are difficult to make.

Figure 30 shows a concrete structure equipped with a concrete panel. Such a structure can be leakproof, but it is heavy to operate.

**FIGURE 27**
Offtake with wooden flash boards

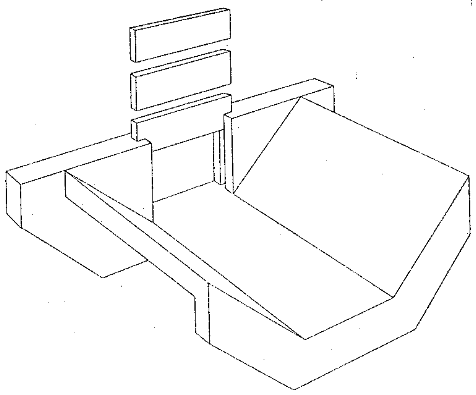


**FIGURE 28**
Offtake with sliding lid

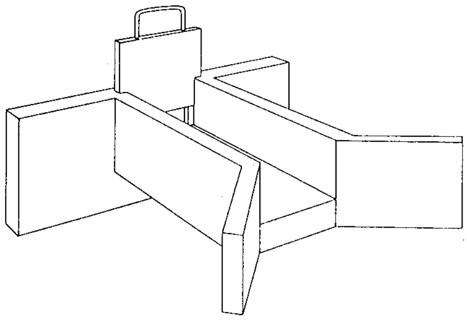


**FIGURE 29**
Offtake with slide gate

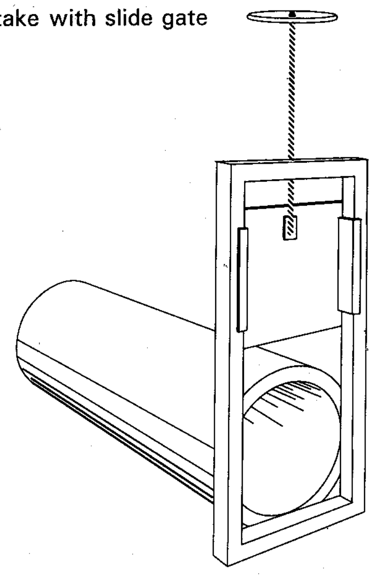


**FIGURE 30**
Offtake with a concrete panel