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WATER MEASUREMENT AND CONTROL AT THE FARM TURNOUT

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WATER MEASUREMENT AND CONTROL AT THE FARM TURNOUT

Charles W. Thomas,* Member ASCE

SYNOPSIS

Measuring devices at farm turnouts on open channel irrigation systems are discussed under six general functional classifications. Illustrations of each type now in use in different parts of the world are cited. Conclusions regarding the type best suited to meet local requirements are not drawn. However, by directing attention to the different solutions, perhaps some deviation from current practice is indicated. By integrating the many designs, it appears possible to devise an improved approach.

INTRODUCTION

Successful operation of an irrigation system depends on adequate control and measurement of flows. At no place is this more important than at the farm turnout. It is at this point where the individual user and the operators meet. On any irrigation system, the largest number of structures of any one type are the farm turnouts. There are over 70,000 on lands served by systems built by the Bureau of Reclamation and another 35,000 are to be found in irrigated areas served under the Warren Act and special lands. These structures have a general average cost of about \$200. Outlets on canals in the Punjab region of India and Pakistan numbered over 41,000 before 1950 and more have been added since that time.

Such facts should indicate the importance of these structures and the reason for drawing attention to the means of controlling and measuring flows through them.

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There are many considerations to be taken into account in the selection of a control and measuring device to best fit conditions at the site. Low loss in head, economy of installation and maintenance, range of discharges to be handled, legal requirements, and many other factors make the selection difficult.

DESIGN AND OPERATION OF IRRIGATION SYSTEMS

General

A review of some of the general aspects of irrigation systems is helpful to fully appreciate and understand the problems associated with control and measurement of water at the farm turnout.

Good design of an irrigation system is based primarily on making maximum use of the water resources available. In general, the land area which may be irrigated is established by the amount of such water resource. By proper regulation and control of the water the area served may be extended.

In the design of the system the quantity of water to be conveyed is based on the acreage to be served. A study of rainfall, soil types, crops which may be grown, depth to the water table and other factors determine this quantity.

Method of Distribution of the Water

In order to make the best use of the water in the system, the designer must consider how it is to be distributed. One of the following general methods may be used:

1. Continuous flow deliveries
2. Rotation or intermittent flow
3. Demand deliveries
4. Some combination of these methods

In an irrigation system designed for continuous flow, each irrigator is supplied his share of water in a continuous stream. This results in large land owners receiving large flows and small owners small flows. To measure the delivery at each turnout, devices in the system would necessarily vary in size from quite small to large. Control would be a factor of less import.

The rotation or intermittent flow system is based on delivering each farm a fixed amount of water at definite intervals. Storage reservoirs are necessary to make the water available and permit delivery at definite intervals during the irrigating season. Systems deriving their source of water from normal stream flow must make deliveries at the time the water is available. A more nearly standardized size of measuring device can be used under this system. In many instances, a saving in the number of measuring devices could result.

The demand delivery system is designed to make water available at all the farm turnouts on call or demand by the farmer. It is certainly the most convenient and economical from the consumers' standpoint. If adequate storage and ample conveyance capacity are provided, and if there is sufficient control of flows to avoid wastage en route or off the end of the system, then the deliveries can be made on a call or request by the farmer.

This system of delivery is not adaptable to projects operating from surface runoff. In this case, the water must be used when and in the amounts available and cannot be supplied to meet the demands of individuals. Measuring devices can be standardized somewhat under this system. Control is of major importance.

Some irrigation projects operate with a combination of the above systems. During periods of high seasonal runoff, the main conveyances are

usually operated to capacity provided the demand exists and there are legal rights to the water. At such times, at least a major portion of the farmers desiring water can be served. When storage reserves are being drawn upon, the project may operate on rotation or demand.

Other combinations of means of distribution may be used. Combinations of distribution methods cause added problems in control and measurement.

Charges for Water

The charges made for water supplied from the irrigation system vary considerably throughout the world. However, there are, in general, four categories into which the majority will fall.

The first system is a charge based on the rate of flow. This necessitates a rate of flow measurement and adequate records. A second broad basis for charges is on a volume basis. This method necessitates a volumetric type of measuring device or a rate of flow device combined with a record of time during which deliveries are made. The third method is a charge based on the acreage of crops matured. The rates vary in accord with the crops grown. Such items as the amount of water necessary to produce a certain crop, the season when most water is necessary for the crop (winter or summer), the value of the crop and comparative cost of irrigation from wells or other means, all enter the formula from which the charge is derived. Measurements of flow as a basis for charges are not necessary under this system but adequate control must be exercised to insure equitable distribution.

The fourth method is a charge based on each irrigation for a given area. In climates where irrigation is not necessary at all times for the successful growth of crops or in locations when the same crop is grown in large

areas year after year, a fixed charge is possible. This system is practiced extensively in rice producing areas.

Operating Organization

In many areas of the world, there is, generally speaking, a large organization to control the conveyance and delivery of the water, to regulate the flows and to keep records necessary for charges.

In parts of India there is generally no manual control on the farm turnouts. The design is such that they work automatically and continuously. In the Punjab area, the lateral systems, which may have a maximum capacity of from 300 to 400 second-feet, are so designed that manual control or regulation is not necessary at any point in the system except at the turnout from the main canal. The internal distribution of water among the various cultivators on the laterals is generally managed by the cultivators themselves and the Government, which operates the canals, keeps no records of the farm deliveries.

METHODS OF MEASUREMENT AND CONTROL

From the foregoing discussion it may be seen that the operation of an irrigation system could be simplified and many of the problems of controlling and measuring the water delivered to the consumers could be solved if some reliable means were available to automatically deliver a fixed, predetermined discharge to each consumer under the system. Technicians have been striving for many years to devise such a device. Many of the schemes offered have never outgrown the paper stage. Others have proven worthless in actual practice or have been discarded because of their complexity and unreliability. There are, however, some methods of treating the problem which have met with success.

The Six General Schemes

For the purpose of this discussion, measuring devices at the farm turnouts are divided into six broad functional classifications. No clear lines can be drawn between these selected classifications, and some examples given overlap into other categories.

The six general classifications are: (1) those devices, known as modules, which will automatically deliver a constant, or near constant, discharge over a range of changes of both upstream and downstream water levels; (2) those devices, known as semimodules, which will automatically deliver a constant, or near constant, discharge over a range of downstream levels but in which the discharge will vary with changes in the upstream water level; (3) those devices which provide an equitable distribution of flow over a range of fluctuations of upstream water surface levels (these devices are generally semimodules); (4) those devices designed to automatically deliver a constant discharge when operated in conjunction with auxiliary equipment to control the upstream water level and which are not affected, within limits, by changes in downstream levels; (5) the structures and equipment in general use in the United States which give a range of discharges depending on upstream and downstream heads and which may require auxiliary means of manual control; and (6) those devices which do not serve as controls, but which totalize the discharge, over a relatively wide range of flows passing them, and thus provide an equitable basis for charges.

It is not the intent of the author to attempt an explanation of the exact design and operation of the various devices mentioned or to argue the many advantages, disadvantages, or possible weak points of each. The classification has been made on a functional basis and it is assumed that if

the device, structure, or combination installation is designed, constructed, and operated as intended, the function will be fulfilled.

The examples cited constitute only a very minor portion of all those developed or suggested. There are many others throughout the world and possibly many of those not mentioned are more popular.

Modules

As previously stated, a device which would automatically deliver the desired quantity of flow to the farm regardless of fluctuations of water surface in the conveyance system or in the farm ditch would essentially solve the problem of control and measurement at the farm turnout.

Many of the old irrigation networks of the world operate on direct flow from the streams without benefit of seasonal storage. Many of these systems are quite extensive. Such operation causes considerable fluctuation in water levels in the conveyances. In periods of high seasonal runoff the canals may be operated to capacity, but as the stream flow subsides, the quantities available for diversion become limited and the canal levels fall. In these areas much work has been done toward evolving a turnout that would meet these conditions.

S. I. Mahbub and N. D. Gulhati in their book "Irrigation Outlets"¹ trace the history of evolution of various types of turnouts on the canals of the Punjab in India and Pakistan. Operation of some of the large canal systems in this area began shortly after 1800. The authors define the module as a device which will deliver a fixed quantity of water automatically regardless of fluctuations of levels of water surface, within limits, in the canal or in

¹"Irrigation Outlets," S. I. Mahbub and N. D. Gulhati (revised and enlarged by N. D. Gulhati), Atma Ram & Sons, Kashmere Gate, Delhi, India, 1951.

the delivery. They cite a number of such devices in use. Some are constructed with moving parts and others without.

One such device cited, which has no moving parts, is known as the Gibbs Module, Figure 1. The water is lead through an inlet pipe into a spiral rectangular trough. This trough is level and is provided with a cover. Free vortex flow develops in this eddy chamber with a consequent rise in water surface at the outer wall. A number of cross baffles with their bottom edges sloped correctly serve to skim off part of the flow and turn it back on the approaching flow. This action becomes more pronounced as the upstream head increases and the velocity in the chamber tends to increase. An impingement results and the velocity is lowered, thus holding the discharge constant. The design is such that the flow passes through critical depth at the downstream end, and changes in water surface levels in the delivery do not reflect in the discharge.

The degree of turn of the spiral depends on the volume of discharge and the variation of upstream head being designed for and varies from 180 to 540 degrees.

Standard designs of this module have been developed in the hydraulic laboratory for discharges and conditions so that the variation from design discharge is said to be not more than 3 percent.

Another example is Khanna's Rigid Module, Figure 2. Water enters the structure through the three openings marked 1, 2, and 3. As long as the water surface in the canal remains just above the main opening, the turnout acts as a submerged orifice. When the upstream water surface rises to opening 1, some eddies are formed at the entrance and the flow is reduced below that which would normally be discharged with the increased head. Additional upstream head causes

Chamber A to fill, and water successively flows into the inclined slots, S, S', and S'', causing an impingement on the forward flow through the opening and a consequent reduction in discharge. Considerable analytical and empirical development was necessary to obtain the correct relationships of size and slope of slots to produce the desired results. Limited changes in downstream water level do not affect the measurement because the flow passes through critical depth at the exit of the turnout.

The old irrigation systems of southern France operate without benefit of storage. Modules have also been developed for use in this area. On the Old Marseille Canal modules with moving parts were once extensively used and some are to be found today.

An example of a recently developed module with moving parts is shown in Figure 3. Changes in upstream water level cause movement of the float which automatically maintains the flow at a constant rate. Considerable variation in upstream level may be tolerated since the float may be adjusted. Changes in downstream water levels do not alter the rate of flow providing the maximum level in the delivery does not exceed the level of the fixed weir at the outlet of the distributor. This exit weir has been calibrated for measuring the rate of discharge.² This device was developed in Italy.

Seminmodules

A seminmodule is a device which will pass a fixed discharge providing either the head water or tail water remains constant. Most of such devices are designed in such a manner that changes in tail water conditions do not reflect in the rate of discharge. Variations in upstream water surface elevations will, however, change the discharge rate.

²New Automatic Channel Flow Regulator, Anonymous, Water and Water Engineering, June 1956, page 250.

Such a device is theoretically better than one which is sensitive to variations in both upstream and downstream water levels.

Starting with a turnout consisting simply of a cut, and later a barrel passing through the canal bank, both of which were subject to changes in discharge with changes in both upstream and downstream levels, the next step would normally be to evolve a device of the semimodule type.

In many parts of the world, interference with the turnout by the water user led to placing checks, cisterns, orifices, and similar structures at the downstream ends of the turnouts to raise the water surface to a level which would be above the maximum level in the delivery channel. Thus, the turnout would not be affected by operational changes made by the water users.

In the Punjab the Harvey-Stoddard Improved Irrigation Outlet, Figure 4, was developed as one such type of device. A fixed crest weir maintains the level at the end of the turnout above the maximum water level in the farm delivery. In the same area the open flume type of turnout was modified by placing a roof block in the flume, Figure 5, to cause the flow to pass through critical depth and thus not reflect changes, within limits, in downstream levels.

Weirs placed in the conveyance downstream from the turnout, as used in the United States, are not included in this classification. Although the weir does prevent changes in the downstream levels from affecting the flow through the turnout, providing the weir is not submerged, the weir structure is nearly always separate from the turnout structure and the control remains at the turnout gate.

Equitable Distribution of Flow

This type of measuring device is so designed that the levels in the conveyance system may vary over a wide range, and all deliveries will remain proportional. This insures an equitable distribution without providing a control device at each individual turnout for periodic regulation.

In areas where charges are based on acreage of crops matured or where water is distributed in the quantity available on the basis of land areas irrigated or for other reasons, an equitable distribution of the available water to the users may suffice. In the Punjab, for instance, measurement is made at the head of the lateral and equitable distribution serves as a basis for farm deliveries.

Open flume turnouts of the type shown in Figure 6 serve this condition quite well. The entrance is shaped so that a fair share of the flow is extracted. Exit conditions are such that changes in downstream level are not reflected to an appreciable degree. Many barrel type turnouts to serve a similar purpose have been developed.

Divisors are used in many parts of the world to effect equitable distribution of flow. These structures simply divide the flow into the desired proportions. To be effective, upstream and downstream flow conditions must be similar across the section. The dimensions of the openings are not necessarily in the same proportions as the desired division of discharge. They may be made rigid or variable. Figure 7 shows a divisor in an old irrigation system near Marrakech, Morocco. This structure also serves the purpose of slowing the flow, which is above critical velocity, for diversion into the turnout.

In other irrigation networks in southern Europe and North Africa, a divisor developed in France is used, Figure 8. The dividing blade is adjustable

and calibrations have been made so that the flow may be proportioned between the two channels in varying amounts. The standard setting for channels on fairly flat gradients is illustrated in this figure. When steep slopes are encountered, the setting is slightly different.³

In many of the old irrigation systems in the United States "division boxes" were used. These were generally constructed of wood. Many of them were of fixed proportions. One type of adjustable divisor is shown in Figure 9. This particular structure, as well as many others of similar proportions, was calibrated for flow measurement at different settings over a range of upstream heads.⁴

Seminmodules with Auxiliary Apparatus

The design of a turnout which will deliver a fixed quantity of water and not be subject to variations of upstream and downstream water levels may become very complicated as indicated by the examples cited. Such devices may also be subject to operational difficulties. The effects of changes in downstream water levels can be removed by relatively simple design. It would seem then that the use of auxiliary equipment to control the level upstream would effect a workable solution.

Examples of distributors which will deliver a near constant quantity will first be explained, followed by examples of auxiliary means employed to automatically control the water surface upstream from the distributor to a near constant level and negate the need for periodic regulation of each turnout.

³Quelques Considerations sur l'Equiptment des Reseaux d'Irrigation
NEYRPIC, Grenoble, France.

⁴Divisors (for the measurement of irrigation water)," V. M. Cone,
Bulletin 228 of the Agricultural Experiment Station of the Colorado
Agricultural College, Fort Collins, Colorado, April 1917.

The distributor shown in Figure 10 is used extensively in southern Europe and North Africa and to a lesser extent in other parts of the world. The sliding plates are either fully open or fully closed. The desired discharge is obtained by opening one or more of the passages. It may be seen from the cross section in Figure 11 that each section of the distributor is formed by a specially shaped sill and a fixed plate. The sill and fixed plate are contained between vertical parallel side plates, thus creating an orifice.

If the water level above the orifice is controlled to permit variation between predetermined limits, the discharge which passes through the orifice remains very nearly constant. The stability of the discharge is maintained because the increase in velocity, which results from the increase in head, is accompanied by a greater degree of contraction of the outgoing stream. A discharge curve is included in Figure 11.

The downstream slope of the sill causes the formation of a hydraulic jump in which part of the kinetic energy is recovered. Thus, the overall loss in head through the apparatus is low. The formation of the hydraulic jump also makes the discharge independent of the downstream water level as long as the jump is not drowned.

Another distributor designed along very similar lines is shown in Figure 12. This distributor can absorb a greater change in upstream level because of the action of the siphon and the consequent added impingement on the jet. A discharge curve is also shown in the figure.

A number of schemes have been devised for automatically controlling the water surface in the canal or lateral. They are used in conjunction with the distributors. A balanced radial gate with a float attached to the upstream

skin plate, Figure 13, provides automatically a near constant water surface upstream from the gate. This automatic control gate is installed in the canal or lateral just downstream from the turnout equipped with a distributor.

A balanced gate for automatically controlling the level downstream from the installation has also been developed, Figure 14. The float, in the foreground, automatically positions the gate leaf over an orifice to maintain a predetermined near constant level. This gate is used on storage reservoirs or on turnouts from canals in which the water level varies. The distributor is placed downstream from this type of gate, Figure 15.

In Algeria and Morocco where the newer conveyances consist for the most part of precast concrete sections, other means are also used to control the water surface to a near constant level. Long, diagonal weirs, Figure 16, and "Duckbill" weirs, Figure 17, are employed. The "Duckbill" weir is also used in conventional lined sections. The distributors are installed upstream from these devices.

Another development for automatically controlling the water surface is a float operated disc valve which may be used on a turnout fed from a source which has a variable level.⁵ The distributor is located downstream from the valve. Figure 18 shows a large installation to illustrate this type. The valves are usually applied to smaller installations but work equally well in the larger sizes.

Measuring Devices in Common Use in the United States

In the United States water is usually distributed on the basis of rate of flow, in most instances cubic feet per second, although this rate,

⁵Amenagement de la Basse Moulouya (Maroc oriental), Florent Granger, Terres Et Eaux, No. 26.

combined with time, may be used to give a volume, acre-feet, as a basis for charges. Weirs, critical depth structures, Parshall flumes, and similar means of measurement require that the head be known to obtain discharge. When the water surface in the conveyance is permitted to fluctuate, adjustment of a turnout gate or similar installation is necessary to obtain the desired head at the point of measurement. The usual practice is to make this adjustment daily and then obtain a reading of head on the measuring structure to serve as a basis of charges and to control distribution. As a general rule, only the larger metering stations are equipped with apparatus to record the head continuously at the measuring section. Farm turnouts are thus excluded. An exception to this practice may be found in areas where the cost of water is high. Since the discharge varies with the head and the head is subject to variations with changes of water level in the canal or lateral, assuming the operator is not present at all times to adjust the turnout gate, it is probable that the rate of flow does not remain entirely constant during the interim between observations of the gage height. Since major changes in flow are not made over short periods of time, the rate of discharge at the turnout remains relatively constant. However, a continuous record of gage height would be desirable. The present cost of providing such a record at each farm turnout is not justifiable in most systems.

Generally speaking, the measuring devices employed at farm turnouts on open channel systems are designed to permit variation of the upstream head and in most cases variation of the downstream head. Observation of the upstream head or the differential head and the use of tables or curves prepared from prior calibrations permit evaluation of the discharge. Regulation of the head is by manual control almost without exception.

There are installations where the water levels in canals and laterals are controlled automatically, but this automatic control has not reached to the farm turnout. The controls are usually employed to raise the water surface a sufficient amount to permit deliveries and not necessarily to provide a constant head on the delivery. Examples of automatic control are to be found but these are exceptions and not the general rule.

It would not be consistent to evaluate the measuring devices in use in the United States in regard to their operational characteristics since those devices previously mentioned have not been completely evaluated. However, the equipment and structures in common use will be mentioned and some evaluation will be made to illustrate usage. Design and operational details and calibration data may be found elsewhere.⁶

A shutoff is in most instances required at a farm delivery because of the manner in which the systems are operated. Economy in installation can be effected if the shutoff also serves as a regulator and as a means of measurement. There have been numerous attempts to provide this combination.

Many irrigation systems have been equipped with metergates such as the one shown in Figure 19. One of the stilling wells is connected to the water prism in the canal and the other to the delivery pipe on the downstream side of the gate. The difference in water levels in the two wells and the gate opening is measured and the discharge obtained from tables developed from standard calibrations.⁷ The total head loss is low. The initial cost is low compared with other means because of the combined features of measurement, regulation,

⁶Water Measurement Manual, Bureau of Reclamation, United States Department of the Interior, Denver, Colorado, May 1953.

⁷Water Measurement Tables for the Aranco Metergate, 1951, Aranco Drainage and Metal Products, Denver, Colorado.

and shutoff. Periodic observations and manual adjustments are necessary. Changes in either upstream or downstream water levels alter the rate of flow.

Other types of gates have been calibrated but the tables are not as complete and the gates are not as well standardized.

The constant head orifice turnout shown in Figure 20 has become popular for measuring farm turnouts as well as for installation in canals and laterals. The operation is manual. Calibration and standardization have been accomplished in the smaller sizes. The upstream gate is set at the required opening, as shown in the rating tables, to deliver the desired quantity. The downstream gate is then regulated until there is a 0.2-foot differential head across the upstream gate as indicated by two enameled scales, one located upstream from the upstream gate and the other between the two gates. Any change in water surface level in the canal or delivery is reflected in the measurement. Periodic regulation and observation are necessary.

The Parshall measuring flume,⁸ Figure 21, is a critical depth measuring device. It was developed empirically, standardized, and calibrated. Hence, if the standard dimensions are followed within close tolerances in the field, the discharge as obtained from observing the depths of flow on the gages and referring to the calibration tables is quite accurate. The flume is a semimodule when set high enough to operate with no backwater. Since the flow passes through critical depth in the flume, changes in tail water levels do not alter the discharge appreciably. The flume has been calibrated to operate in a low level position. Under this condition a high degree of submergence can

⁸Improving the Distribution of Water to Farmers by Use of the Parshall Measuring Flume, R. L. Parshall, Colorado Agricultural College Experiment Station, Fort Collins, Colorado, Bulletin 488, May 1945.

be tolerated and the measurement will retain its accuracy. The depth of flow in the converging section and at the throat is necessary to obtain discharge when operating with submergence. If operating submerged, changes in either upstream or downstream levels will change the rate of discharge.

The device most extensively used in the United States for measurement of deliveries to the farm is the sharp crested weir. The Cippoletti, Figure 22, is probably the most used type of weir. However, a considerable number of rectangular weirs, both contracted and suppressed, may be found. Where discharges from small turnouts are to be measured, a V-notch weir is used. The weir when operated under normal conditions, that is, with a free falling nappe and without submergence, together with the turnout gate may be considered as a semimodule. Changes in water level in the delivery do not reflect in the measurement unless the level exceeds the height of the fixed crest. Any change in upstream level results in a change of discharge.

Adjustable length weirs are used in many installations to avoid errors in measurements introduced by small errors in observation of head when low flows are passing. By shortening the weir, thus increasing the head for a given discharge, the percentage error is reduced.

Devices Which Provide an Equitable Basis for Charges

A sixth functional class of measuring devices are those which do not in themselves control the flow but are operated in conjunction with separate controls and provide a totalized record of the volume of flow which passes. They are effective over a quite wide range of discharges and are not affected by changes in water levels upstream or downstream providing the downstream level does not fall below a predetermined limit and the differential head lies between certain rather broad limits. The totalized record of the volume of

flow, which may vary over considerable range of discharge, provides a direct and equitable basis for charges.

Velocity, turbine, and positive displacement type meters with totalizing mechanisms are in use throughout the world on closed conduit systems. There are also many installations on closed systems where instruments are employed in conjunction with the measuring equipment to provide a record of upstream water levels or differential levels. Some of these may also be found on open channel systems at the farm turnout.

A measuring device which is now being used on irrigation turnouts in the western United States is the open flow meter, Figure 23. This is a velocity type meter. The propeller drives an appropriate gear train, with mechanical connections, to operate a totalizer which registers the volume of water passing through the turnout irrespective of variations of head.

Some irrigation systems which operate on a rotation basis also rotate the meters. Some operators rotate the meters but have a totalizing unit for each turnout which remains locked to the turnout.

In Algeria some of the larger installations which have automatic water level control equipment and distributors employ recorders on the shutoff device to provide a record of the time that it is either fully open or closed (normal operation). This practice is being extended to the smaller turnouts. An equitable basis for charges is thus provided. This system introduces an extra step in computing charges which is not included in the use of the totalizing meters which register volume direct.

NEW DEVELOPMENTS

In the United States two recent developments of vane meters show promise. One type employs a long near conical shaped vane operated with the

apex down and projecting into the flow. This meter is designed to indicate the rate of flow on a graduated scale as sensed by the vane in accordance with the velocity and position of the water surface. The other meter employs an elongated near triangular shaped vane. The long sides of the triangle are curved toward each other and vane is slightly convex in the direction of flow. The apex of the triangle is down and reaches into the flow. An inexpensive recorder is envisioned for this meter, which will record the rate of flow on a time scale. Both meters are designed to be placed in structures of rectangular cross section in which the surface level need not remain constant. It is proposed that the instruments will be standardized, calibrated, and assembled to cover a range of flows adequate to meet the needs at farm turnouts.

CONCLUSIONS

It would be an extremely difficult task to draw conclusions as to which of the many types of controls and measuring devices are best suited to meet the wide variety of physical conditions that can possibly exist at a farm turnout. There is also the human element to contend with, such as, what the users are accustomed to and their tendency to resent change, or to tamper with the control and measuring medium. In fact, there may be a number of possible choices and the final selection might be made on other than technical decisions.

It is hoped that by directing attention to the many different possible solutions, perhaps some deviation from current practice is indicated. The evolution of the design of turnouts has progressed more or less independently in widely separated geographic areas of the world. By integrating the many designs, it appears possible to devise an improved approach. Such a procedure would involve breaking away from established practice in the local areas and would no doubt require considerable work and demonstration.

Current extraordinary demands being placed on the available water resources of the globe may in the near future force quite revolutionary changes in handling the problems connected with control and measurement of flows in irrigation systems.

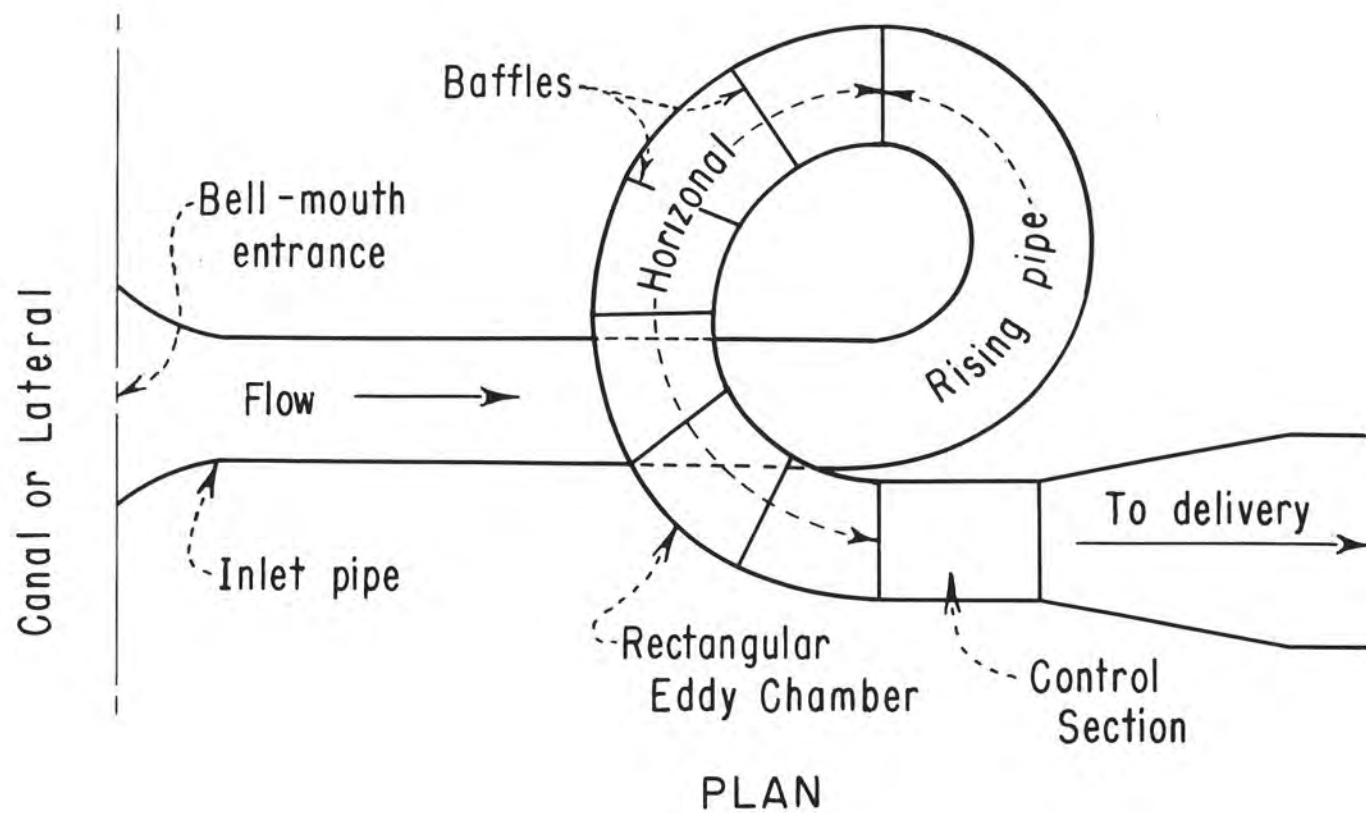


FIGURE 1- GIBB'S MODULE

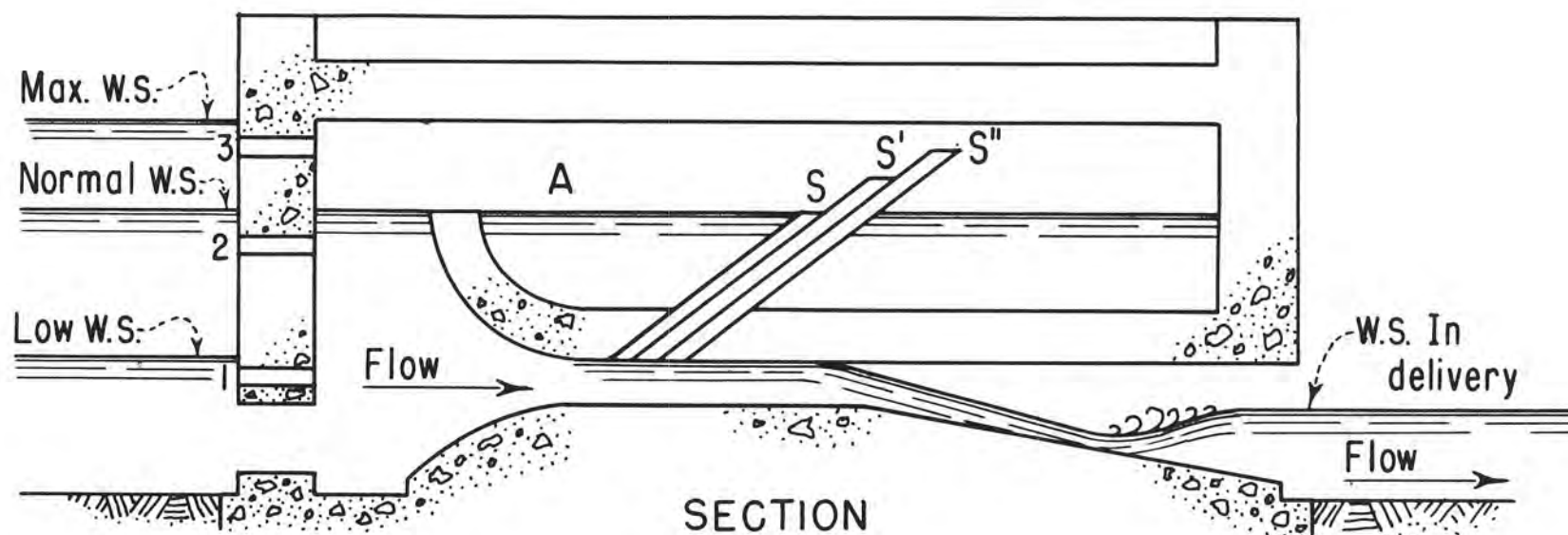


FIGURE 2—KHANNA'S RIGID MODULE

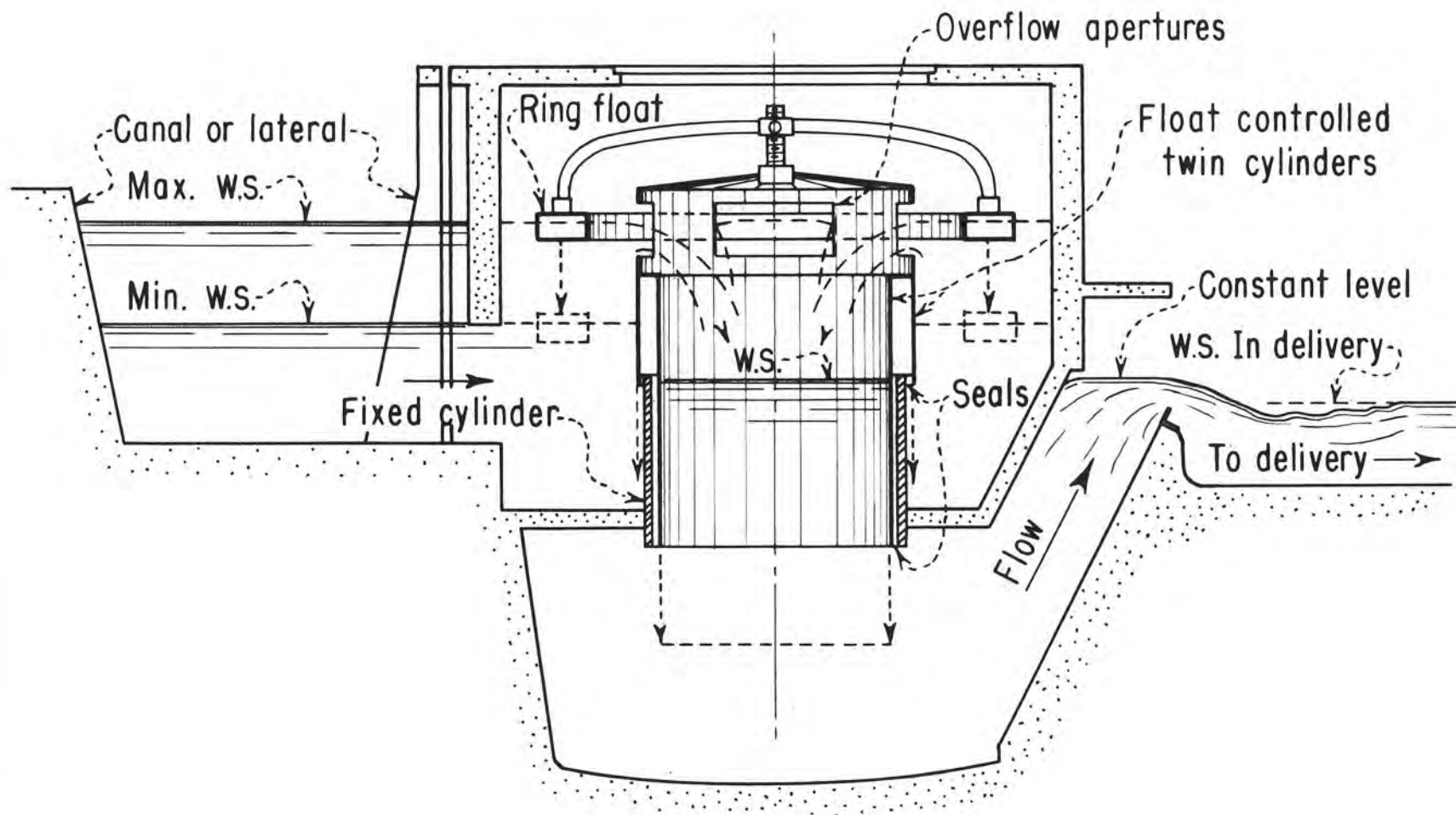
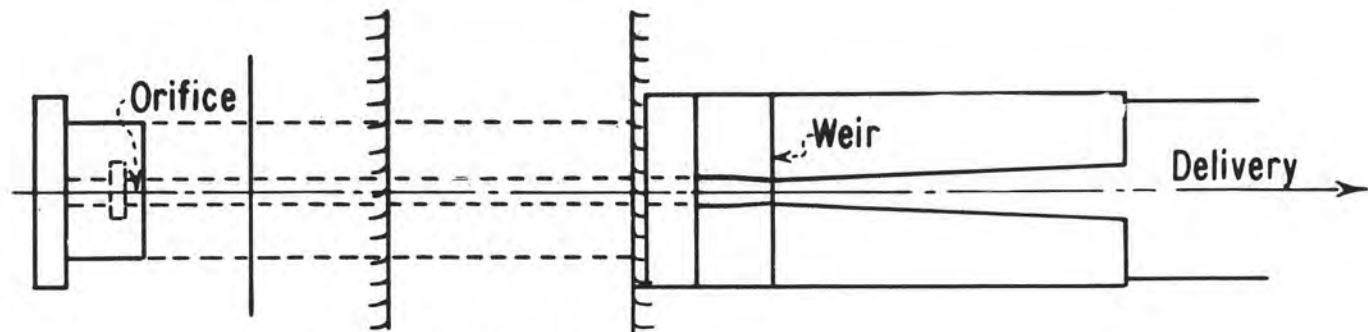
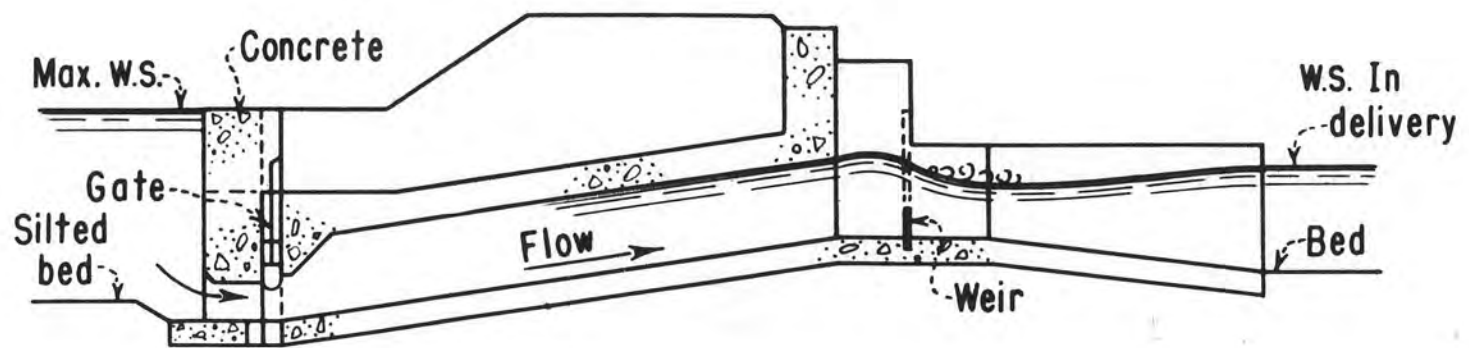


FIGURE 3-MODULE WITH MOVING PARTS



PLAN



SECTION

**FIGURE 4-THE HARVEY-STODDARD IMPROVED
IRRIGATION OUTLET**

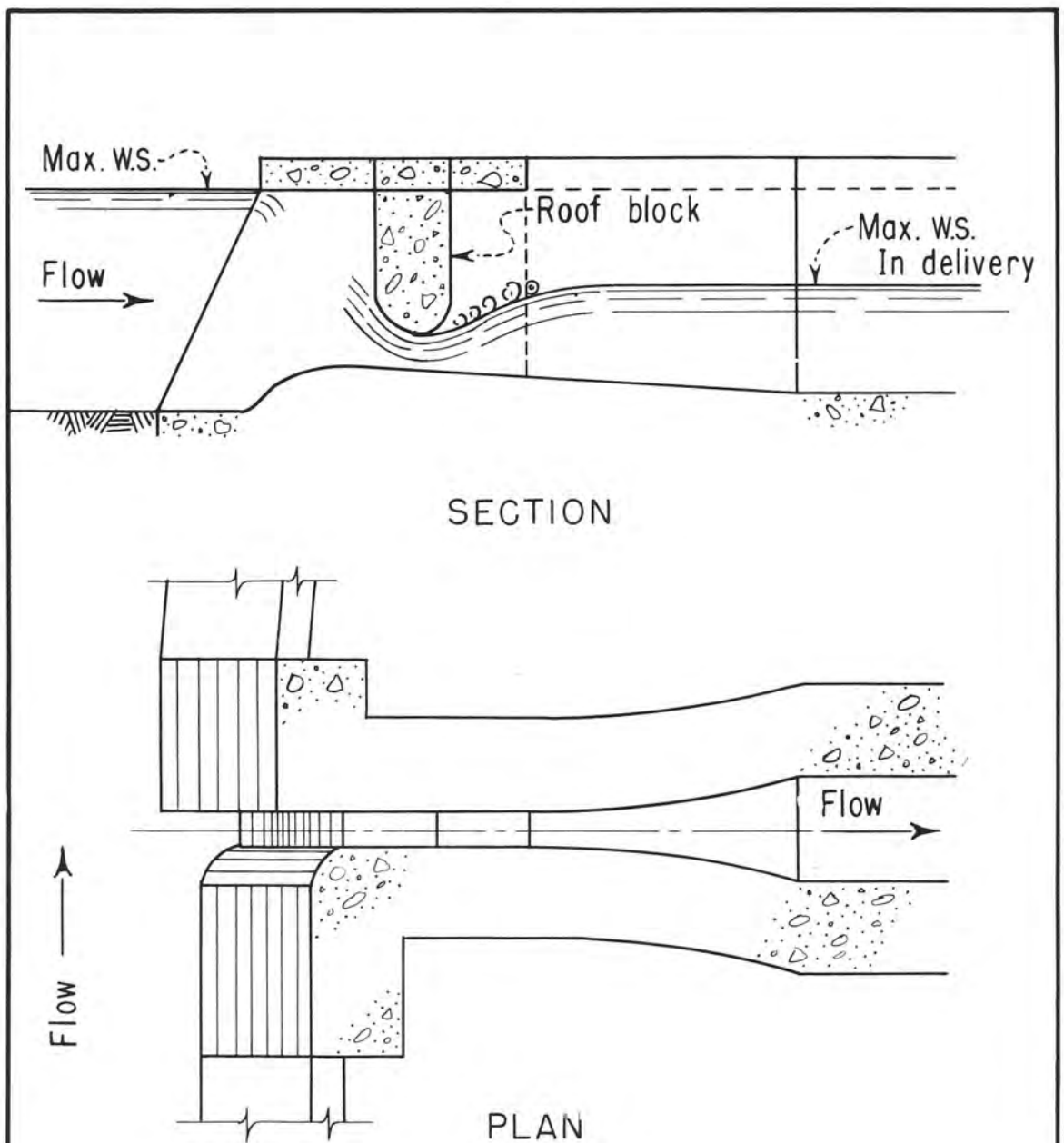


FIGURE 5- A STANDARD DESIGN OF SEMI-MODULE USED IN THE PUNJAB

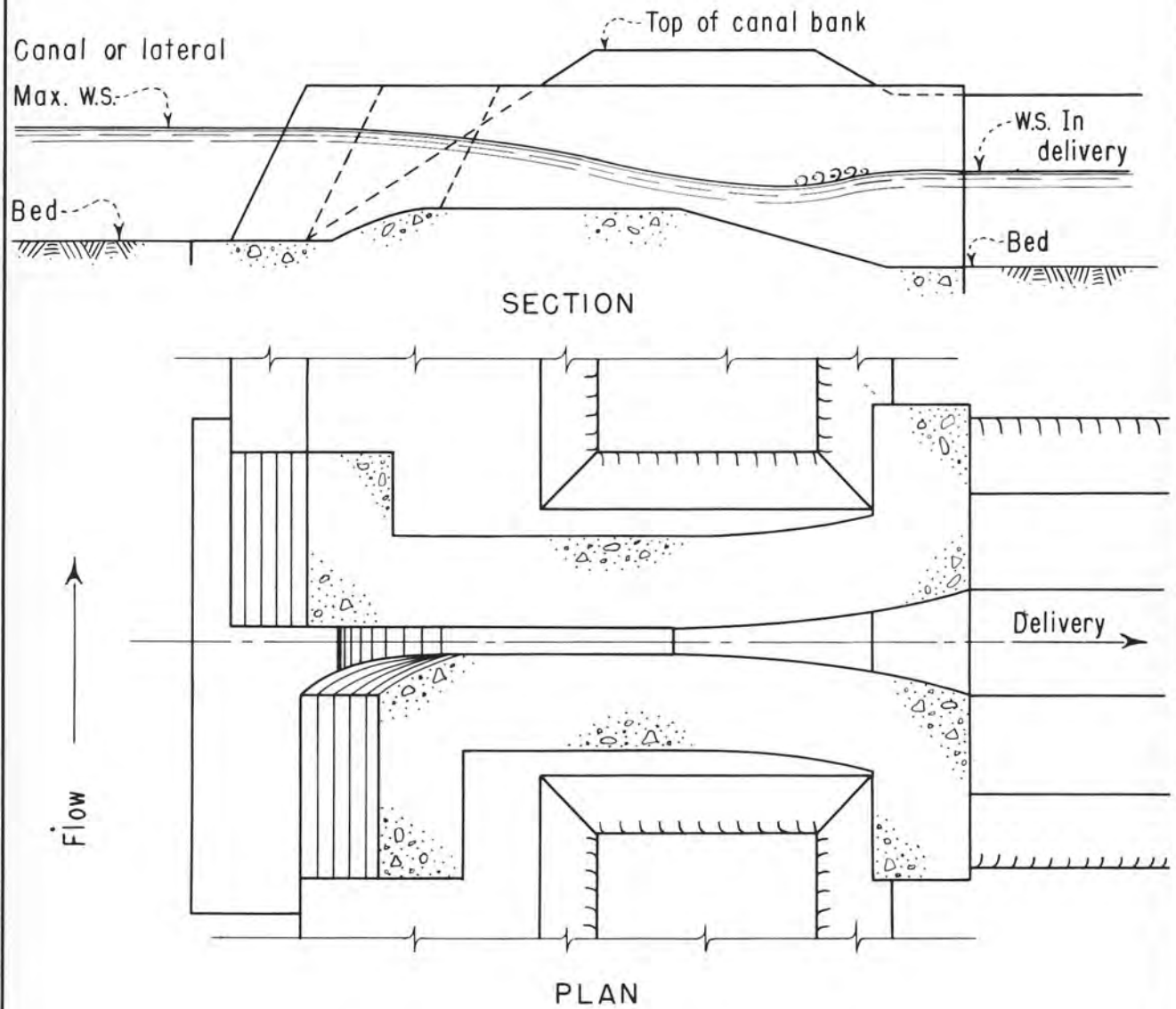
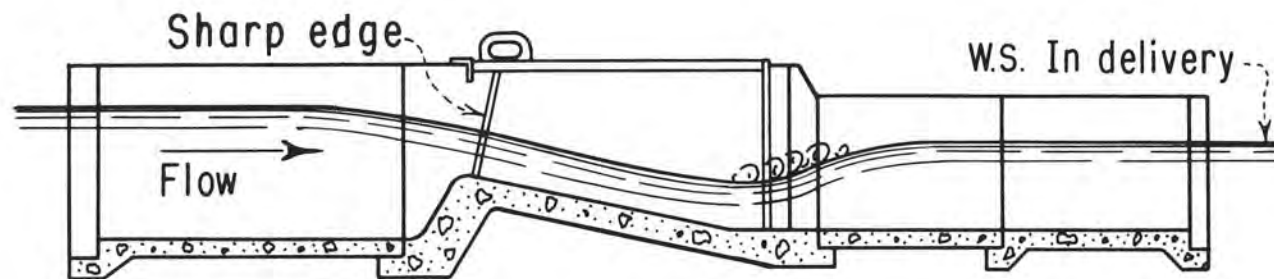


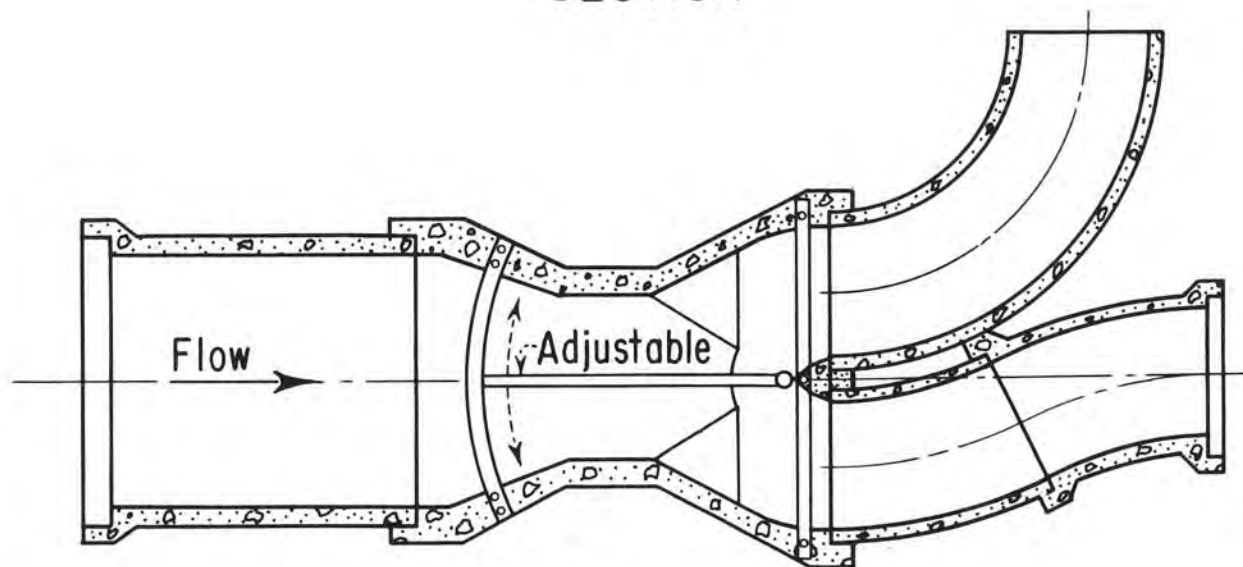
FIGURE 6 - CRUMP'S OPEN FLUME OUTLET



Figure 7. Divisor in Old Irrigation System in Morroco



SECTION



PLAN

FIGURE 8-FRENCH TYPE PROPORTIONAL DIVISOR

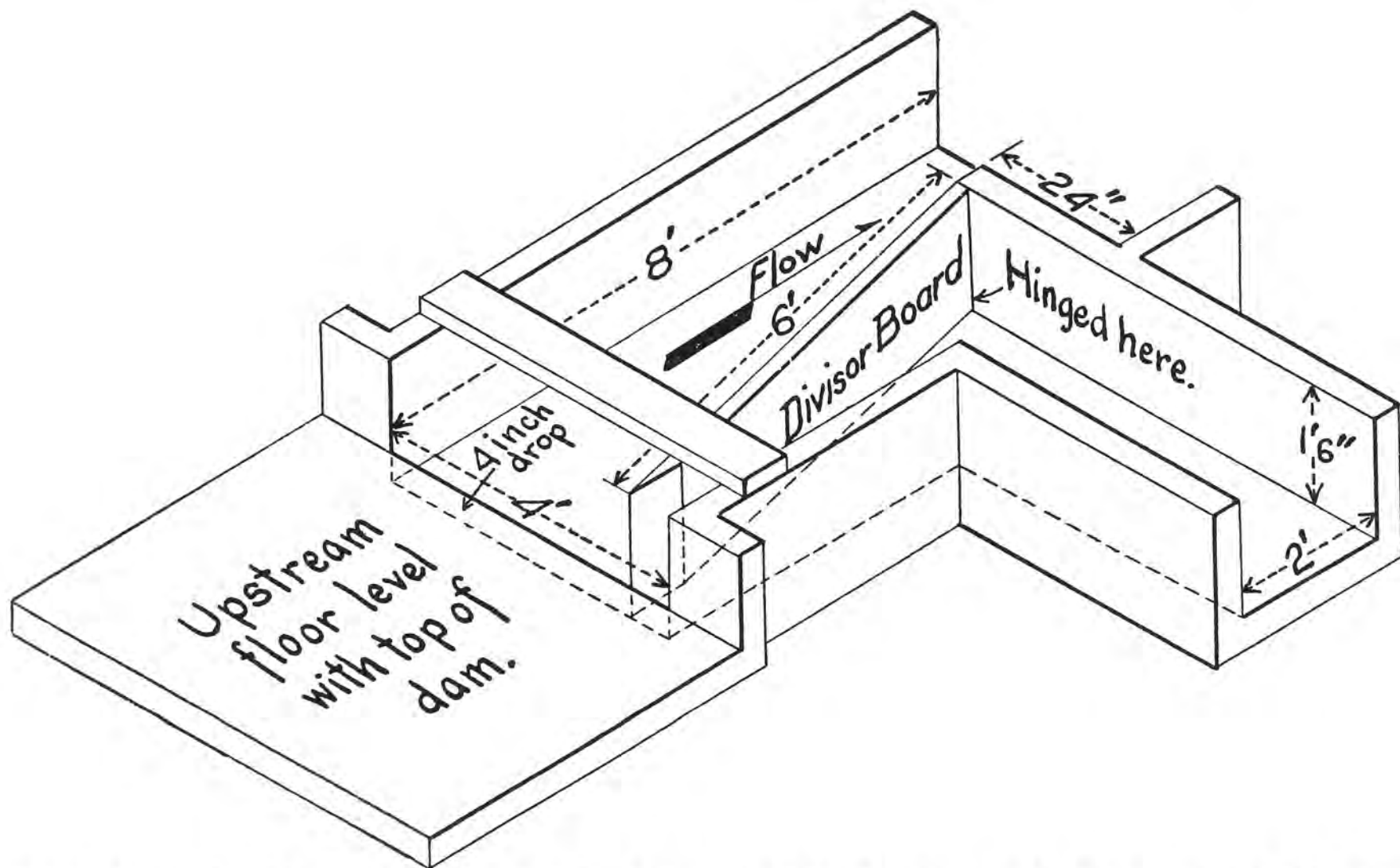


FIGURE 9. U. S. TYPE PROPORTIONAL DIVISOR

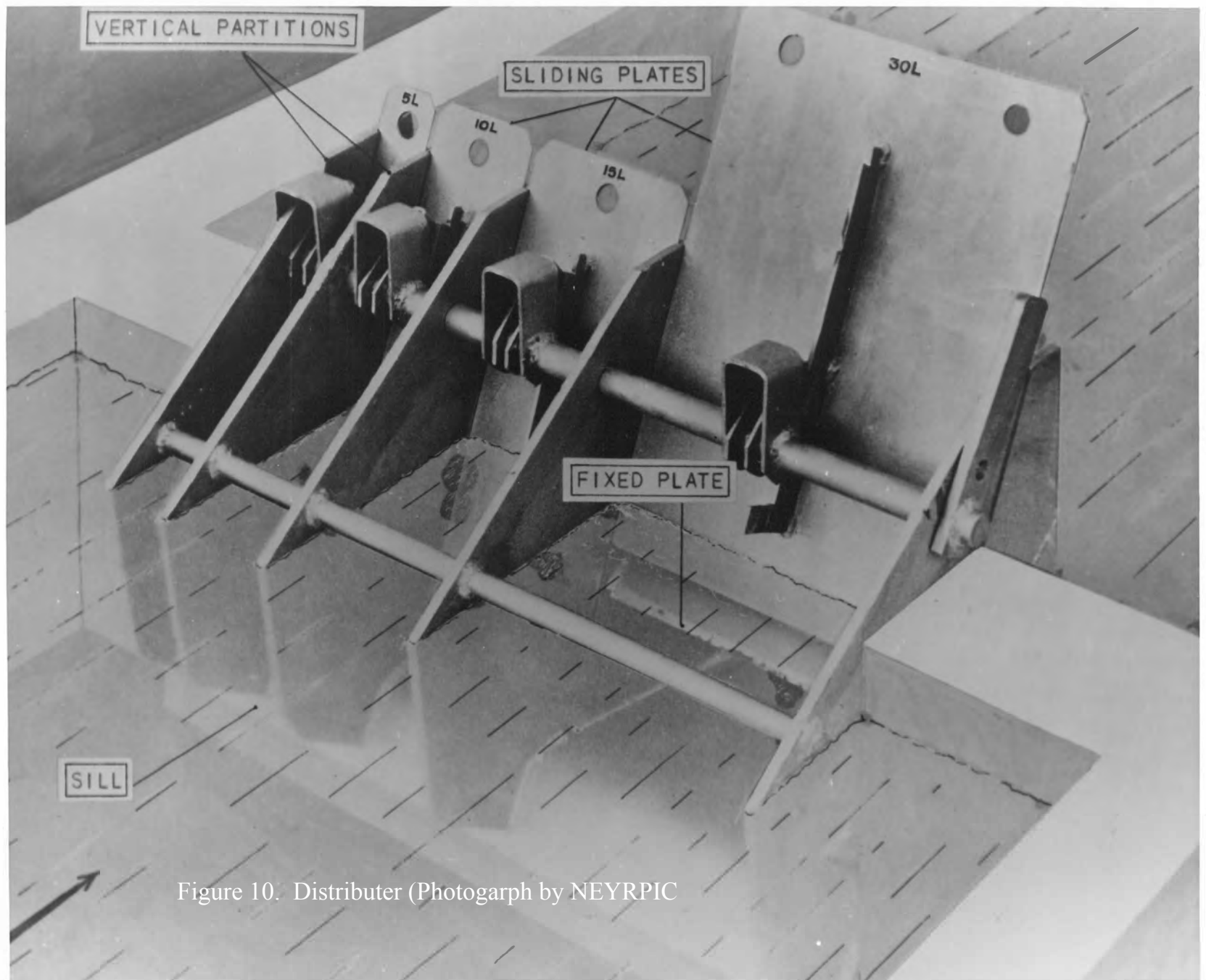


Figure 10. Distributer (Photograph by NEYRPIC)

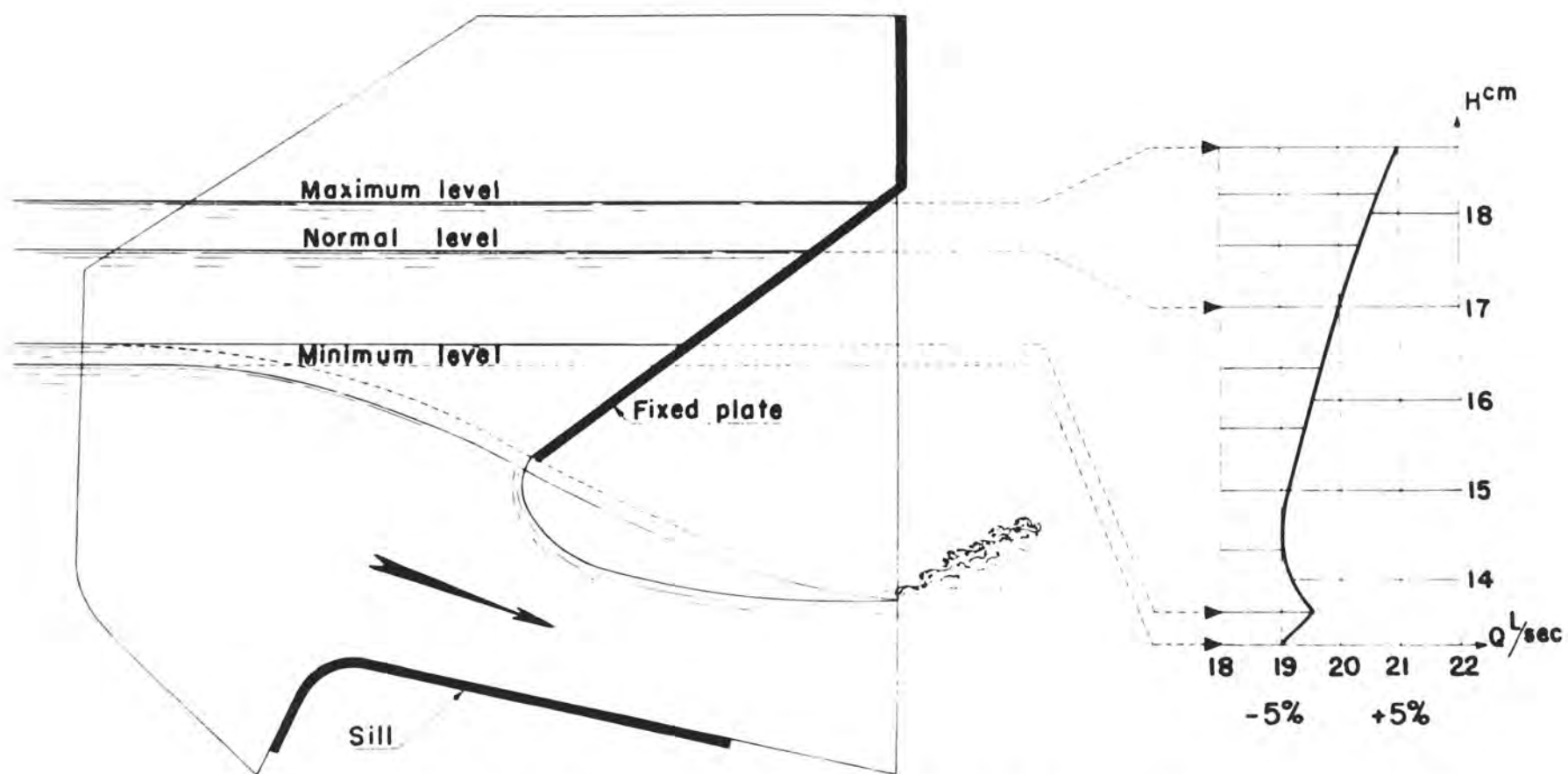


FIG. II. DISCHARGE CURVE OF DISTRIBUTOR

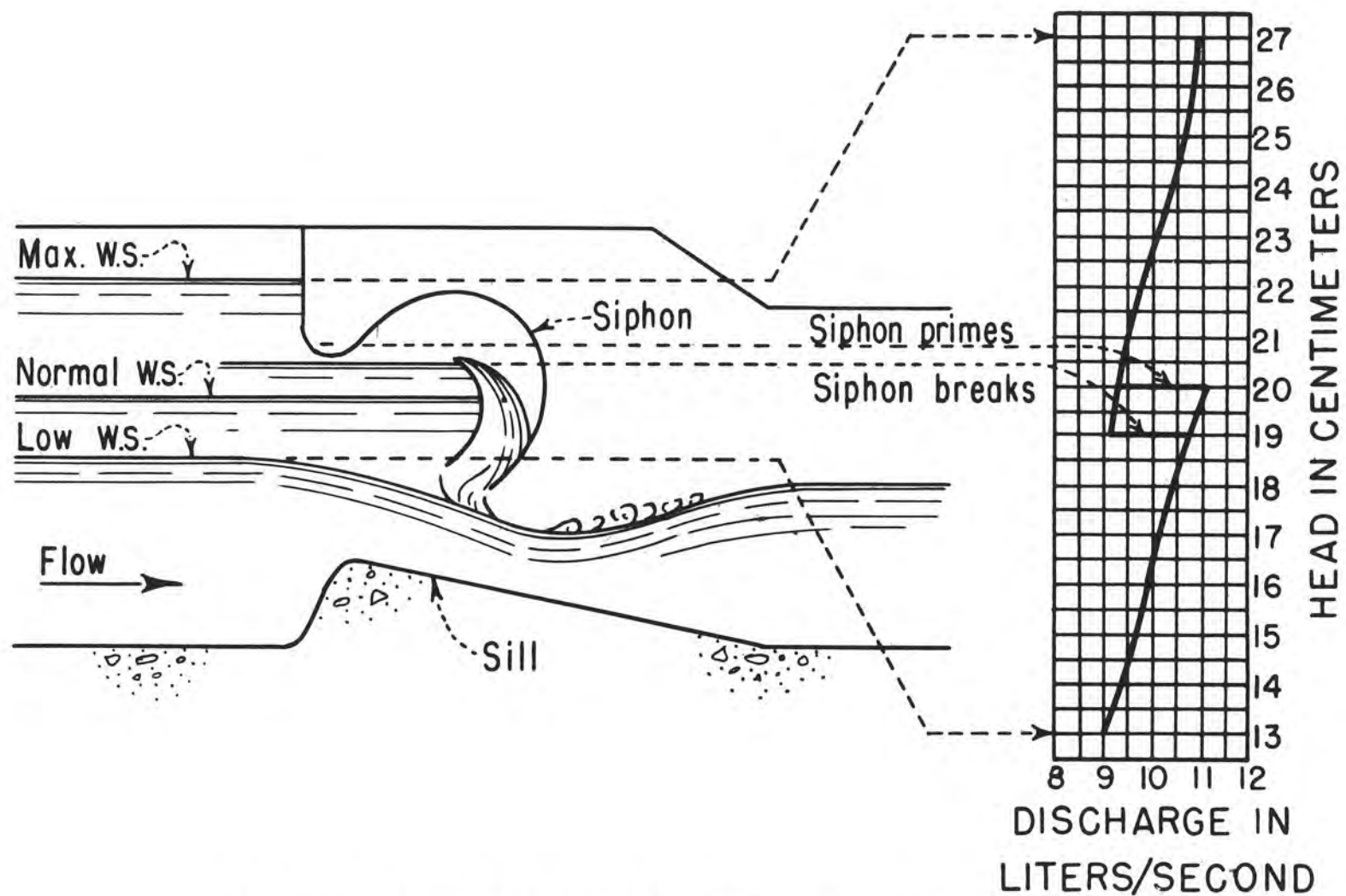


FIGURE 12-DISTRIBUTOR WITH SIPHON



Figure 13. Constant Upstream Level Automatic Gate

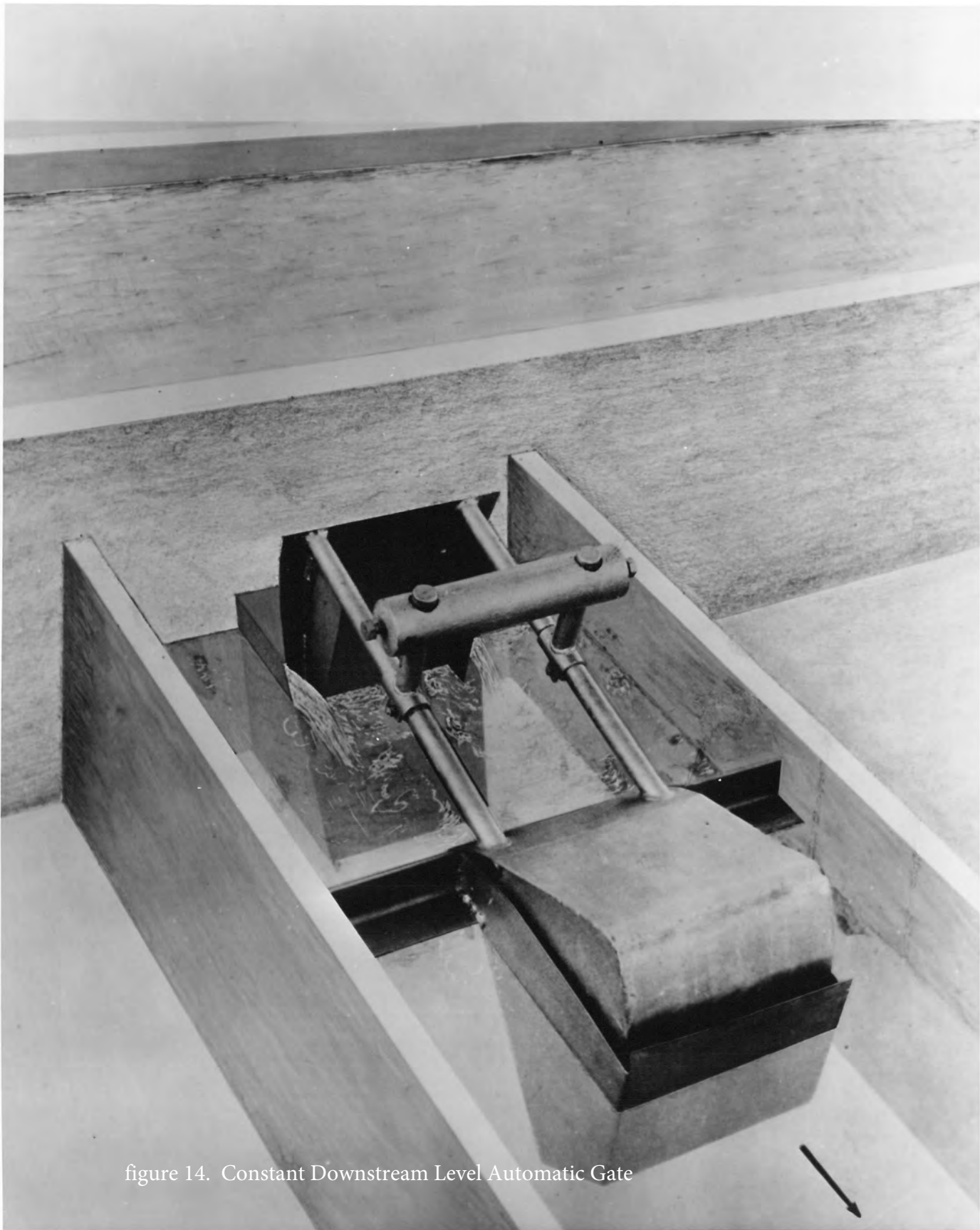


figure 14. Constant Downstream Level Automatic Gate



Figure 15. Constant Downstream Level Automatic Gate and Distributer



Figure 16. Diagonal Weir in Precast Concrete Lateral



Figure 17. Duckbill Weir in Precast Concrete Lateral

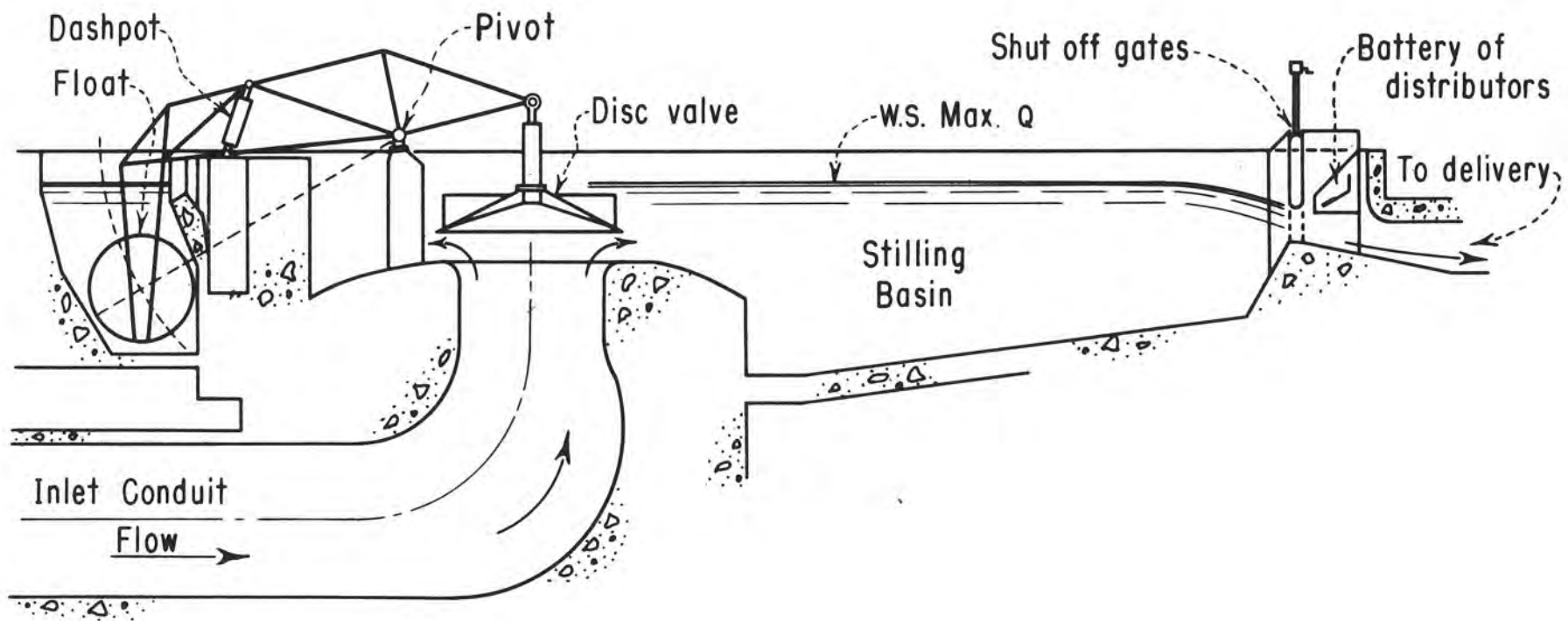


FIGURE 18-DISC VALVE CONSTANT LEVEL REGULATOR



Figure 19. Twelve-inch Metergate

H-835-1



Figure 20. Figure 20. Constant Head Orifice Turnout

H-1292-1



Figure 21. Parshall Measuring Flume



Figure 22. Cipolletti Weir

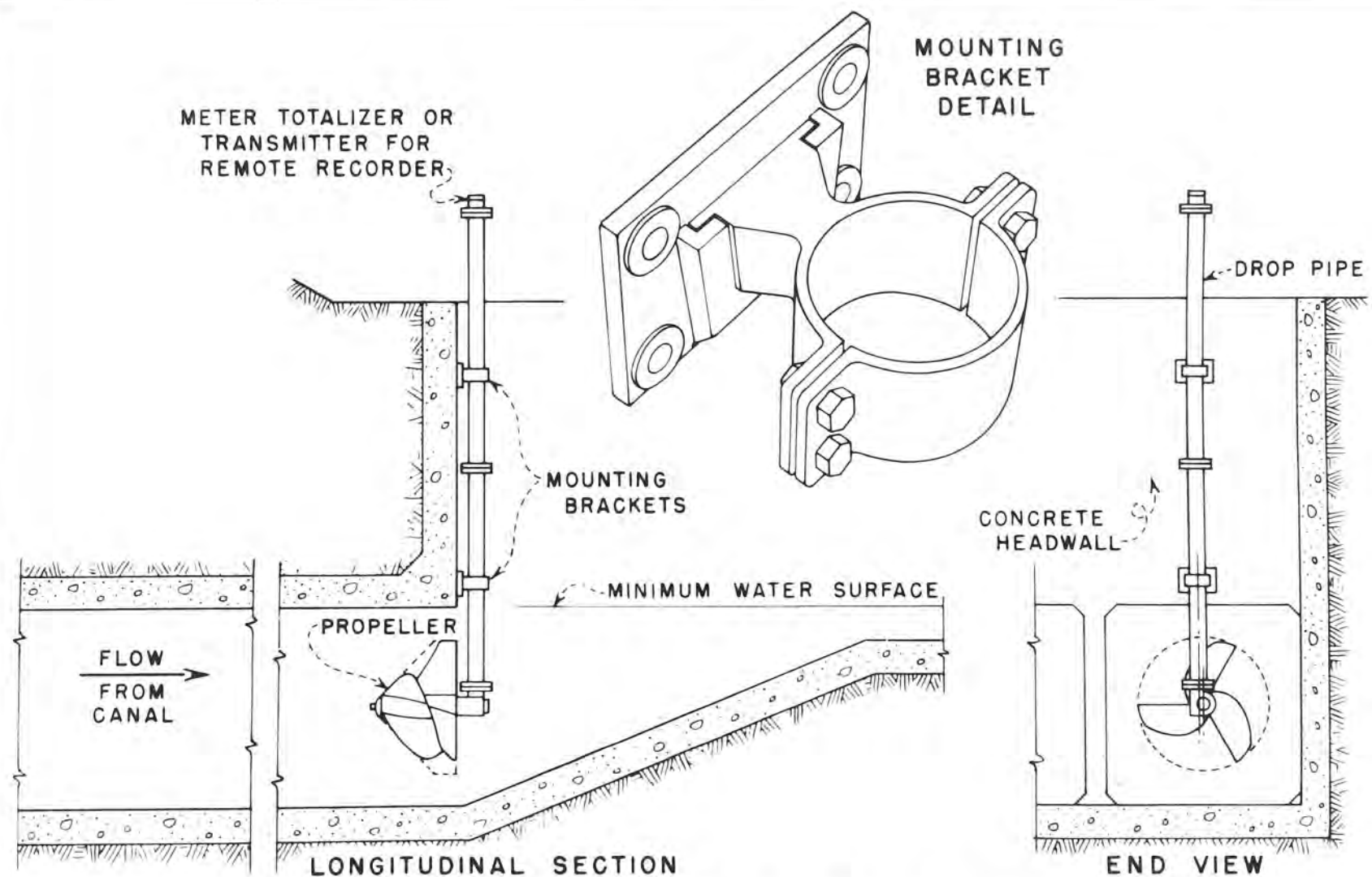


FIG.23. OPEN-FLOW METER ON FARM TURNOUT