REFERENCE MANUAL

MEASUREMENT OF IRRIGATION AND STORM WATER

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(REVISED)

SALT RIVER PROJECT

MEASUREMENT OF IRRIGATION AND STORM WATER

PREPARED BY
JIM MC DADE
HYDROLOGY
WATER RESOURCES & SERVICES
SALT RIVER PROJECT
PHOENIX, AZ.

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SECTION I

F O R E W O R D

It is the intent of this manual to discuss procedures which, if applied by those involved in water measurements, can promote the rapid and accurate measurement of deliveries to our shareholders, and accurately estimate storm and flood waters.

In order to accomplish this purpose, it is necessary to understand the basic principles of water measurement, the measuring instruments available, and the structures through which the water is to be measured.

The physical characteristics of the Salt River Project irrigation delivery system are undergoing a change as a result of urbanization. Urbanization means, generally, more pipelines, less open laterals, and more submerged structures, some even under traffic intersections.

Accompanying this change in conditions is a change in the methods of measuring deliveries. Within the past twenty years, three new instruments for the measurement of irrigation deliveries have been devised. Within the next few years, as conditions continue to change, other new instruments will probably come into being. As these events occur, this manual will be revised to meet these changes.

I N T R O D U C T I O N

The early Greeks recognized the influence of velocity. Hero of Alexandria who was born in 150 B.C. wrote in a manuscript known as "Dioptra":

> "Given a spring to determine its flow, that is, the quantity of water which it delivers....It is to be noted that in order to know how much water the spring supplies, it does not suffice to find the area of the cross section of the flow, which in this case we say is 12 square digits. It is necessary also to find the speed of flow, for the swifter is the flow, the more water the spring supplies, and the slower it is, the less."

The Romans did not recognize velocity in water measurement. They measured open channel flow by cross-sectional area only and couldn't understand why measurements taken at different places along an aqueduct varied.

The use of weirs then is not a recent invention. They have been in use for centuries. Leonard De Vinci in 1500 was chief engineer to Cesare Borgia, supervising construction of canals and waterworks in Middle Italy. It was here that he left drawings of contracted weirs. These drawings showed the contraction of the nappe, also the drawdown in the channel of approach above the crest.

B A S I C F O R M U L A

The basic formula for determining the quantity of flow of a liquid, whether in open channel or pipeline or through an orifice, is:

$$Q = A V$$

$$Q = A \times V$$

This means the QUANTITY, or rate of flow, or discharge is equal to the cross-sectional AREA of the flowing stream multiplied by the average VELOCITY of that stream.

It is upon this basic formula that all our measuring devices are based.

This formula must be expanded by the application of a coefficient (C) to account for the contraction which is caused by the shape of the area of the weir, or orifice. In many cases an additional coefficient is needed to account for the behavior of the Velocity.

$$Q = C A C V$$

These coefficients may be combined for simplification so that the formula becomes:

$$Q = C_1 A \times C_2 V$$

$$C_1 \times C_2 = C_3$$

$$Q = C_3 A V$$

$$Q = C A V$$

The value of these coefficients sometimes may be calculated, but many times must be established by experimentation.

All discharge or rate of flow, must be expressed in units of volume per interval of time.

Examples:

		Volume	Interval of time
Miner's Inch (1/40 cfs)	M.I.	1/40 cubic foot	second
Gallons per minute	GPM	Gallon	minute
Cubic foot per second	CFS	Cubic Foot	second
Million Gallons per day	MGD	Million Gallons	day

D E F I N I T I O N S

1. Discharge - (rate of flow) - the volume of water that passes a particular reference section in a unit of time.

2. Units of Discharge:

   A. Miner's Inch - a unit of measurement relating to flowing water, the value of which is fixed by statute of the State of Arizona as being 1/40th part of 1 cubic foot per second. (The value of a Miner's Inch varies with different states, each state fixing the value thereof.)

   B. Cubic Foot per Second - (cfs, second foot, cu-sec) - a unit of measurement relating to flowing water, which is a volume of 1 cubic foot of water passing a particular point in an interval of 1 second. One cubic foot per second is equal to 40 miner's inches.

   C. Gallons per Minute - (GPM) - a unit of measurement relating to flowing water, which is a volume of one gallon of water passing a particular point in an interval of one minute.

   D. Millions of Gallons per Day - (MGD) - a unit of measurement relating to flowing water, which is a volume of one million gallons of water passing a particular point in an interval of 24 hours.

3. Units of Volume:

   A. Acre foot - the quantity of water required to cover one acre of land to a depth of one foot (43,560 cubic feet). (A square plot of ground comprising one acre would measure 208.71 feet on each side.)

4. Head - the water elevation above a specified level. This is expressed in linear measure (when used in this manual, this will be the definition intended).

5. Head of Water - a rate of flow - i.e., the user requested a 50 MI head. (When this definition is intended in this manual, the word "delivery" will be used.)

6. Hydraulic Structure - any device placed in a water channel for purposes of diversion, impounding, releasing, measuring, or otherwise controlling the flow of water.

   A. Weir - an overflow structure built across an open channel for the purpose of measuring water flow.

   B. Open Lateral Delivery Structure - a hydraulic structure placed in an open ditch or lateral for the purpose of diverting water from that ditch to an additional ditch or ditches.

   C. Pipeline Delivery Structure - a hydraulic structure placed in a lateral pipeline for the purpose of diverting water from that pipeline to additional pipelines or open ditches.

   D. Orifice - "an opening placed in a wall or channel or vessel carrying or holding water, so that the opening lies completely below the upstream surface of the water. The wall may have any angular position from horizontal to vertical, the opening may have any geometric shape, the water may discharge into air or into water, and the issuing stream may or may not be contracted." 1/

1/ Water Measurment Manual, USBR, 1953, p. 71.

SECTION II

TYPES OF MEASURING TOOLS

There are numerous devices available for the field measurement of irrigation water. Most available have disadvantages; they are too expensive, too time consuming, too heavy, too cumbersome, or they require excessive use of mathematics, or cover too large an area of land, etc. Every tool now in use by Water Operations, Hydrology and Groundwater personnel to determine the quantity of flowing liquids, measures the velocity of that liquid either directly or indirectly.

The five devices or tools used by our field forces to measure irrigation deliveries were developed on this project by Project personnel to meet our specific requirements.

TYPES OF MEASURING TOOLS AVAILABLE FOR GENERAL FIELD USE

CLAUSEN WEIR RULE:

The measurement of water in open channels over weirs is accomplished by the use of the Clausen Weir Rule. This device was designed and developed in 1921 by I.M. Clausen, Superintendent of Irrigation SRVWUA and R.A. Pierce, Chief Hydrographer SRVWUA. The first Rule was a single stick 1½" wide, 3/4" thick and 5' long. It was placed in general use in 1923 and measured flows over free-flowing weirs only. Clausen and Pierce continued their studies of weir measurements, and in 1929 placed the "Double Stick" into use. This Rule measured both free-flowing and submerged weirs.

Slight modifications have been made on the Rule since 1929 so that at this time it bears the name Clausen Improved Weir Rule. Due to the infrequency with which submerged measurements are made, the complete Clausen Improved Weir Rule is not distributed to all concerned. The Piezometer tube has been removed from most of the Rules now in use, however, one complete Rule is available at each Field Office for use on submerged weirs. The Clausen Improved Weir Rule is described by the USBR as "a graduated extensible rod equipped with a piezometer on the back. Measurements are made with the rod held vertically on the crest of the weir. The rod is so designed and calibrated as to include the effect of velocity of approach for free-flowing weirs. The discharge over submerged weirs is observed with the use of the extension feature and the piezometer in two operations. The gage is generally found to be more accurate for free-flowing weirs than for submerged weirs.[1/]
The Clausen Weir Rule combines the approach velocity and the actual head (depth of water) measurement to calculate the quantity (Q) in Miner's Inches. Since the cross-sectional area (A) of the water stream flowing over the weir (nappe) is equal to the width times the depth, then Q = (w x d) x V. The scale on the weir rule combines the depth measurement with the velocity measurement and this product need only be multiplied by the width of the weir to give the quantity or discharge.

1/ Water Measurement Manual - USBR, 1953.

The velocity is measured indirectly by calibrating the rise of water against the face of the rule. This calibration scale adds the velocity of approach in the channel above the weir to the normal velocity over a weir in a still pool.

CLAUSEN IMPROVED WEIR RULE

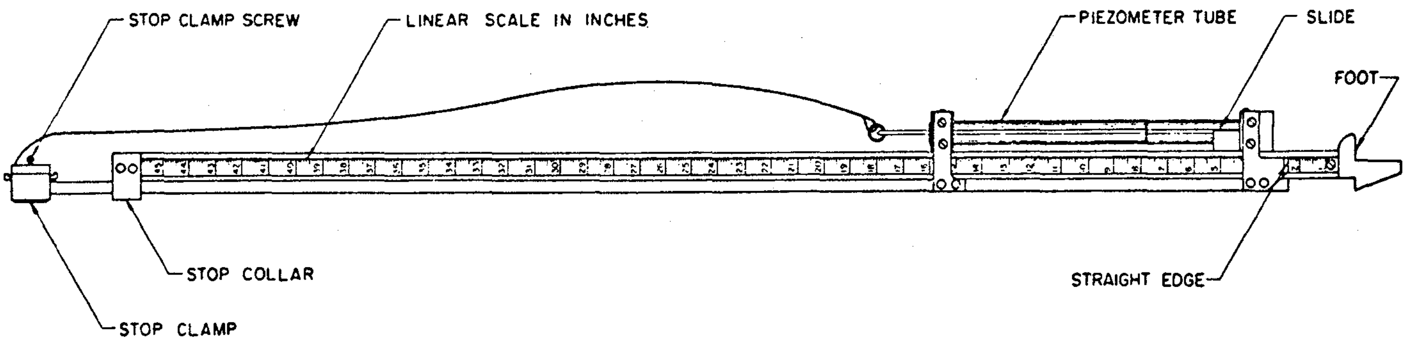


FIGURE 1 - SIDE VIEW

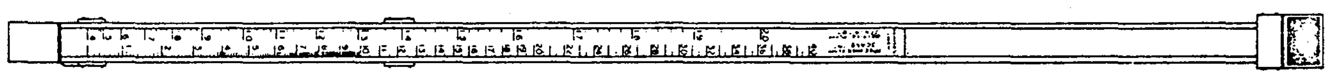


FIGURE 2 - SIDE VIEW

CALIPERS:

It has been proven that discharge can be accurately determined through an orifice if certain data are known. These data are: the area of the orifice, the height of the water in front of the orifice, and the height of the water behind the orifice. In our structures the opening under the gate is a rectangular orifice; therefore, the orifice flow formula may be used to measure water through this rectangular opening.

The Calipers are used to obtain some of the necessary data for an accurate measurement; namely, gate opening and gate width--these give the orifice area (A). They can also be used to obtain the upstream head (H_1), and in open laterals, the downstream head (H_2).

In studies of open lateral structures in the summer of 1958, W.D. Chapman, Jr. of the Hydrology Division devised the Calipers and they have found ready acceptance by the Association's field forces. They are very simple to operate and are quite accurate.

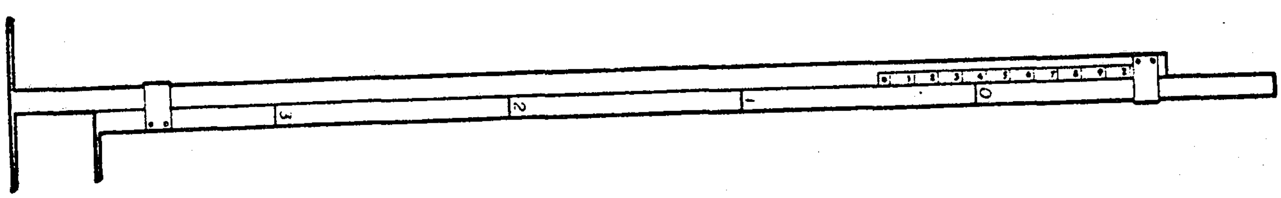


Figure 3 - Calipers

PROBE:

In 1959 a need arose, as a result of urbanization, to be able to obtain a downstream water elevation in a pipeline structure. The Calipers could be used to obtain the upstream water elevation and the gate opening. D.W. Nichols of the Association's Drafting Section designed the Probe to be used in conjunction with an access tube, cast in the wall of the pipeline structure immediately downstream of the gate. When all hydraulic features of the structure are correct, the Probe is an accurate, fairly simple device to operate. Plans are in progress to improve the features of those "problem structures" so measurement data may be obtained.

Since the initial field application of the probe, in 1959, it has been redesigned and modified to the presently used "beeper" type.

Previously, the Probe was a self-contained electric circuit. The circuit was closed when the two points made contact with the water. This closure was indicated by the milliamp meter. The Probe had only one "point"; the other "point" was an aligator clamp which was fastened to the gate stem. When the point touches the water surface, the circuit is completed and registered by the meter. Aerated water is not a good enough conductor of electricity to cause the meter to register full contact. The Probe, with practice, can be used to penetrate back splash and locate true water level in many "problem structures."

Today, the modern probe is of the beeper type. In the past a milliamp meter registered a reading when the downstream elevation of the water surface came in contact with the probe end. The accuracy of the measurement was dependent upon the operator's experience and the reading of the gage which sometimes was not always in plain sight. With the new "beeper" type probe, the milliamp meter is replaced with a little box which emits an audible "beep" when the tip of the probe comes in contact with the downstream water elevation. This is much more efficient, because no light conditions or sight function is necessary to obtain the point of contact.

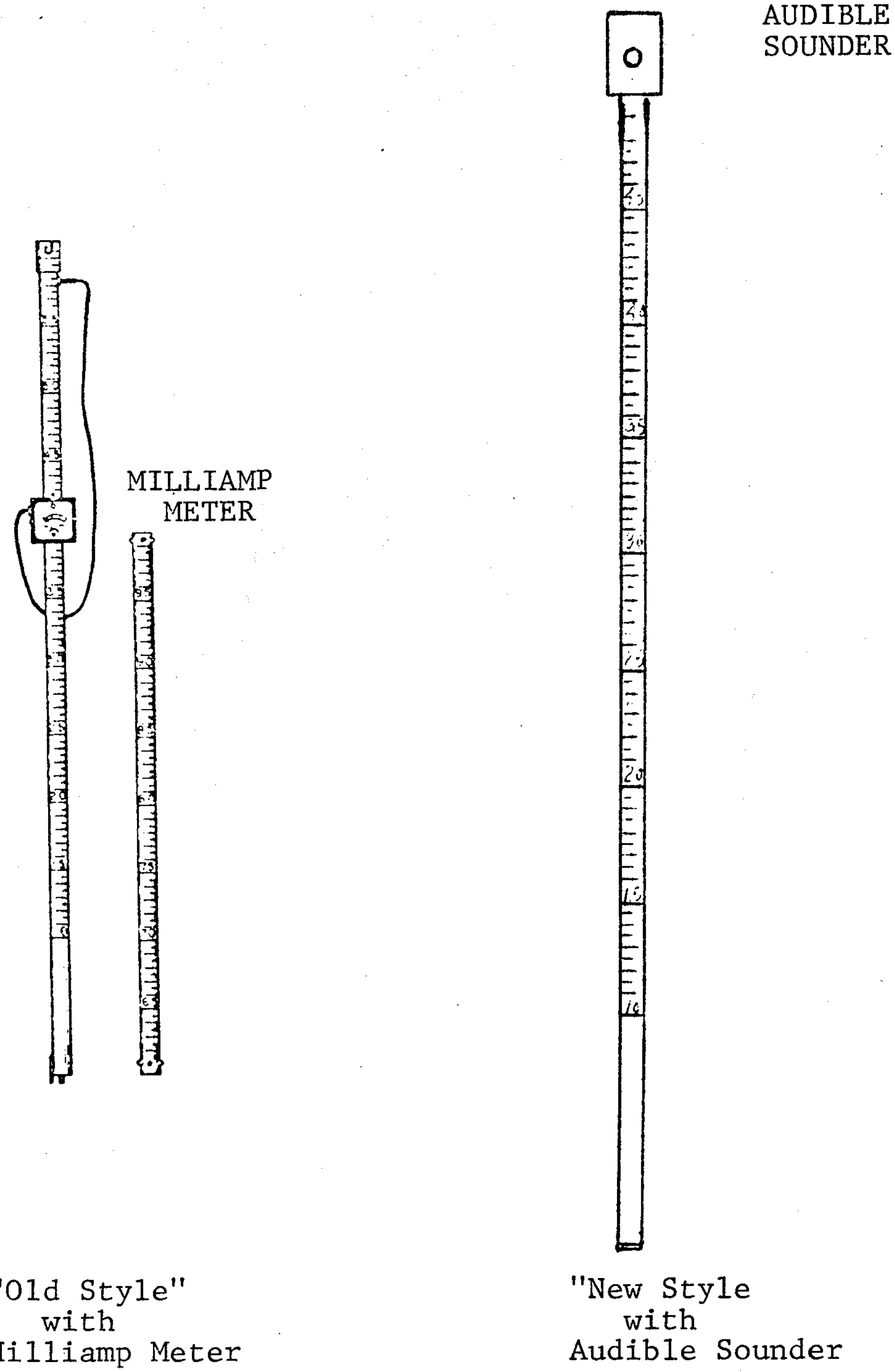


Figure 4 Probes

SOUNDER:

In 1964 the need was recognized for an instrument which would overcome the limitations of the Probe. J.M. Acuff of the Groundwater Division modified the Electric Well Sounder for use as an irrigation water measuring device. This Sounder had been in use by the Groundwater Division for a number of years, to determine the static water level in irrigation wells.

The Calipers, Probe, and Sounder are devices to obtain water level data for use with the "Calibration Tables for Irrigation Delivery Gates" to determine the quantity of flow.

The Sounder works on the same electrical principle as the Probe. This will be noted by comparing Figure A with Figure B on page 15. The only difference between the two instruments is that the Probe has a rigid body whereas the Sounder is a flexible line. The more recent modifications of the Probe have improved its adaptability for field use, while the Sounder is still in the experimental stage.

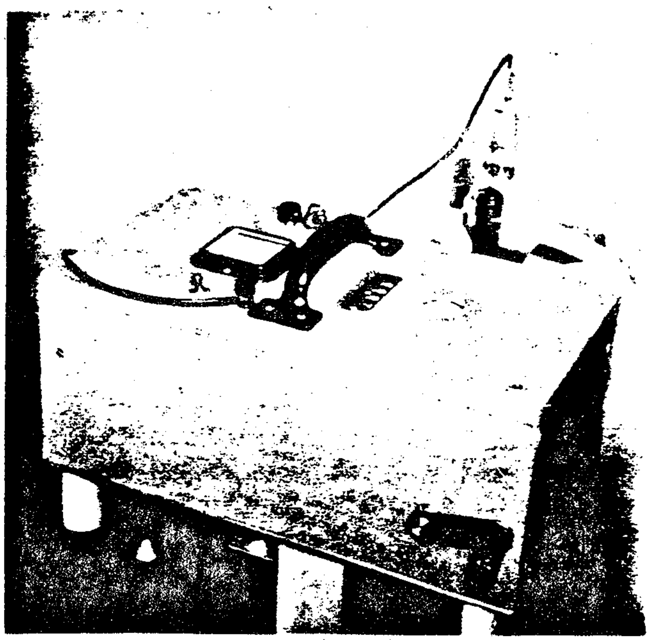


Figure 5 - Sounder

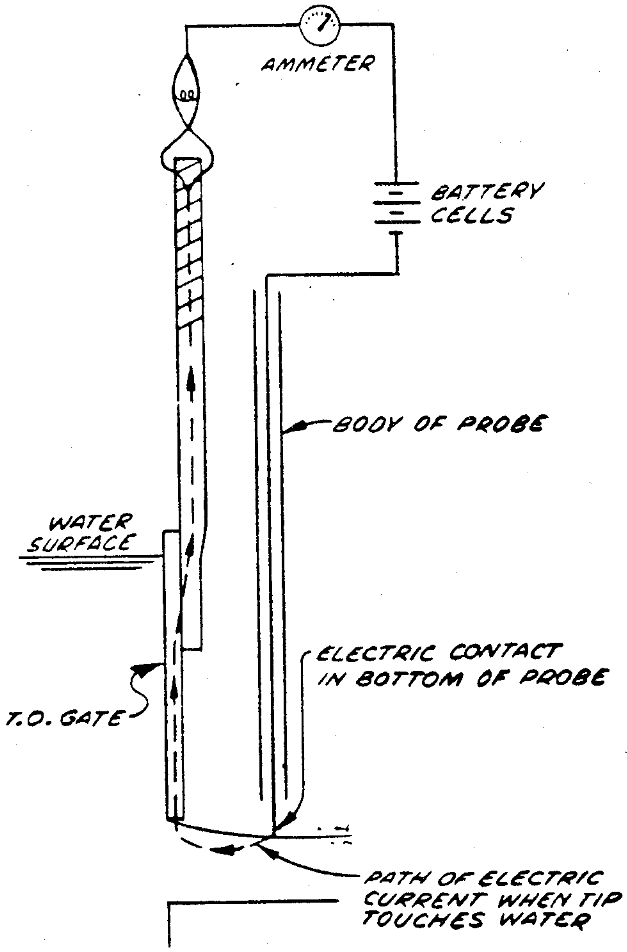


Fig. A Probe Circuit

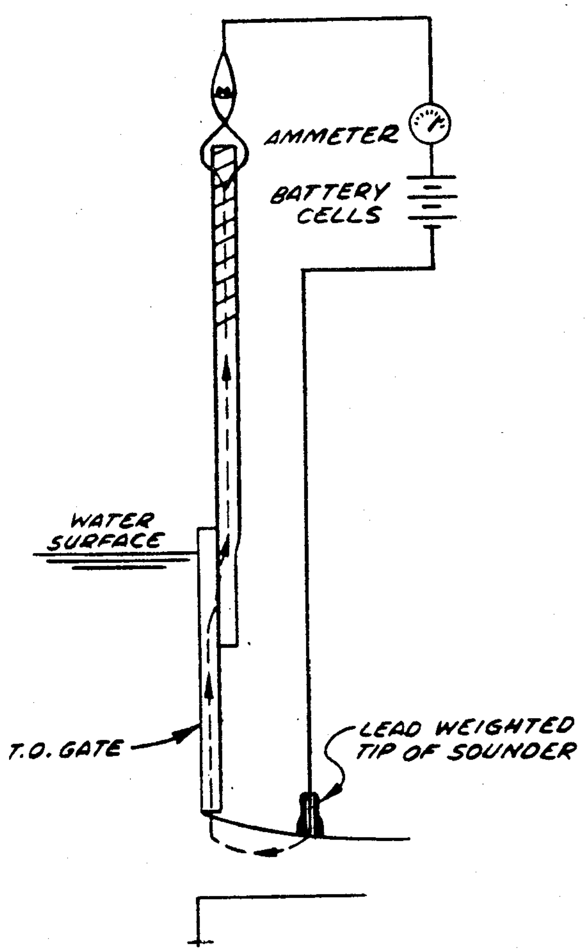


Fig. B Sounder Circuit

SUMMARY:

In summary, since the cross-sectional area of a flowing stream multiplied by the average velocity of the stream equals the discharge, or Quantity (Q), each of the described tools is designed to give us one of these factors. The information obtained is used with tables, or sometimes nomographs, to determine the discharge for the measured conditions. These tables and nomographs have the proper coefficients "built in" so that no further computation is necessary.

SECTION III

WEIRS AND WEIR FLOW

There are five (5) basic types of weirs in use in the irrigated West. They are:

The Contracted Rectangular Weir
The Suppressed Rectangular Weir
The Cipolletti Weir
The V-Notch Weir
The Broad-Crested Weir

Each of these types of weirs may further be subdivided:

Free-Flowing or Submerged
Sharp-Crested or Flat-Crested

For installation in the Project, the flat-crested, effectively suppressed rectangular weir and the sharp-crested Cipollette weir are standard. Both these types of weirs have similar discharge coefficients for computing water flow, and it was upon these weirs that the Clausen Weir Rule was developed. However, the broad-crested weir has now been field-tested and has proven itself to the point of becoming a SRVWUA standard.

A contracted and suppressed weir differ in that the crest length on a suppressed weir is equal to the channel width, and on a contracted weir, the crest length is less than the channel width.

A contracted weir may be converted to an effectively suppressed weir by the addition of a 2 x 2 board placed in a vertical position approximately 2" from the notch on each side of the upstream bulkhead. This causes the falling sheet of water to fill the weir notch, and makes the contracted weir act as a suppressed weir.

"In the case of a free-flowing weir, the water fall over the weir is free; i.e., not impeded by the water below the weir, and the downstream water elevation is lower than the weir crest. In the case of a submerged weir, the downstream water elevation is higher than the weir crest."[2]

There should be free access for air under the falling water column in the free-flowing weir, otherwise the hydraulic characteristics are changed and if measured with the Clausen Weir Rule will tend to yield a discharge which is lower than the actual quantity of water being discharged.

One method of determining if the weir is free-flowing or submerged is to attempt to obtain a piezometer reading on the back of the Weir Rule. If the water will not rise in the piezometer tube, consider the weir free-flowing.

The broad-crested weir is an intermediate case in which the water flow is not straight or parallel to the sides of the ditch, and one in which boundary resistance or drag causes the stream flow to be straight. Here, accelerative and viscous effects must be considered in order to determine the amount of water flowing. Therefore, the Clausen Weir Rule is not used; instead, a permanently installed, easily readable gage is employed to assure measurement accuracy.

CONTRACTED - SUPPRESSED

These two terms refer to the shape of the overfall of the weir. This nappe (falling sheet of water) may contract, or spring away from the sides of the weir and become narrower than the weir crest. In such cases the weir is said to be contracted.

2/ Reference Manual of Association Operations SRVWUA, November, 1962.

If the nappe falls the same width as the weir crest, the contraction has been suppressed. The weir is then referred to as a suppressed weir.

CIPOLLETTI WEIR:

Cipollette was an Italian Hydraulic Engineer. His weir was designed so that the amount of contraction could be compensated for by increasing the width progressively with the depth of water over the weir. For this reason the formula for the Cipolletti Weir and the Suppressed Rectangular Weir are the same and may be measured with a high degree of accuracy with the Clausen Weir Rule.

VEE-NOTCH WEIR:

The V-Notch Weir is used primarily for determining accurately the quantity of small flows. These flows may be as small as 2 MI. Depending on the size of the weir, V-Notch Weirs are accurate up to 175 MI.

BROAD-CRESTED WEIR:

If the crest of a weir is sufficiently broad to prevent the nappe from springing free at the upstream edge, the weir is classified as broad-crested.

EFFECTIVELY SUPPRESSED RECTANGULAR WEIR:

The Clausen Weir Rule was designed to measure water flow over a Cipolletti and Suppressed Weir. The suppressed condition existed in most of the check structures. To make the Rule usuable on all weirs in the Project, the end contractions of the Rectangular Weirs were effectively suppressed.

As water particles approach the weir opening in converging paths from all directions, and since it is not possible for the water particles to change their directions abruptly, they travel in curvilinear paths, causing the nappe to contract. The effectively suppressed weir prevents the approach of the water from the sides, and thus restricts or suppresses the contraction, hence the name Effectively Suppressed Weir.

WEIR FLOW:

Weirs of all types are designed to solve the equation Q = AV. Since velocity is not a tangible thing and cannot be seen or grasped, it cannot be measured directly as we would measure the length of a board or the depth of a liquid above some fixed level.

In the case of water flowing over an obstruction in its path, such as a weir, the velocity over the obstruction is proportional to the depth of water above the obstruction, therefore, for every depth of water, there is one corresponding velocity.

Because of this fact, when we measure the depth of water flowing over a weir, we are indirectly measuring the velocity. This is why all discharge equations for weirs contain an expression of head instead of velocity.

The standard weir equation can be derived from the standard discharge formula by substituting other pertinent relationships.

$Q = AV$ and $A = LH$

where H = head over crest of weir

L = length of weir crest

A = area of water flowing over weir

Velocity can be related to the Head (H) by the expression

$$V = \sqrt{2gH}$$

This expression in effect says that the velocity of a liquid is equal to the square root of twice the effect of gravity times the elevation or head causing that flow. Another way of writing square root is $(2gH)^{\frac{1}{2}}$.

These factors can now be introduced into the standard discharge formula so that:

$$Q = A \times V$$

$$Q = (LH) \times (2gH)^{\frac{1}{2}}$$

By combining like terms and including a coefficient, this can be rewritten as:

$$Q = C_c \times (2g)^{\frac{1}{2}} \times L \times H^{3/2}$$

Coefficients are necessary to account for the peculiar physical characteristics created by each type of weir. By combining the coefficient of contraction, C_c, for suppressed and Cipollette weirs with $(2g)^{\frac{1}{2}}$, the weir equation becomes:

$$Q = 3.33\ L\ H^{3/2}$$

The Clausen Weir Rule combines 2 of these factors in the reading on Scale A on the face of the Rule, (3.33 and $H^{3/2}$). This leaves L or length to be measured.

For the Clausen Weir Rule, Quantity in Miner's Inches equals the reading on Scale A multiplied by the length of the weir in inches.

The broad-crested weirs used in the Project don't require a standard formula, but instead use a "mathematical iteration process," a computer program developed by a Hydraulic Engineer, Dr. John Replogle of the U.S. Water Conservation Laboratory.

The following conditions are the physical specifications for the construction and maintenance of a proper, accurate, measuring weir. If these specifications are not met, or do not exist at the measuring site, deliveries will be inaccurate.

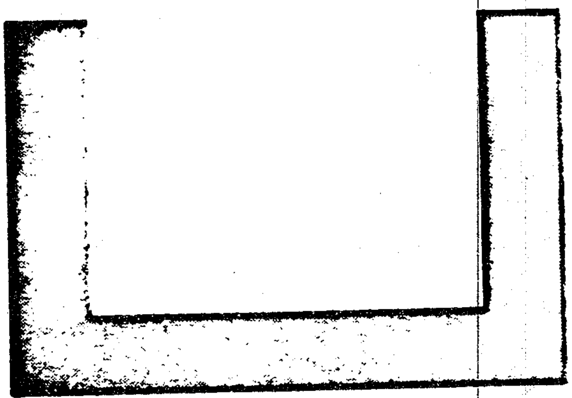
1. The upstream face of the bulkhead should be smooth and in a vertical plane perpendicular to the direction of flow.
2. The entire crest should be level, both side edges should be plumb, and the upstream corners of the crest and sides should be straight, square, and smooth.
3. The distance from the crest to the bottom of the approach channel should not be less than twice the depth of water above the crest and in no case less than 1 foot.
4. The overflow sheet (nappe) should spring free from the upstream edge of the crest and flow straight along the sides.
5. Air should circulate freely both under and on the sides of the nappe.

Summary

The structures for measuring and controlling the flow of water inside the Project's service area are the heart of the delivery system.

The user is charged and billed on the basis of the accurate operation of and measurement through these structures. As the water supply declines, more and more emphasis must be put on the accurate operation of these measuring and control points.

With the full understanding of the capabilities and limitations of the measuring devices and measuring stations, the Field Operations personnel are better equipped to give fast, accurate service to the users. This is the aim, and purpose, of the Association.



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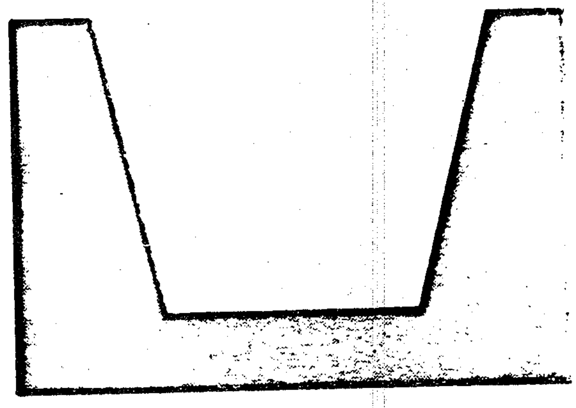
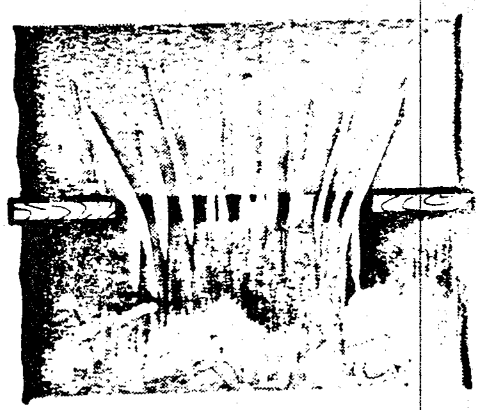


CIPPOLETTI



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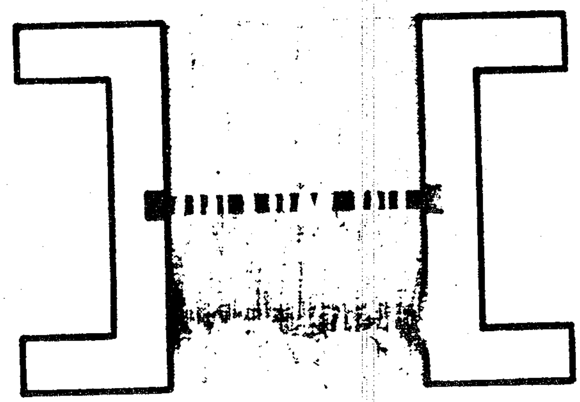

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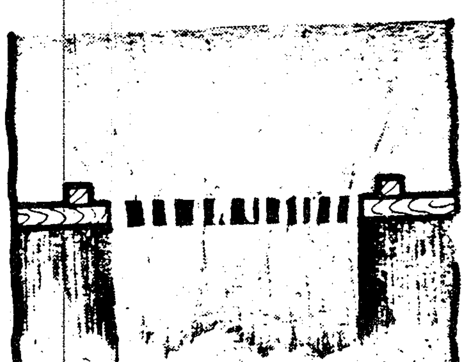
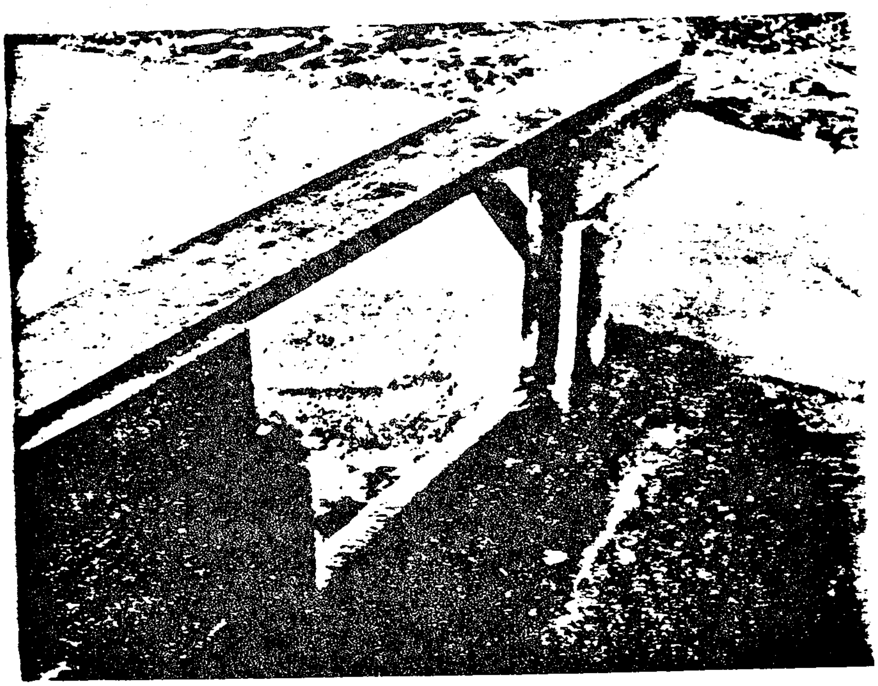


EFFECTIVELY SUPPRESSED

Figure 6

CIPPOLETTI WEIR



STANDARD RECTANGULAR WEIR - EFFECTIVELY SUPPRESSED

FIGURE 7 - WEIRS

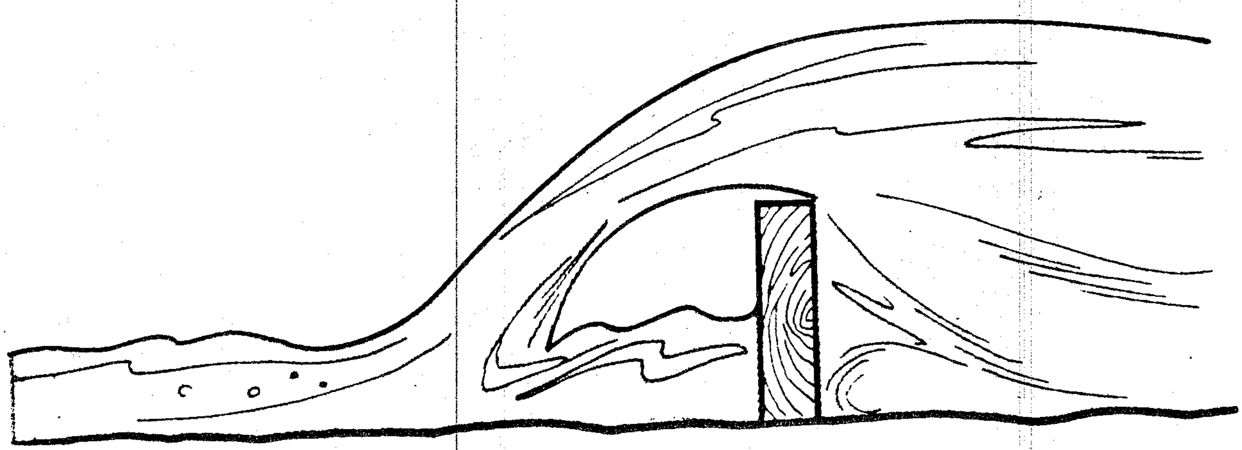


FIGURE 8 - FREE FLOWING WEIR

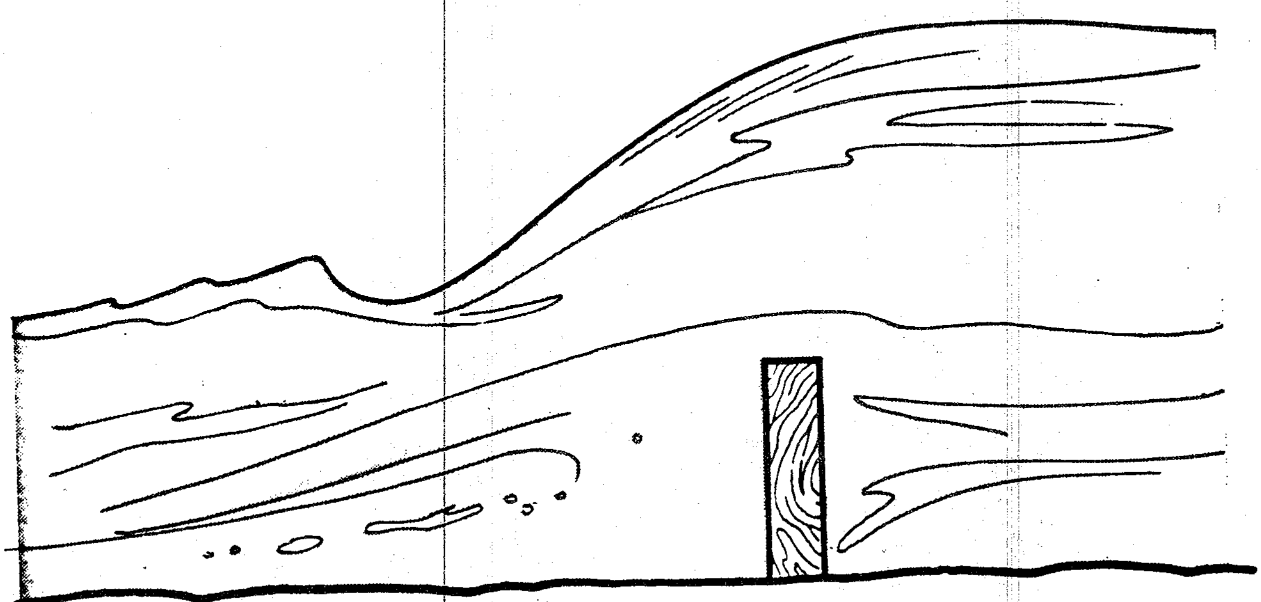


FIGURE 9—SUBMERGED WEIR

SECTION IV

TYPES OF LATERAL STRUCTURES

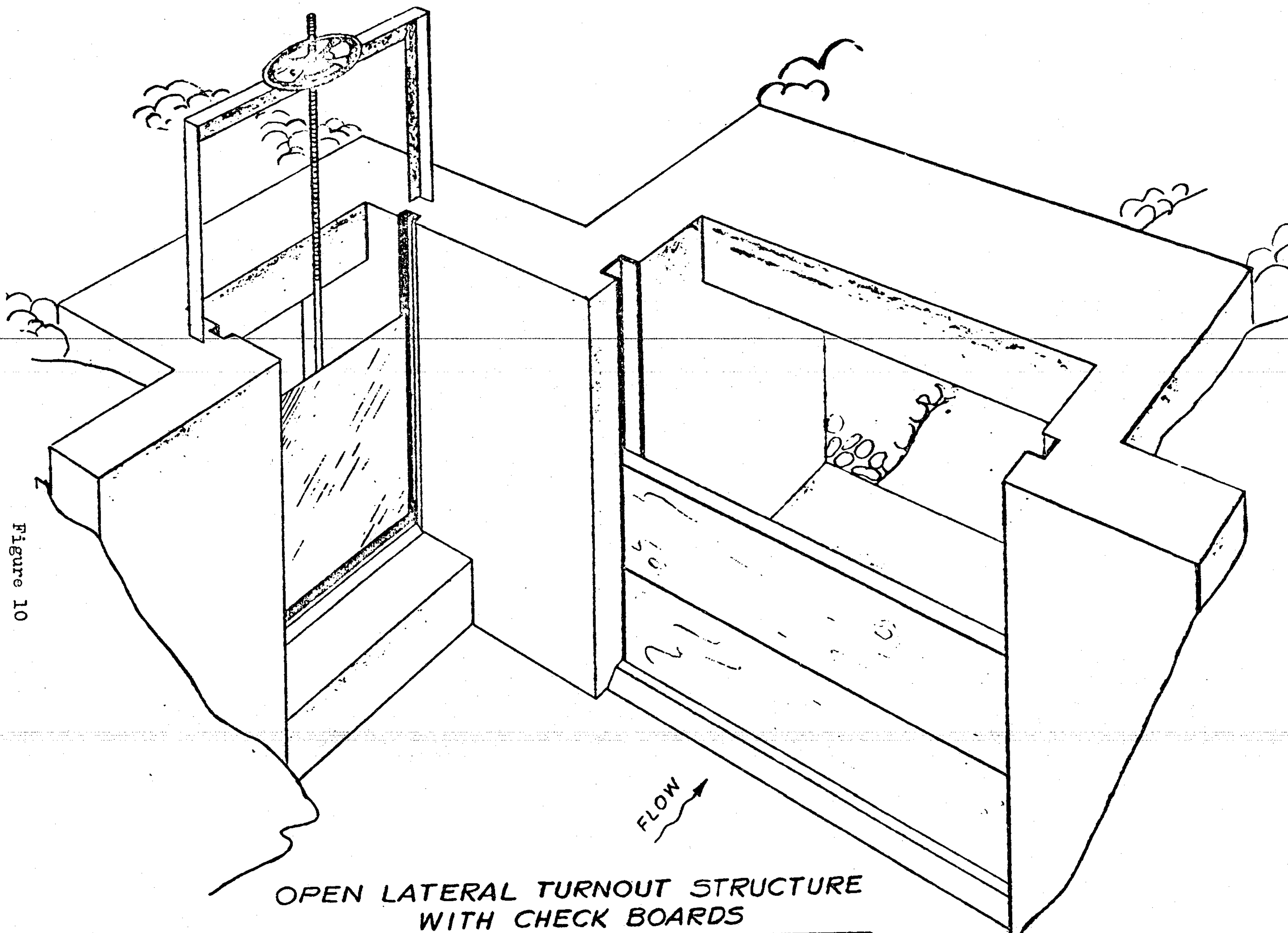
OPEN LATERAL DELIVERY STRUCTURES:

Prior to 1930, practically all the lateral structures were constructed of redwood. The irrigation delivery was generally through an orifice which was adjustable by raising or lowering a gate constructed of redwood in guides also constructed of redwood. The lateral forebay was maintained by placing 2" x 6" redwood "checkboards" in guides across the main lateral. A rectangular effectively suppressed weir was placed in the delivery ditch some distance downstream from the delivery gate. In this fashion then the water being delivered could be measured over the weir and the checkboards served as a weir to measure the quantity of water flowing down the main lateral.

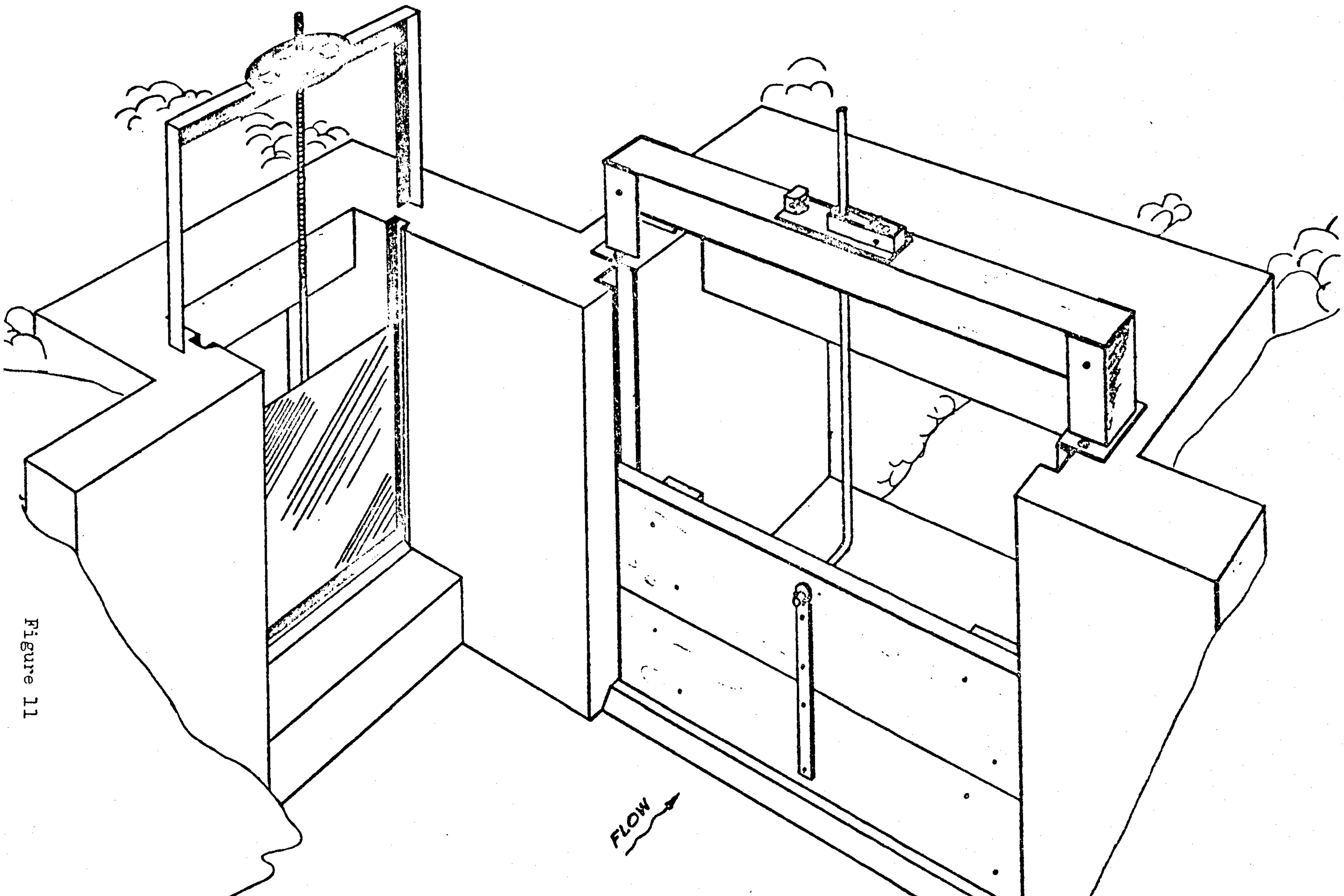
This same style of structure is in use today, the only change being in construction materials. The Open Lateral Structures are now constructed of concrete with a steel "Type 1" gate placed in a rubber guide and seated upon a rubber seat. The lateral forebay is controlled either by 2" x 6" checkboards or by a friction lift gate which is several 2" x 6" checkboards fastened together and raised or lowered by means of a level bar and a friction life handle.

In many cases these structures have been modified to accommodate a pipeline delivery instead of an open ditch delivery. These once modified structures are being remodified or replaced (as time permits" so that accurate measurements may be obtained.

Figure 10



OPEN LATERAL TURNOUT STRUCTURE
WITH CHECK BOARDS



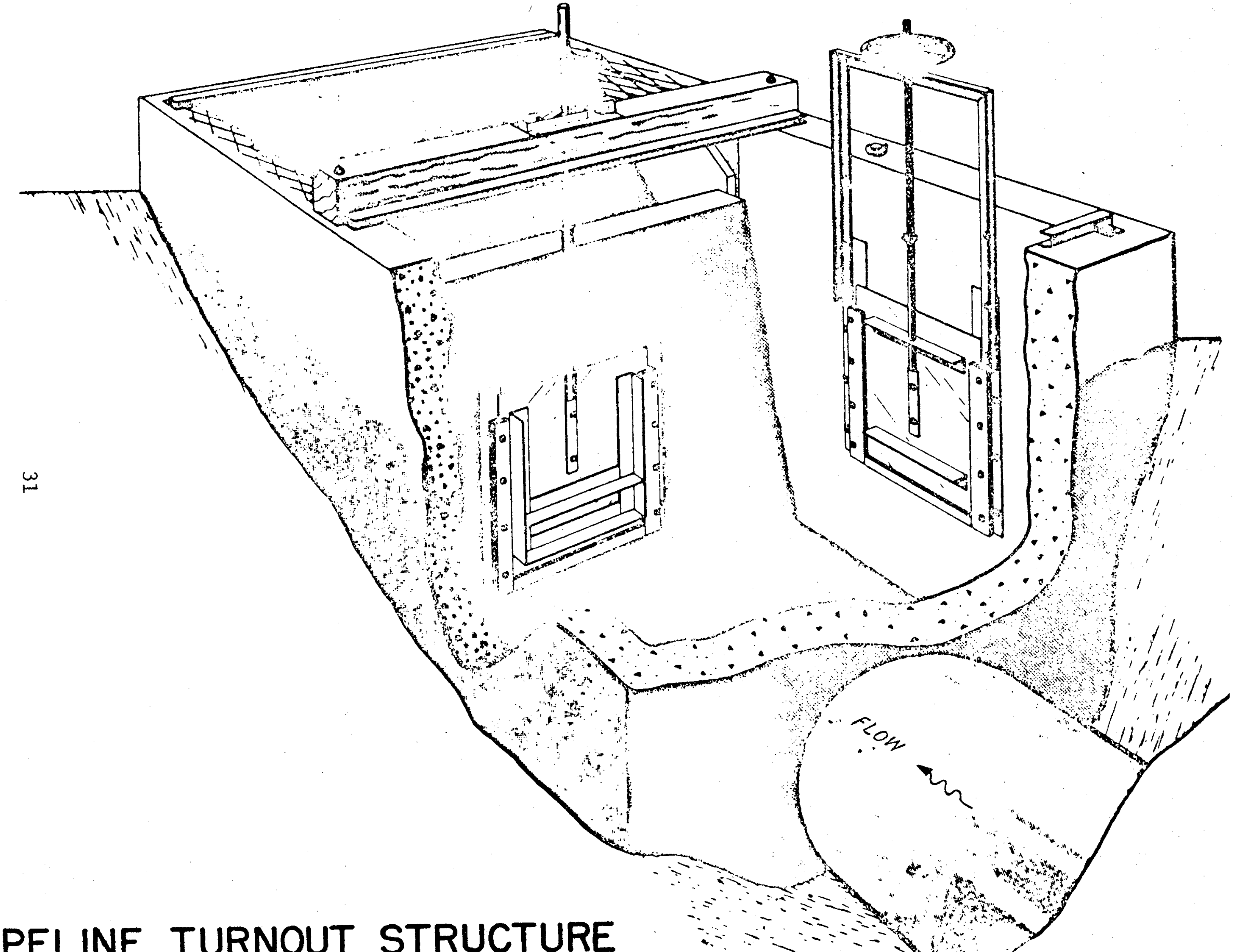
OPEN LATERAL TURNOUT STRUCTURE
WITH REDWOOD FRICTION LIFT GATE

Figure 11

PIPELINE LATERAL DELIVERY STRUCTURES:

For some time water had been measured successfully through the orifice in open lateral structures, but with the advent of the pipeline structure, it was necessary to devise some method of determining the elevation of the water downstream of the gate. The upstream head and the opening of the orifice could be determined with the calipers then in use, but not the downstream head. The probe was then designed and an access tube placed in the wall of the structure so the downstream water elevation could be determined.

The Probe operated successfully in those structures which were fully submerged. However, some which were free-flowing had a splash which registered as submergence on the Probe. This caused improper and inaccurate measurements. A transition was devised to prevent this backsplash, and on recent pipeline structures, no difficulty from this problem is found. The Sounder is very effective for use on these older structures. It records a partial reading if splash is present, but will not record full readings until "solid" water is encountered.



PIPELINE TURNOUT STRUCTURE

Figure 12

FORMULAS:

Measurement of flow through an orifice with a fixed area (A) is identical to that over a weir, but when the area of the orifice is variable or adjustable, such as our delivery gates, then the quantity cannot be merely related to a particular head. Now the quantity of flow, or discharge, will change as the gate opening is changed, even though the head may remain constant.

The mathematical reason for this difference in the two types of measuring devices can be noted by studying the formulas presented below:

Weir Formula

$$Q = C \times A \times V$$
$$= C \times (L \times H) \times (2gH)^{\frac{1}{2}}$$
$$= C\sqrt{2g} \times L \times H^{3/2} \times H^{\frac{1}{2}}$$
$$Q = C_d \times L \times H^{3/2}$$

Orifice Formula

$$Q = C \times A \times V$$
$$= C \times (L \times b) \times (2gH)^{\frac{1}{2}}$$
$$= C\sqrt{2g} \times L \times b \times H^{\frac{1}{2}}$$
$$= C_d \times L \times b \times H^{\frac{1}{2}}$$

In the earlier discussion of weir flow, the fact was pointed out that for each particular depth of water flowing over or through an obstruction, there is a definite velocity. This fact can be expressed thus:

$$V = \sqrt{2gH} \quad \text{or} \quad V = (2gH)^{\frac{1}{2}}$$

This expression is substituted for velocity in Step 2 of both formulas. The real difference in the two forms will be noted in the factors comprising the area. In the weir formula, the vertical component of the area is (H), or the head, and is identical to the head causing the velocity, therefore, these two factors can be combined as in Step 4.

In the orifice formula, the vertical component of the area is (b), the gate opening, which is independently adjustable and therefore cannot be combined with any other factor.

It was found by experimentation with actual gates in use on this Project, that the combined coefficient of discharge (C_d) varied slightly with different gate openings and heads. To compensate for this change and maintain a fixed coefficient, the exponents of the gate opening (b), and head (H), were changed slightly. The final formula for free flow and submerged gates are as shown below:

$$Q = 4.33 \times L \times b^{0.93} \times H^{0.57} \quad \text{free flow}$$

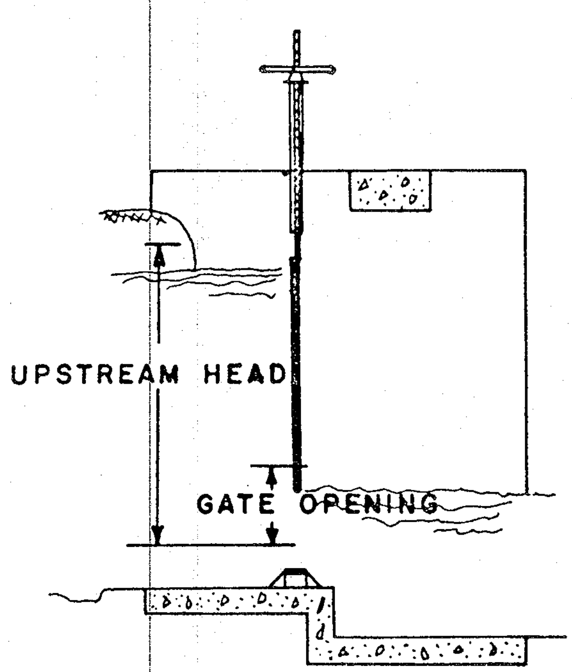
$$Q = 5.50 \times L \times b \times H^{0.52} \quad \text{submerged flow}$$

No satisfactory method is available to combine these factors for easy field computation as was done in the case of the Clausen weir rule. However, two (2) sets of calibration tables were developed, one for free flowing gates and one for submerged gates.

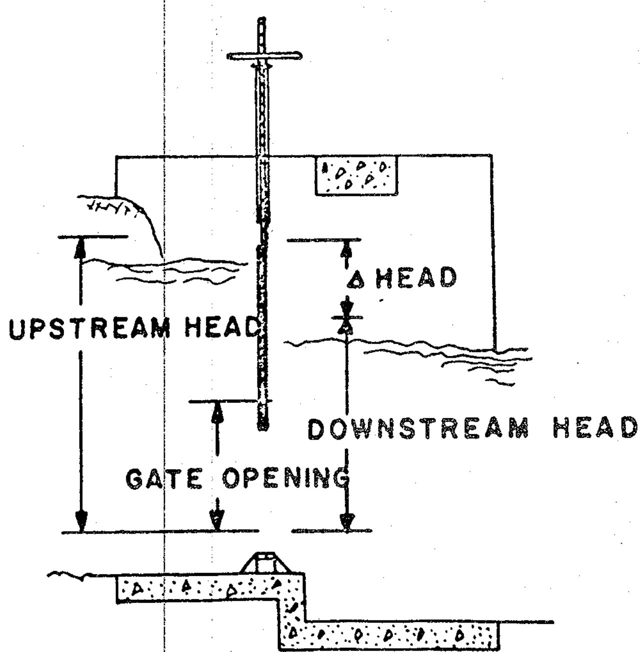
With these tables only the head value and the gate opening need be applied to the proper table to arrive at a "Q" for one foot of gate width (L).

Gate width (L) then is multiplied in the field to determine total discharge.

OPEN LATERAL STRUCTURES



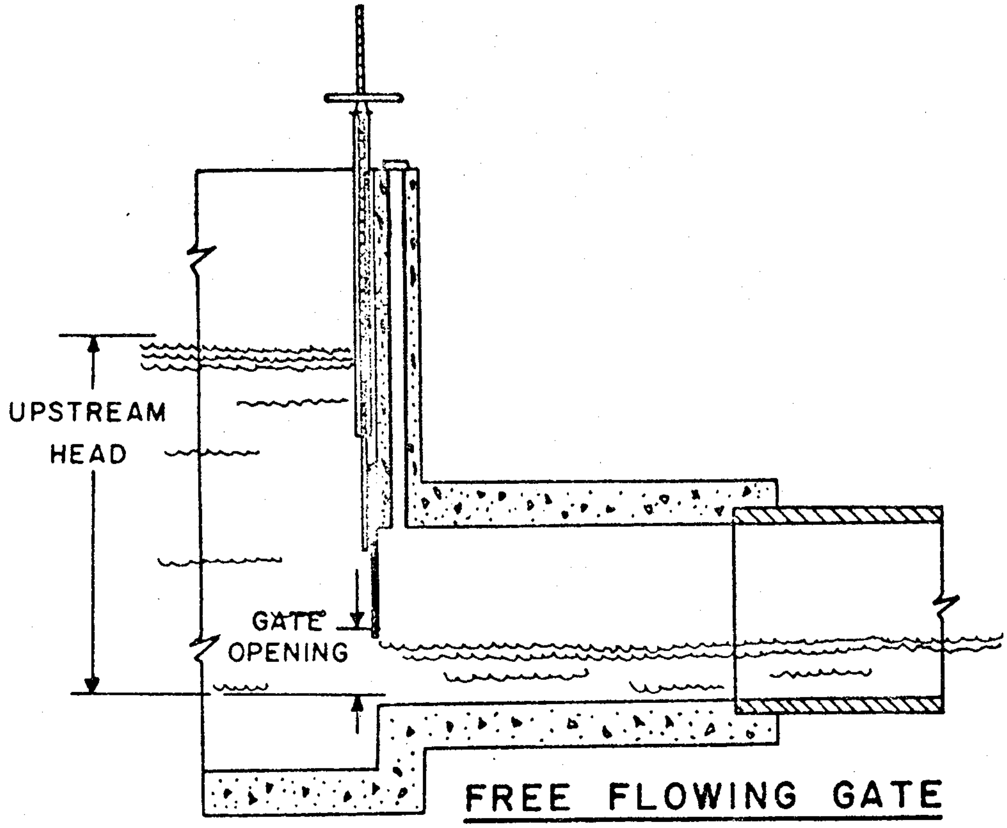
FREE FLOWING GATE



SUBMERGED GATE

Figure 13 - Open Lateral Structures

PIPELINE DELIVERY STRUCTURES



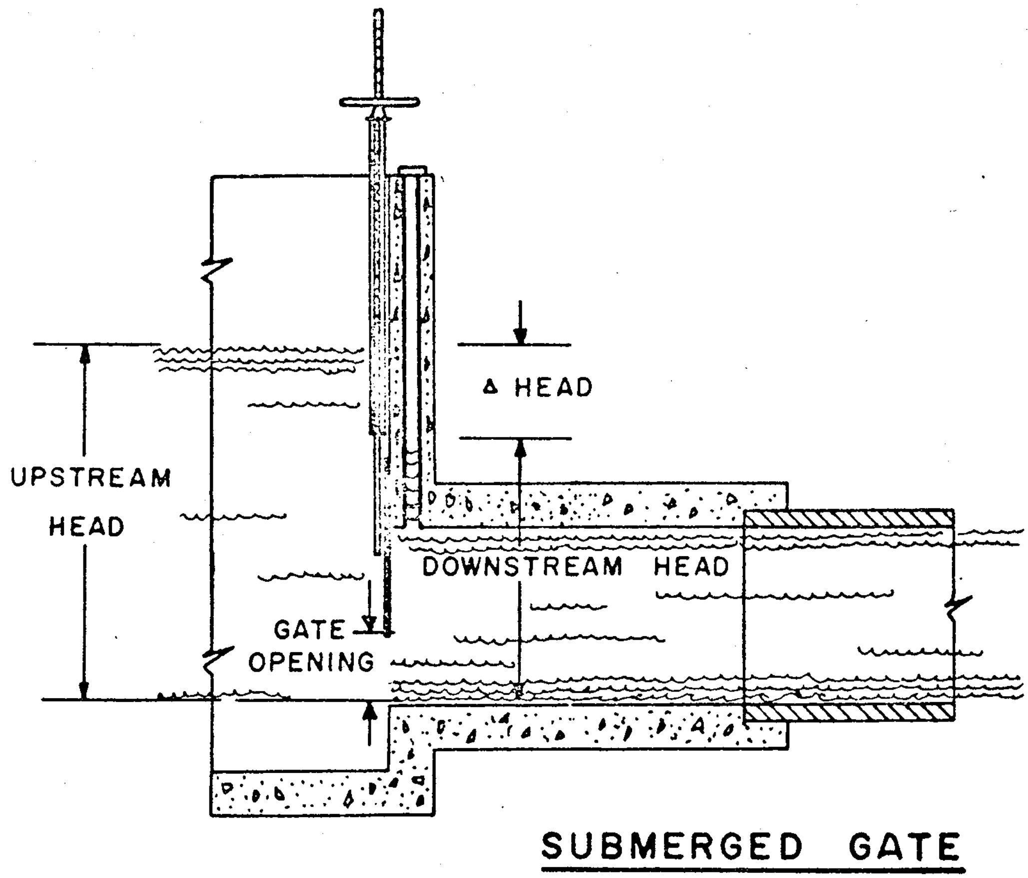


Figure 14 - Pipeline Structures

ORIFICE FLOW:

"An orifice is defined as an opening placed in a wall of a channel or vessel carrying or holding water, so that the opening lies completely below the upstream surface of the water. The wall may have any angular position from horizontal to vertical, the opening may have any geometric shape, the water may discharge into air or into water, and the issuing stream may or may not be contracted."1/

In our structures, the opening under the gate is an orifice. The width of this orifice remains constant, and the height of the orifice is adjustable. This height is called the Gate Opening. The orifice width is known as the Gate Width. The borrom of the orifice is the Gate Seat and the top is the Lip of the Gate.

Orifice flow may be contracted or suppressed, free or submerged. If the lip of the gate is submerged in water on the downstream side, the orifice is submerged. If the downstream water surface is level with or below the lip of the gate, the flow is free. The quantity of discharge will vary with these various flows and the type of flow should be considered in the measurement of the discharge.

The Calibration Tables for Irrigation Delivery Gates were determined for the contracted orifice so no modification is necessary other than selection of the appropriate table -- free-flowing or submerged.

1/ Water Measurement Manual, USBR, 1953.

CONDITIONS REQUIRED FOR MAXIMUM ACCURACY OF MEASUREMENT IN GATE DISCHARGE:

To accurately measure the water which flows through delivery gates used by the Association, the gate structure must conform to certain standards. The upstream and downstream water conditions adjacent to the gate must also be in proper order. Some of the major factors which influence the accuracy of measurement are listed below:

1. The condition of flow; i.e., FREE-FLOW or SUBMERGED, must be determined.
   This is a fairly obvious observation and one that the Zanjero can readily make through the use of his measuring equipment and by knowledge of his assigned portion of the water delivery system. It is imperative that he know which condition exists since the Gate Rating Tables are set up for these two specific conditions.
2. If the delivery condition is FREE-FLOW, the upstream head (H_1) must be at least three (3) times the height of the gate opening. If the gate is open too wide or the head is not great enough to exceed this 3 to 1 ratio, the coefficient of discharge cannot be predicted with consistency, and therefore, the total delivery will not be accurate. This is why no values are given in the rating tables for head to gate opening ratios less than 3 to 1.
3. The channel should be free of obstructions a distance of at least five (5) times the gate width upstream, and equal to gate width downstream.

The upstream obstructions are normally trash or debris, which must be cleaned out before attempting to make a measurement. If a certain structure consistently gives erroneous readings, it should be inspected at the first opportunity, to see if there is an obstruction immediately downstream of the gate. If there is an obstruction that cannot be easily removed, it should be reported to the Construction & Maintenance Department in order to correct the problem.

4. Turbulence in the channel upstream from the gate should be minimized.

   There are some structures which have excessive turbulence in them, particularly the pipeline structures with large incoming pipes at maximum capacity.

   This turbulence is characterized by the rapid fluctuation of the upstream water surface. At present, there are no effective structural remedies to this situation.

   If the Zanjero and/or Watermaster will request the installation of a staff gage in these structures, the extremes of fluctuations (highs and lows) can be noted by the Zanjero and a usable upstream head (H_1) may be averaged out of the two extreme readings.

5. Certain features of the structure must be consistent to insure an accurate measurement. These features briefly stated are as follows:

a. The gate should be a Water Users' Association Type I or Type II only.

b. The upstream face of the orifice wall should be vertical.

c. The orifice should be rectangular in shape.

d. The area immediately behind the orifice should be equal to or larger than the orifice opening.

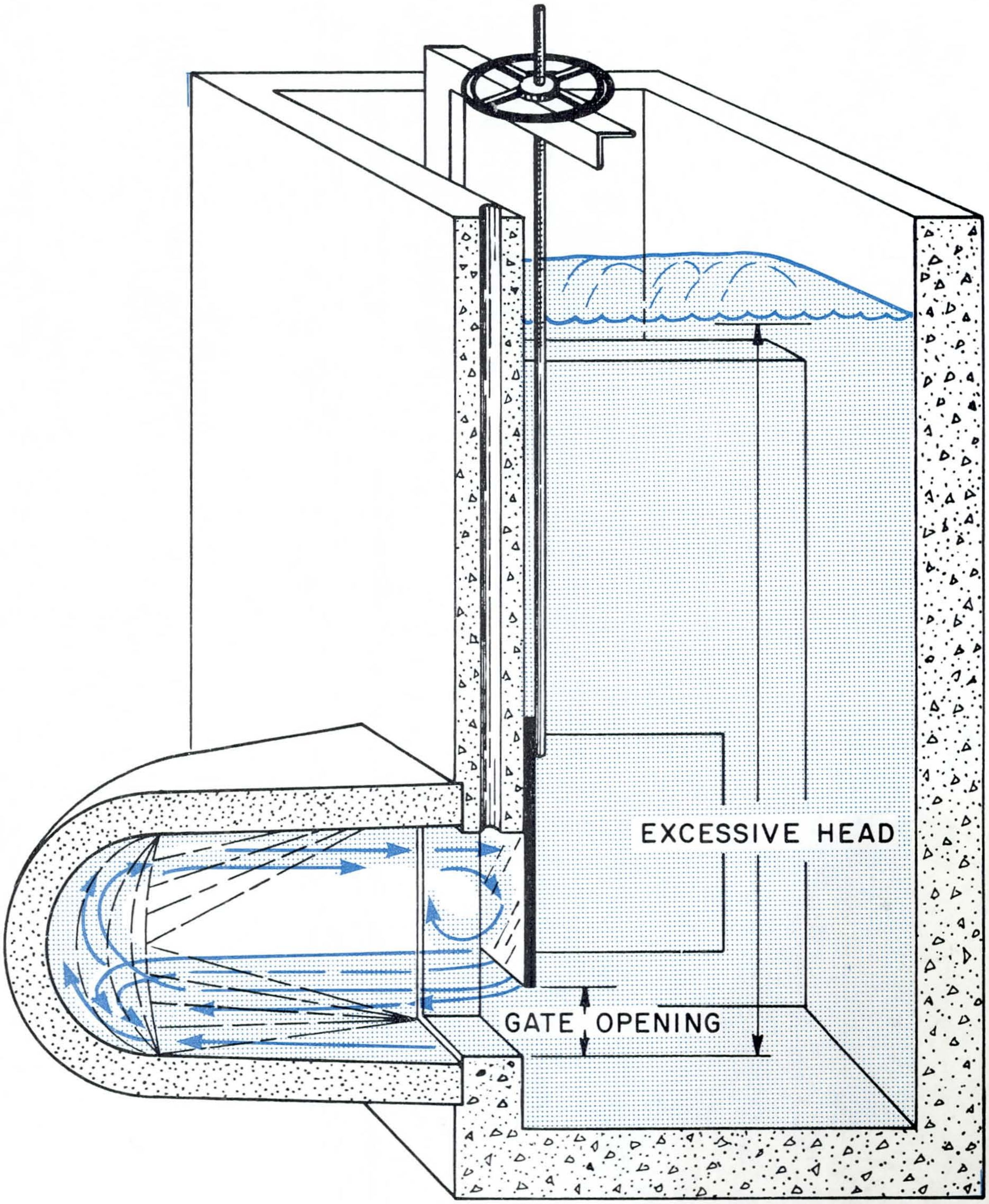
e. The seat of the orifice (gate) should be at least 6 inches from the floor and sides of the structure.

SUMMARY:

The structures for measuring and controlling the flow of water inside the Project's service area are the heart of the delivery system.

The user is charged and billed on the basis of the accurate operation of and measurement through these structures. As the water supply declines, more and more emphasis must be put on the accurate operation of these measuring and control points.

With the full understanding of the capabilities and limitations of the measuring devices and measuring stations, the Field Operations personnel are better equipped to give fast, accurate service to the users. This is the aim, and purpose, of the Association.



90° TRANSITION UNDER EXCESSIVE HEAD

FIG. 14a.

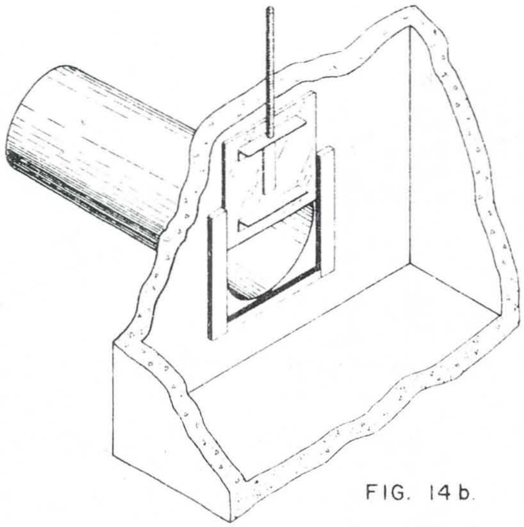


FIG. 14b.

ROUND PIPE BUTTED AGAINST
RECTANGULAR ORIFICE

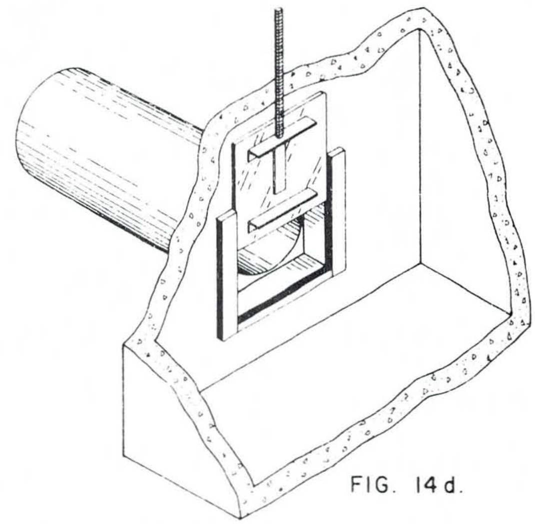


FIG. 14d.

ROUND PIPE BUTTED AGAINST STRUCTURE
WALL, NO TRANSITION SECTION

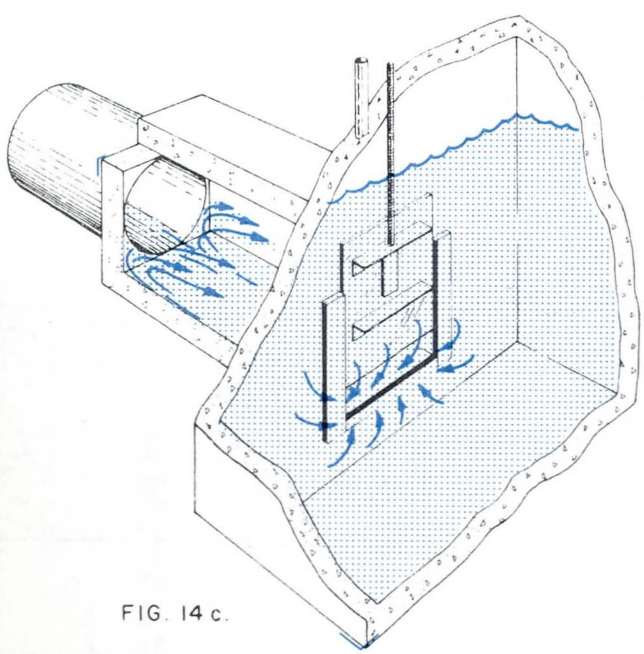


FIG. 14c.

ROUND PIPE BUTTED AGAINST
RECTANGULAR BOX, NO FILLETS

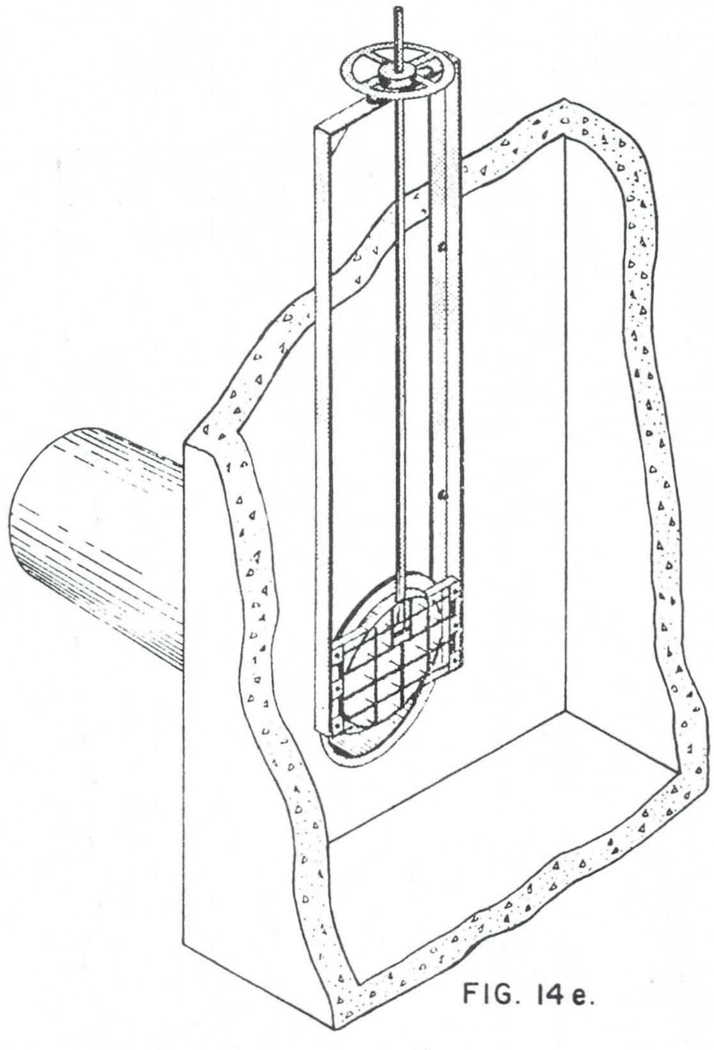


FIG. 14 e.

ROUND GATE,

CRESCENT SHAPED ORIFICE

SNOW GATE

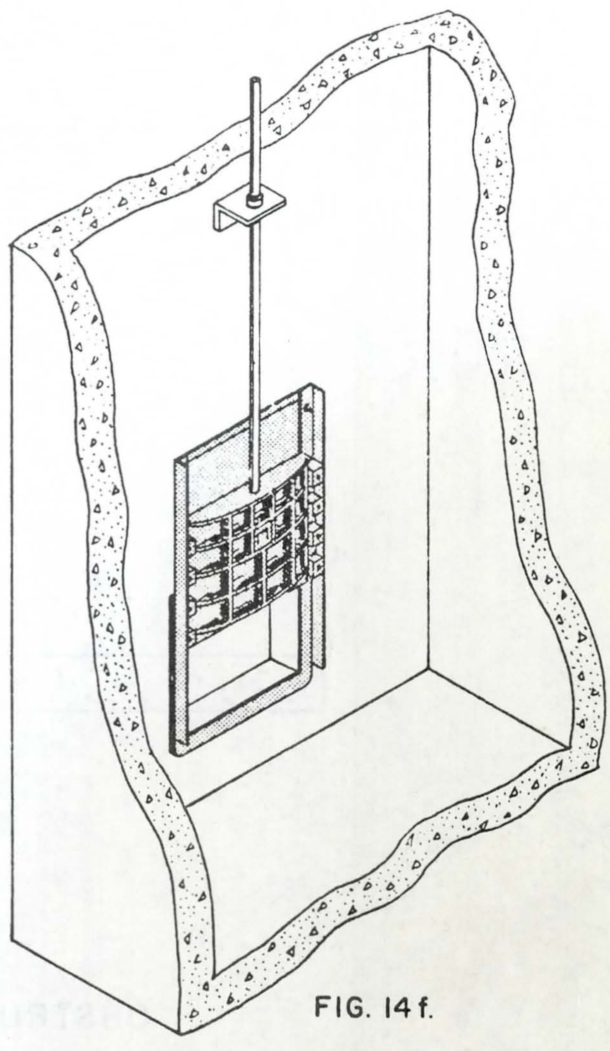


FIG. 14 f.

CAST IRON RECTANGULAR GATE

HARDESTY GATE

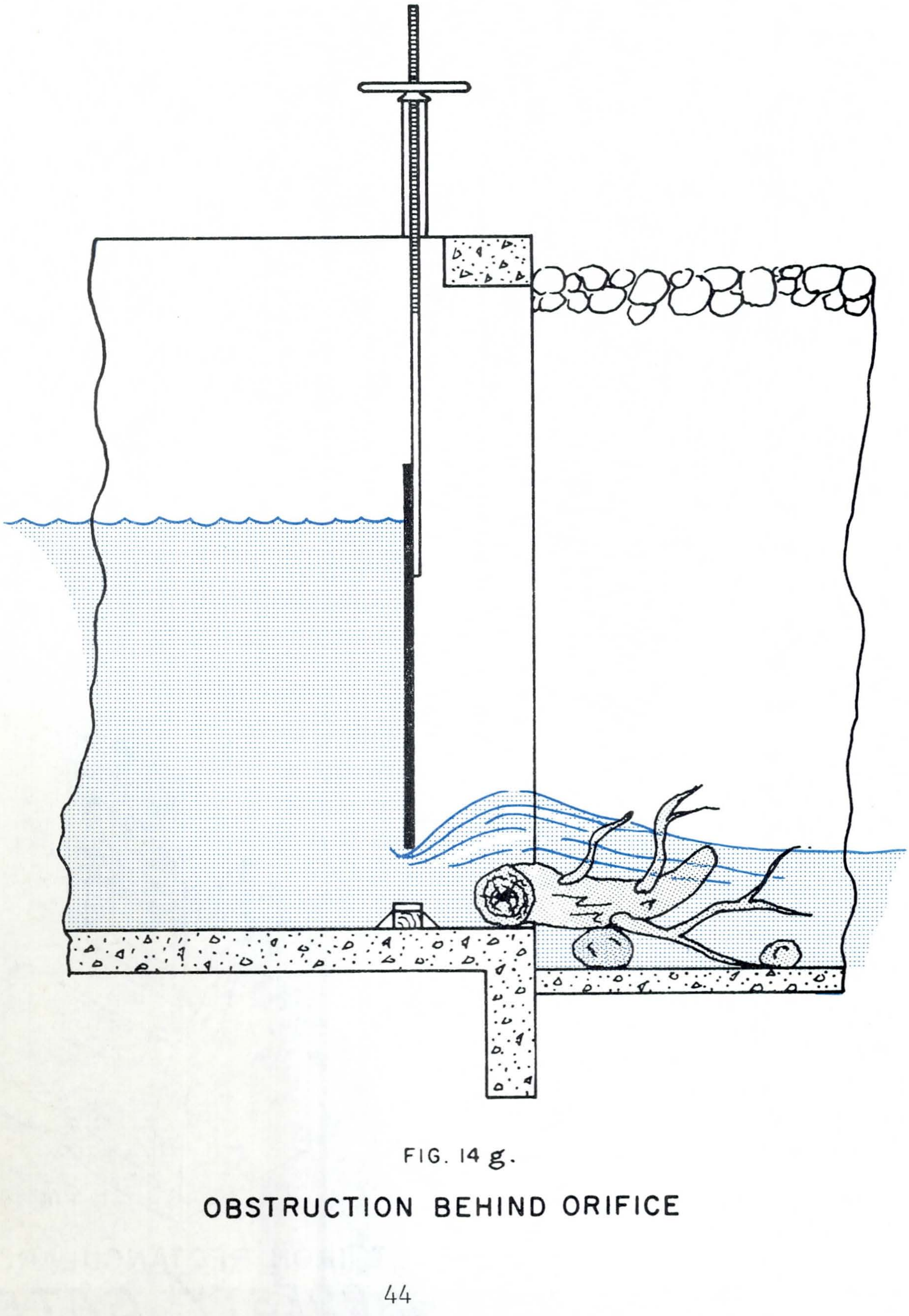


FIG. 14 g.

OBSTRUCTION BEHIND ORIFICE

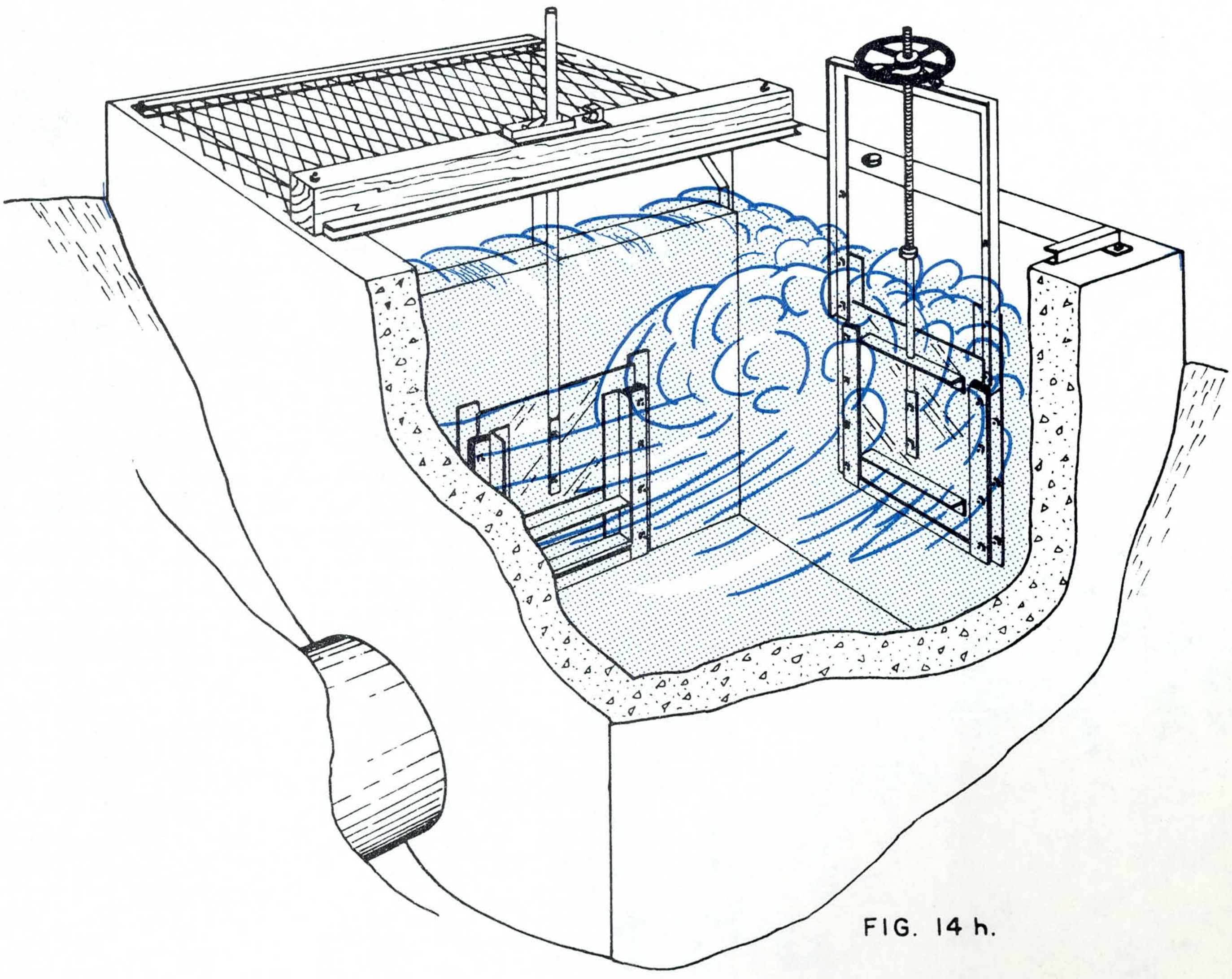


FIG. 14 h.

EXCESSIVE TURBULENCE IN UPSTREAM CELL

FORM 82-6680 HYDROGRAPHIC MEASUREMENT BLANK MEAS NO.______

DATE ______________ 19___ ____ A.M. P.M. STREAM ______________

BEG. S.G. ______ REC. G ______ PARTY ______________ LOCALITY ______________

END ______ ______

ORIFICE OPENING	DISCH. SQ. INCH ORIFICE	DISCH. 1 LINEAL INCH ORIFICE	FREE FLOWING	DISCH. 1 LIN. INCH SUBMERG-ED WEIR	WIDTH	TOTAL DISCH. M.I.

REMARKS

TOTAL	
C.F.S.	

SECTION V

DETAILED PROCEDURE WEIR MEASUREMENT:

Materials needed: Improved Clausen Weir Rule, Hydrographic Measurement Blank - Form 82-6680

Step 1. On Hydrographic Measurement Blank enter Date, Canal, Lateral, and Gate Number, Time, and Operator

Step 2. Type of Weir

A. Free-Flowing (See Weir Flow, Figure 16, Page 52) Proceed with Step 3.

B. Submerged (See Weir Flow, Figure 15, Page 52) Omit Step 3 and proceed with Step 4.

Step 3. Free-Flow Measurement

A. Field Data

1. Free- weir- flow reading

a. Wet the Clausen Weir Rule and dust the face of the Rule. (A practical method of carrying "Weir rule dust" has been used for years by Association Hydrographers. A small container, such as a pop bottle or salt shaker, etc., is partially filled with a fine sand and capped with a plastic sprinkler head in a cork. A small amount of "dust" can be applied to the wet Weir Rule by shaking the inverted bottle several times.)

b. Open or extend the Rule and place the foot of the Rule on the upstream edge of the weir crest (Figure 22, Page 54)

c. Hold the Rule perpendicular and close the rule.

d. Reopen the Rule after a few seconds and remove from the weir crest.

e. Read and enter the amount shown on Scale A (Figure 21, Page 54) - Free Weir Flow - on the Hydrographic Measurement Blank in the column marked free flowing.

f. Repeat several times if the water is turbulent.

g. Average the figures and enter the average as the last figure in Free Flowing column.

2. Width of Weir

a. Measure the width of the weir in inches with the linear scale on the side of the Clausen Weir Rule (Figure 17, Page 52) (the width of the weir is painted on many structures.)

b. Enter the width in the column on the Hydrographic Measurement Blank marked Width.

B. Computation

1. Multiply the last figure in the Free Flowing column by the Width in inches.

2. Enter this product as Total Discharge in Miner's Inches.

Step 4. Submerged Measurement

A. Field Data

1. Orifice Opening

a. Fill the piezometer tube (Figure 19, Page 53) by immersing the tube in water and opening the needle valve by pulling the cord attached to the tube. Release the cord, thus closing the needle valve and remove from the water.

b. Loosen the "Stop Clamp Screw" (Figure 18, Page 53), extend the Rule and slide the "Stop Clamp" down to the "Stop Collar."

c. Place the foot of the Rule on the Weir Crest (Figure 18, Page 53).

d. Close the Rule until the bottom of the piezometer tube is submerged 2 to 3 inches below the Downstream Water Level (Figure 18, Page 53).

e. Tighten the "Stop Clamp Screw," making sure the "Stop Clamp" is flush with the "Stop Collar."

f. Pull the cord attached to the piezometer tube. Allow sufficient time for the tube water elevation to become established. Release the cord and remove the Weir Rule from the weir structure.

g. Holding the Rule vertical, slide the indicator up (Figure 19, Page 53) the piezometer tube until the bottom of the indicator is level with the top of the water in the tube.

h. Read the scale on the side of the weir Rule in inches and tenths of inches (Figure 19, Page 53).

i. Enter this figure in the Orifice Opening column on the Hydrographic Measurement Blank.

2. Adjust the Rule for Free Flowing Reading

a. Loosen the "Stop Clamp Screw."

b. Adjust the Rule so the straight edge at the bottom of the piezometer tube bracket indicates the amount of the orifice opening (Figure 19, Page 53).

c. Slide the Stop Clamp down flush with the Stop Collar and lock in place with the Stop Clamp Screw.

d. Open and close the Rule to test the setting.

e. The Rule is now adjusted to measure the amount of "Free Flow" above the amount of Submergence.

3. Amount of "Free Flow" above the amount of Submergence

a. Wet the Clausen Weir Rule and dust the face of the rule.

b. Open or extend the Rule and place the foot of the Rule on the upstream edge of the weir crest.

c. Hold the Rule vertical and close the Rule.

d. Reopen the Rule after a few seconds and remove from the weir crest.

e. Read and enter the amount shown on Scale A - Free Weir Flow - on the Hydrographic Measurement Blank in the column marked Free Flowing.

f. Repeat Step 4, Item A, 3a - 3e several times if the water is turbulent.

g. Average the figures and enter the average as the last figure in Free Flowing Column.

4. Width of weir

a. Measure the width of the weir in inches with the linear scale on the side of the Clausen Weir Rule (Figure 17, Page 52 (the width of the weir is painted on many structures).

b. Enter the width in the column on the Hydrographic Measurement Blank marked Width.

B. Computation

1. Discharge per Square Inch of Orifice

a. Read the value on Scale B opposite the figure obtained for free-flow. (Scale B is the left hand scale on the face of the rule, (Figure 20, Page 52).

b. Enter this figure as Disch. Sq. Inch Orifice in the column so marked on the Hydrographic Measurement Blank.

2. Discharge of One Linear Inch of Orifice

   a. Multiply the Orifice Opening by the Discharge per Square Inch of Orifice.

   b. Enter the product as Disch. 1 Linear Inch Orifice.

3. Discharge for 1 Linear Inch of Submerged Weir

   a. Add the Discharge for 1 Linear Inch Orifice to the Free Flowing figure.

   b. Enter the sum as Disch. 1 Lin. Inch Submerged Weir.

4. Total Discharge in Miner's Inches

   a. Multiply the Width of the weir by the Discharge for 1 linear inch of Submerged Weir.

   b. Enter the product as Total Discharge in Miner's Inches.

A submerged weir is an obstruction over which water flows to a downstream level higher than the weir crest. Note that in the free-flowing weir the downstream level is lower than the weir crest, while in the submerged weir the downstream level is higher than the weir crest.

Fig. 15

SUBMERGED WEIR

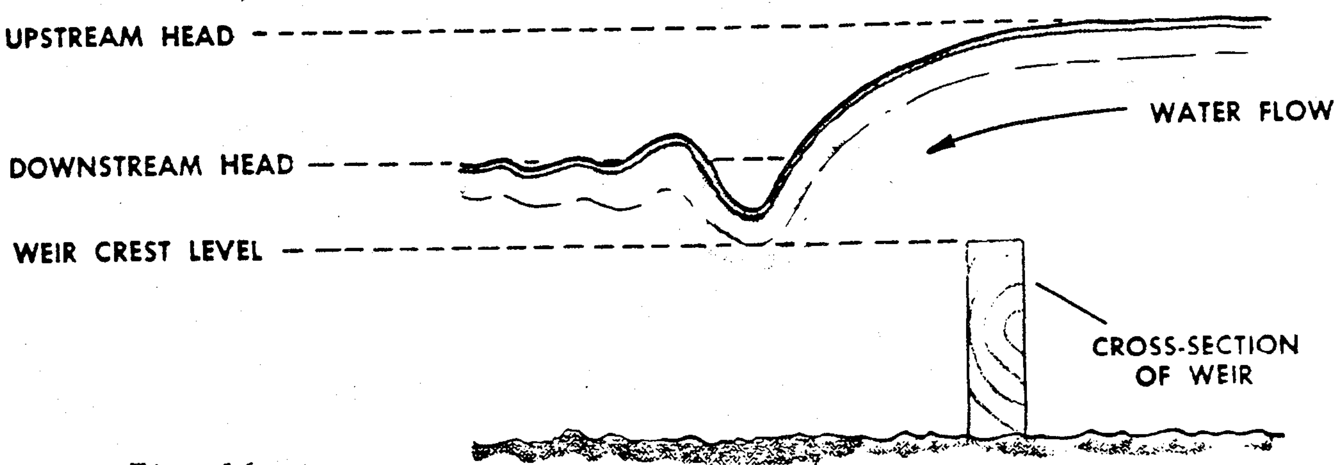


Fig. 16

FREE-FLOWING WEIR

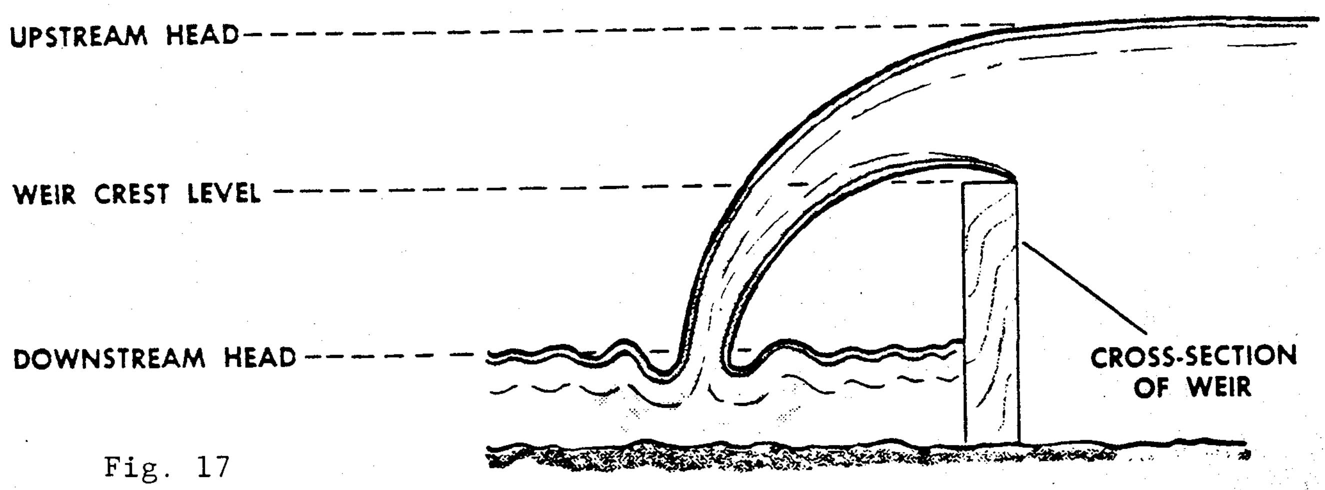
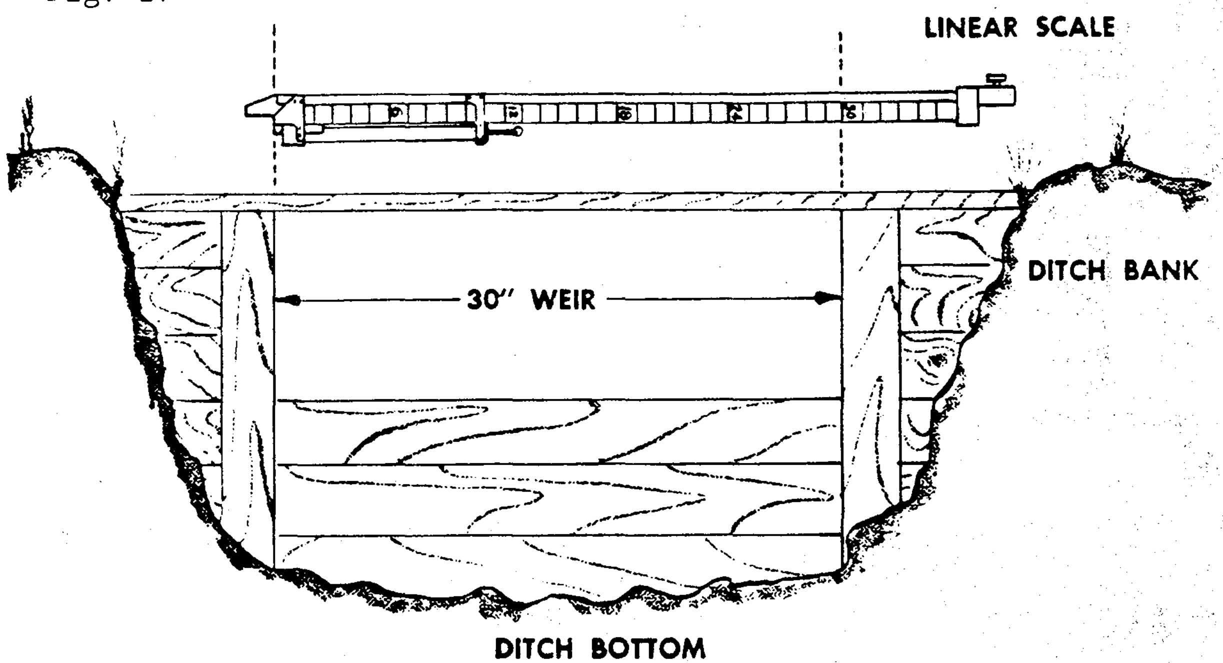


Fig. 17



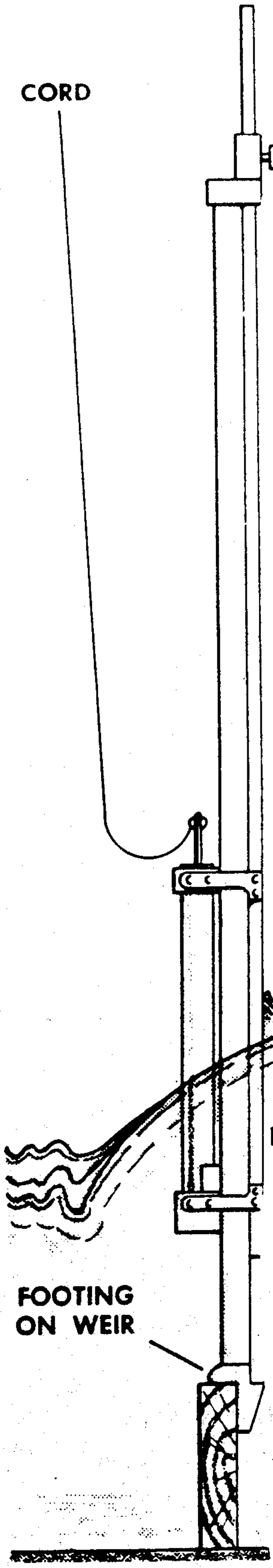


Fig. 18

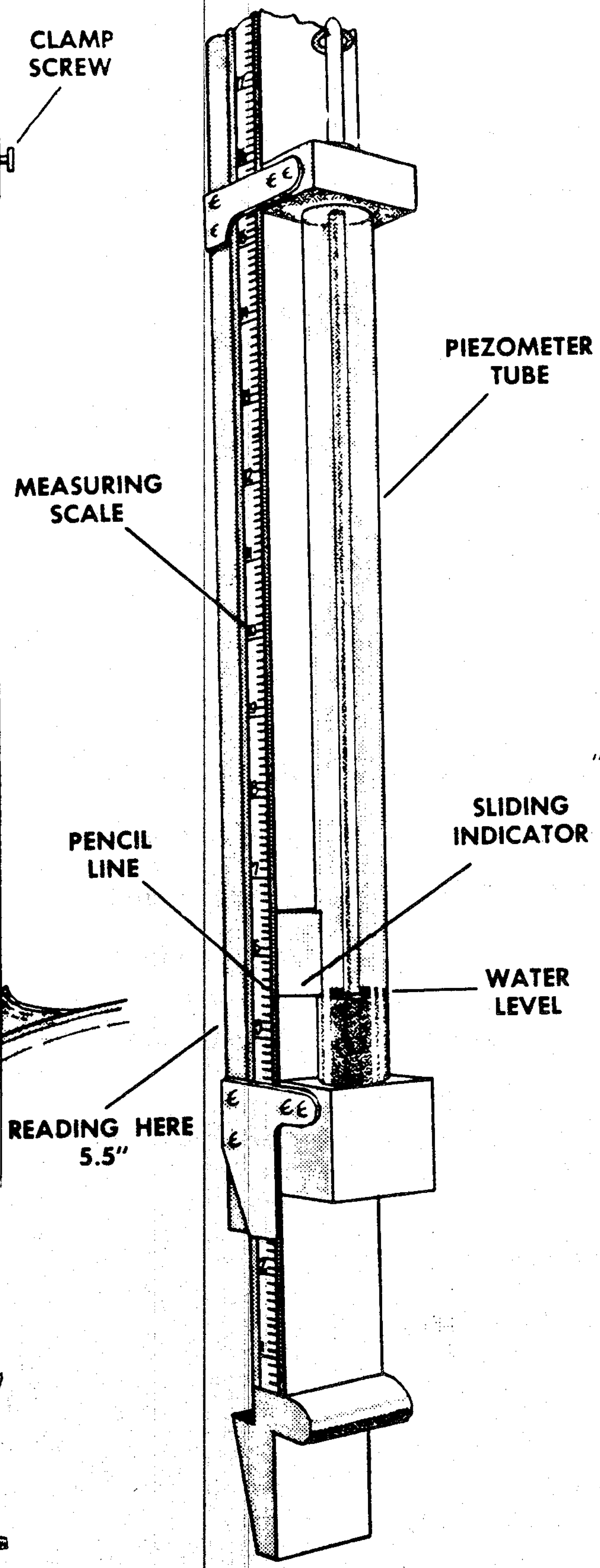


Fig. 19

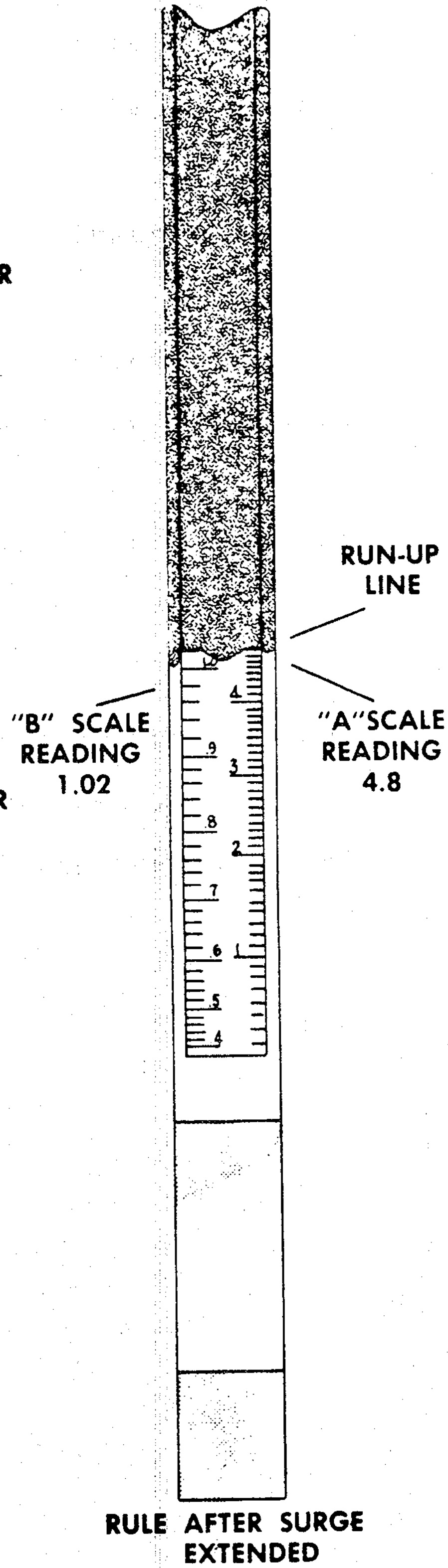


Fig. 20

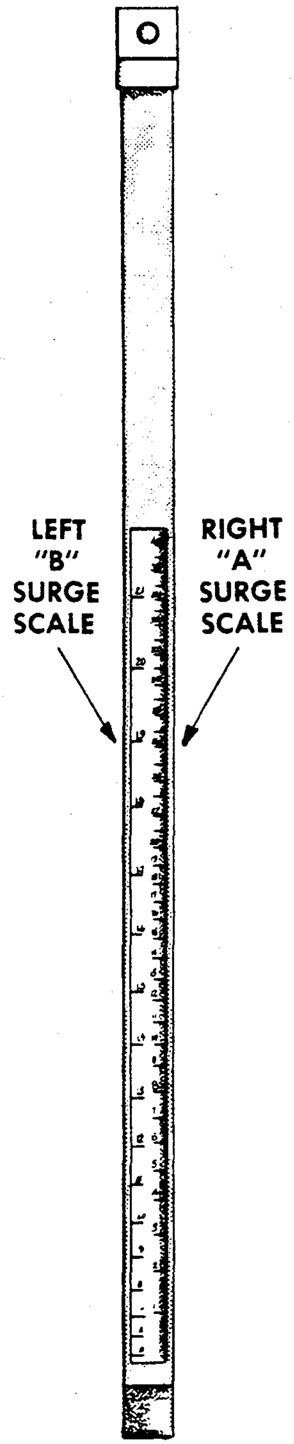

LEFT "B" SURGE SCALE
RIGHT "A" SURGE SCALE

Fig. 21

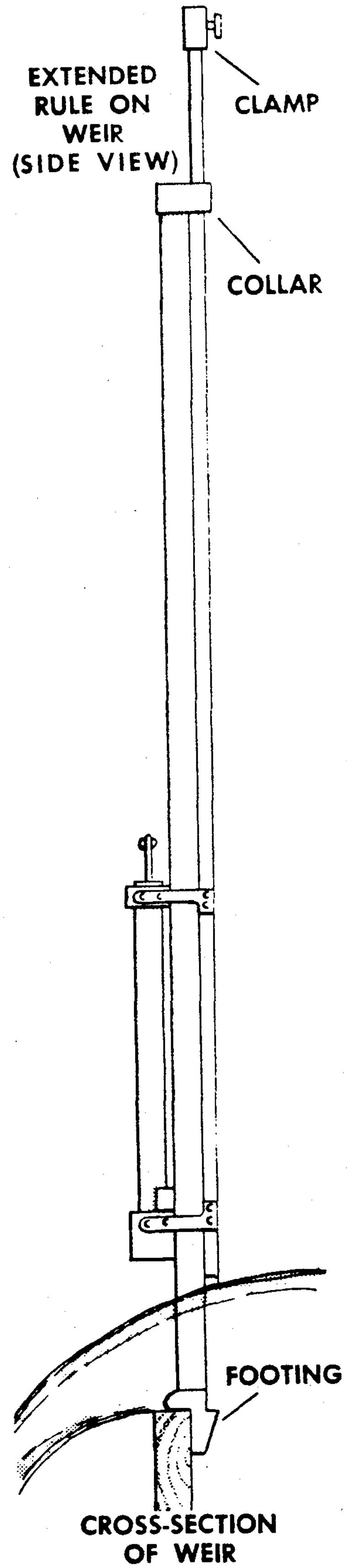

EXTENDED RULE ON WEIR (SIDE VIEW)
CLAMP
COLLAR
FOOTING
CROSS-SECTION OF WEIR

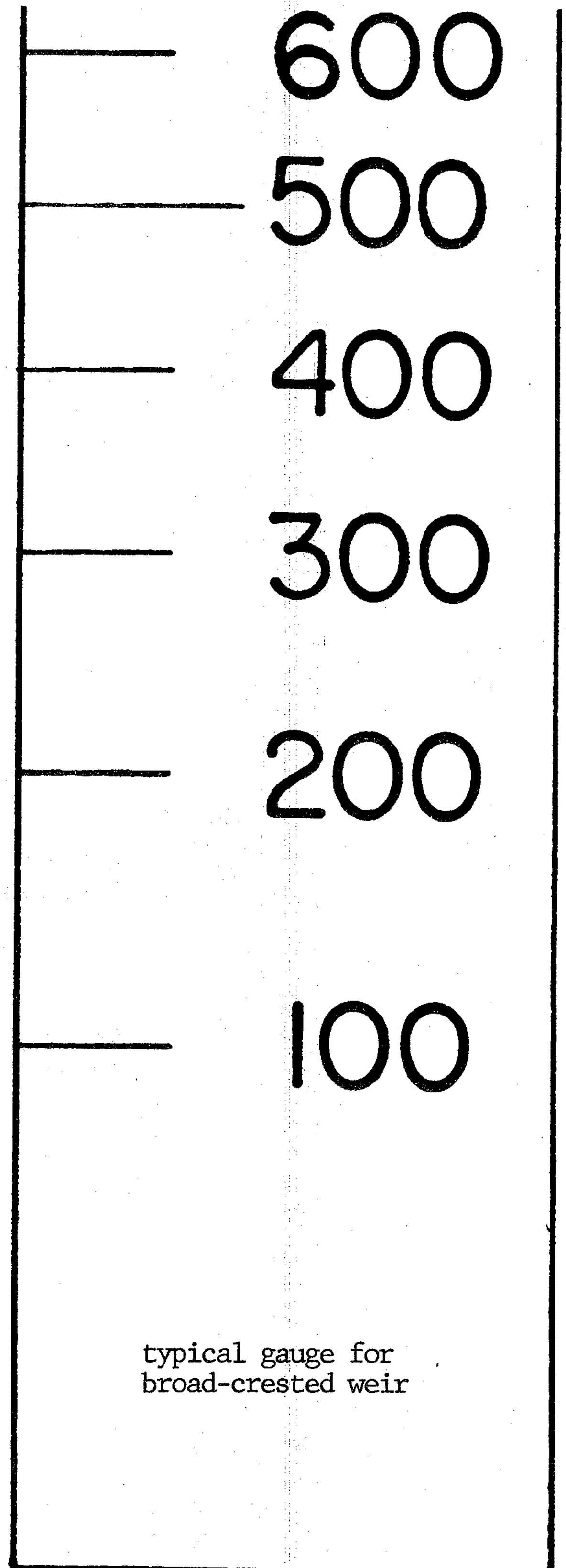
Fig. 22

DETAILED PROCEDURE FOR MEASURING A BROAD-CREASTED WEIR

A typical gauge used with broad-creasted weirs by the SRVWUA looks similar to the example at the right. The numbers represent the flow in miner's inches (40 miner's inches is equal to one cubic foot per second) passing over that particular broad-crested weir.

There are different size gauges for different size weirs, but they all represent units in miners inches.

If the water level is "bouncing" take an average between the high bounce and the low bounce. That is considered a good average (mean) reading. For instance, if the water were bouncing between the numbers 200 and 300, it would be read as 250 miner's inches.



typical gauge for broad-crested weir

DETAILED PROCEDURE FOR MEASURING OPEN LATERAL STRUCTURE:

Materials Needed: Caliper, Gate Discharge Measurement Form 82-6580, and Calibration Tables for Irrigation Delivery Gates Form 82-6290, or the Hatcher Hydraulics Calculator

Step 1. On Gate Discharge Measurement Form 82-6580 enter the Canal, Lateral, and Gate Numbers, Date, Time, and Operator

Step 2. Obtain the following Field Data and enter on Form 82-6580

A. Gate Opening

1. On the upstream side of the gate place the double foot extension of the Calipers in the gate orifice with the lower foot resting on the gate seat.
2. Open or extend the Calipers to the lip of the gate.
3. Read in position if possible, but if the Calipers must be removed from the water, grasp both sections firmly to prevent slippage. Read the scale on the side of the Calipers in feet, tenths, and hundredths. (At the point where the scribed line intersects the foot rule, read the whole number of feet on the scribed member, and the tenths, and hundredths on the scale attached to the other member (See Figure 23, Page 61).
4. Enter this figure on Form 82-6580 as Gate Opening.

FORM 82-6580
REV. 1/66

GATE DISCHARGE MEASUREMENT

Opr.________________

C.____ L.________ G.________ User________________ Date:________________, 19______, ____________ AM PM

Field Data:

(a) Gate Opening ________Ft.

(b) Upstream Head ________Ft.

(c) Downstream Head ________Ft.

(d) Δ Head ________Ft.

(e) Gate Width ________Ft.

Type of Gate

A. Free Flow____________

B. Submerged ____________

A. Free Flow - - - Table I

Table value of

(a) to (b)____________

This value times (e)__________

Equals M.I. Disc.__________

(ADDITIONAL SPACE OTHER SIDE)

B. Submerged Gate - - - Table II

Difference of (b) & (c)

equals (d)____________.

Table value of

(a) to (d)__________.

This value times (e)________

Equals M.I. Disc.__________

B. Upstream Head

1. On the upstream side of the gate place the single foot extension of the Calipers in the gate orifice with the foot resting on the gate seat.
2. Open or extend the Calipers until the upstream water surface barely skims the top surface of the Caliper foot.
3. Read in position if possible, but if the Calipers must be removed from the water, grasp both sections firmly to prevent slippage. Read the scale on the side of the Calipers in feet, tenths, and hundredths. (At the point where the scribed line intersects the foot rule, read the whole number of feet on the scribed member and the tenths, and hundredths on the scale attached to the member (See Figure 23, Page 61).
4. Enter this figure on Form 82-6580 as Upstream Head.

C. Type of Gate

1. Observe the downstream side of the gate
   a. If the water surface is <u>NOT</u> higher than the lip of the gate, place a ✓ in the box indicating "Free-Flow" on Form 82-6580 and proceed with Step F, page 59.
   b. If the water surface <u>IS</u> higher than the lip of the gate, place a ✓ in the box indicating "Submerged" on Form 82-6580 and continue below.

D. Downstream Head

1. On the downstream side of the gate place the single foot extension of the Calipers in the gate orifice with the foot resting on the gate seat.
2. Open or extend the Calipers until the downstream water surface barely skims the top surface of the Caliper foot.
3. Read in position if possible, but if the Calipers must be removed from the water, grasp both sections firmly to prevent slippage. Read the scale on the side of the Calipers in feet, tenths, and hundredths. (At the point where the scribed line intersects the foot rule, read the whole number of feet on the scribed member and the tenths, and hundredths on the scale attached to the member (See Figure 23, Page 61).
4. Enter this figure on Form 82-6580.

E. Differential or Δ Head (Submerged Gates Only)

(The symbol "Δ Head" is read "Delta Head." Delta is the Greek Letter D and is substituted for "Difference" or "Differential" by hydraulic engineers when they refer to the distance between different water levels.)

1. Subtract the Downstream Head from the Upstream Head.
2. Enter the difference on Form 82-6580 as Δ Head.

F. Gate Width

1. Place the Calipers parallel with the top of the gate.
2. Open or extend the Calipers to the inside dimensions of the concrete structure.
3. Read the scale on the side of the Calipers in feet and tenths. (If the gate is in a standard open lateral structure, the width will be in ½ foot increments. If the gate is an odd dimension, read to the nearest tenth on the scale.)
4. Enter this figure on Form 82-6580.

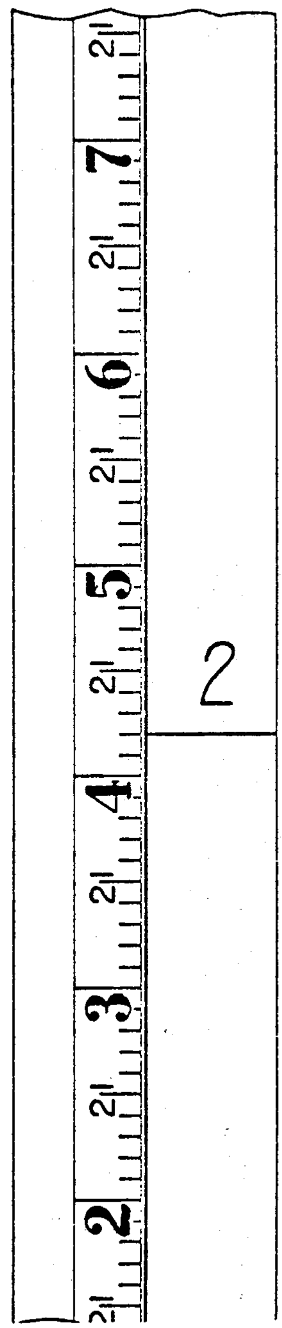
Step 3. Computation of delivered water in Miner's Inches

A. Free-Flowing Gate

1. Using Table I (See Operating instructions, Calibration Tables for Irrigation Delivery Gates) find the discharge per foot of gate width.
2. Enter this figure in the blank space on Form 82-6580 indicated Q = ______ M.I./Ft.
3. Multiple the discharge per foot of gate width by the gate width in feet and tenths. The Product is quantity of delivered water in Miner's Inches for that particular gate at that particular time.
4. Enter this figure on Form 82-6580 as ______ M.I.

B. Submerged Gate

1. Using Table II (See Operating instructions Calibration Tables for Irrigation Delivery Gates) find the discharge per foot of gate width.
2. Enter this figure in the blank space on Form 82-6580 indicated Q = ______ M.I./Ft.
3. Multiply the discharge per foot of gate width by the gate width in feet and tenths. The Product is quantity of delivered water in Miner's Inches for that particular gate at that particular time.
4. Enter this figure on Form 82-6580.



Linear Scale-Calipers. Illustration is read 2.42 feet.

Figure 23

DETAILED PROCEDURE FOR MEASURING PIPELINE STRUCTURES

Materials Needed: Probe or Electric Sounder; "Engineer's" Rule calibrated in feet, tenths, and hundredths, and in feet and inches; Gate Discharge Measurement Form 82-6580; Calibration Tables for Irrigation Delivery Gates, Form 82-6290, or the Hatcher hydraulics calculator

Step 1. On Gate Discharge Measurement Form 82-6580 enter the Canal, Lateral, and Gate Numbers, Date, Time and Operator

Step 2. Obtain the follwoing Field Data and enter on Form 82-6580

A. Gate Opening

1. Remove the slack or play from the gate wheel by turning the wheel in the open direction.
2. Locate the "hack-saw" mark on thread of gate stem.
3. Measure the distance from the hack-saw mark to the top of the gate wheel hub in feet, tenths, and hundredths with the "Engineers" rule.
4. Enter this figure on Form 82-6580 as Gate Opening.

B. Upstream Head

1. Place the Probe or Sounder in the upstream water surface until full contact is registered on the ammeter.
2. Read the distance from the water surface to the top of the gate mantel as indicated on the scale on the side of the Probe or Sounder.
3. Subtract this distance from the figure stamped in the metal of the gate mantel.

4. Enter this difference on Form 82-6540 as Upstream Head.

C. Type of Gate, and Downstream Head

1. Subtract the figure obtained for Gate Opening from the figure stamped on the gate mantel.

2. Unlock the Probe access tube and insert the Probe or Sounder until full contact is registered on the ammeter. IN NO EVENT SHOULD THE PROBE OR SOUNDER BE INSERTED ANY DISTANCE GREATER THAN THE DIFFERENCE CALCULATED IN ITEM 1 ABOVE.

3. Read the distance from the water surface to the top of the gate mantel as indicated on the scale of the Probe or Sounder.

   a. If the distance is the same as Item 1 above, the gate is Free-Flowing. Place a ✓ in the box indicating "Free-Flow" on Form 82-6580, and proceed with Gate Width, Item E-2.

   b. If the distance is less than Item 1 above, the gate is submerged. Place a ✓ in the box indicating "Submerged" on Form 82-6580, and continue below.

4. If the gate is submerged, subtract this distance from the figure stamped on the top of the gate mantel.

5. Enter this difference on Form 82-6580 as Downstream Head.

NOTE: If the structure is known to be in a condition of submerged discharge at all times, with no exception, the measurement from the mantel to the water surface on the upstream and downstream sides need not be subtracted from the figure stamped on the gate mantel. Instead subtract the upstream reading from the downstream reading. The difference between the two direct readings may be entered as Δ Head.

D. Δ Head (Submerged Gates Only)

1. Compute the difference between the Upstream Head and the Downstream Head.
2. Enter the difference on Form 82-6580 as Δ Head.

E. Gate Width

1. Measure the outside dimensions of the gate mantel in feet and inches.
2. Subtract 8 inches from this measurement.
3. Enter this figure on Form 82-6540 as Gate Width.

NOTE: Gate Mantels are fabricated in two types: standard, which is of 2 inch angle iron, and heavy duty, which is of 3 inch angle iron. In both types the outside dimensions of the gate mantel is 8 inches wider than the gate orifice.

Step 3. Computation of delivered water in Miner's Inches

A. Free-Flowing Gate

1. Using Table I (See Operating instructions, Calibration Tables, Irrigation Delivery Gates) find the discharge per foot of gate width.
2. Enter this figure in the blank space on Form 82-6580 indicated Q = __________ M.I./Ft.
3. Multiply the discharge per foot of gate width by the gate width in feet and tenths. The product is quantity of delivered water in Miner's Inches for that particular gate at that particular time.
4. Enter this figure on Form 82-6580 as _______ M.I.

B. Submerged Gate

1. Using Table II (See Operating instructions, Calibration Tables, Irrigation Delivery Gates) find the discharge per foot of gate width.
2. Enter this figure in the blank space on Form 82-6580 as indicated Q = _________ M.I./Ft.
3. Multiply the discharge per foot of gate width by the gate width in feet and tenths. The product is quantity of delivered water in Miner's Inches for that particular gate at that particular time.
4. Enter this figure on Form 82-6580 as _______ M.I.

DETAILED PROCEDURE FOR USAGE OF THE HATCHER HYDRAULICS CALCULATOR

Materials Needed: Calipers, Probe, Tape, or any other tools necessary to obtain the same data as required to measure open lateral and pipeline structures

Step 1. Determine first if gate is free-flow or submerged.

A. Free-flow. Proceed with Step 2.

B. Submerged. Omit Step 2 and proceed with Step 3.

Step 2. Free-Flow

A. Field Data

1. Obtain upstream head measurement.
2. Obtain gate opening measurement.
3. Obtain gate width.

B. Calculate discharge

1. Use upper half of Hatcher calculator.
2. Find upstream head on white sliding scale.
3. Find gate opening on stationary upper scale.
4. Align upstream head on white sliding scale with gate opening on stationary upper scale.
5. Find gate size in inches at lower right-hand corner of calculator.
6. Read water flow rate in miner's inches directly above gate size.

C.[1/] Gate Opening to Upstream Head Ratio

1. Obtain upstream head measurement.
2. Find upstream head on sliding white scale.
3. Align upstream head with blue arrow.

1/ Refer to "Reference Manual" measurement of irrigation water under Types of Structures and Orifice Flow Part V

4. Read maximum gate opening in feet at upper right-hand corner.

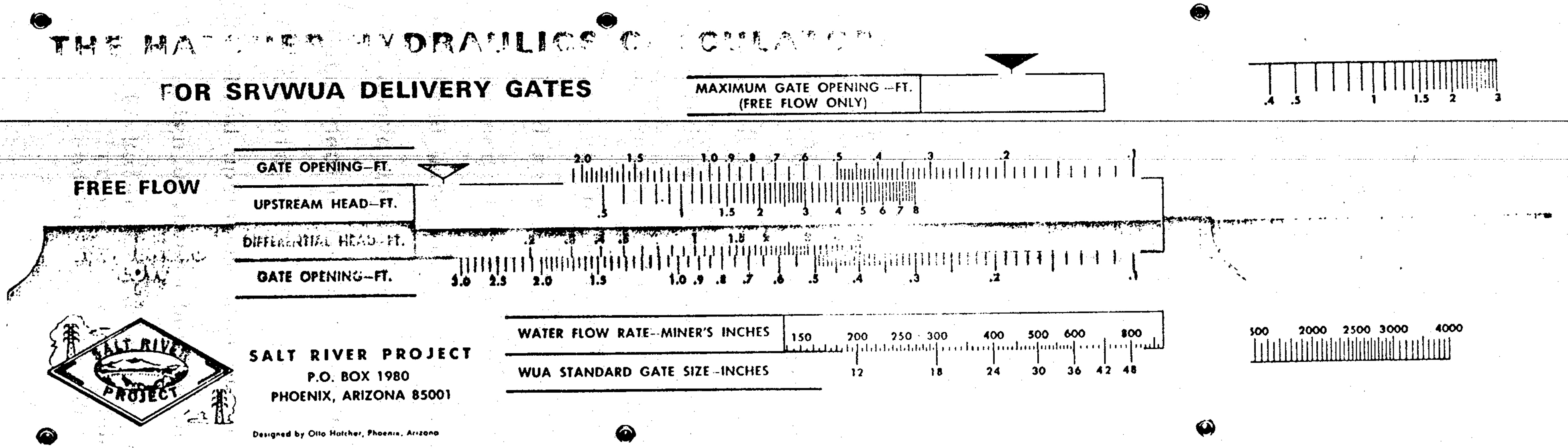
Step 3. Submerged

A. Field Data

1. Obtain upstream head measurement.
2. Obtain downstream head measurement.
3. Calculate differential head (Δ).
4. Obtain gate opening measurement.
5. Obtain gate width.

B. Calculate discharge

1. Use lower half of Hatcher calculator.
2. Find differential head on sliding blue scale.
3. Find gate opening on stationary lower blue scale.
4. Align differential head on sliding blue scale with gate opening on stationary lower blue scale.
5. Find gate size in inches at lower right-hand corner of calculator.
6. Read water flow rate in miner's inches directly above gate size.


FOR SRVWUA DELIVERY GATES
MAXIMUM GATE OPENING – FT. (FREE FLOW ONLY)
FREE FLOW
GATE OPENING–FT.
UPSTREAM HEAD–FT.
DIFFERENTIAL HEAD–FT.
GATE OPENING–FT.
WATER FLOW RATE–MINER'S INCHES
WUA STANDARD GATE SIZE–INCHES
SALT RIVER PROJECT
P.O. BOX 1980
PHOENIX, ARIZONA 85001
Designed by Otto Hatcher, Phoenix, Arizona

STORM AND FLOOD WATER ESTIMATIONS

First let's return to our basic formula:

$$Q = A V$$

which is Q = Quantity, or rate of flow, equals the cross-sectional area (A) of the flowing stream multiplied by the average velocity (V) or speed of that stream

To obtain the area (A), it is a simple matter of calculating the width of the stream and multiplying it times the measured depth. For example: If a stream of water were going through a box culvert, and a measurement showed it to be 20 feet wide and 2.1 feet deep, the calculations would proceed as follows:

Example A

Width	x	Depth	=	Area
20'	x	2.1'	=	42 sq. ft.

That is a simple example. Often during storm and flood conditions, the proceudre is not that easy. If possible, a measurement with a tape measure should be used for calculating width, and if all else fails, try and "step-off" the width (an average size man's average step is 3') over a bridge or some other form of structure.

As for depth or height, the simplest method is to read the staff gage provided. During storm and flooding conditions, an estimate of flow will be requested from a particular location. Usually a standardized staff gage will be provided. The reading of the standard gage is explained later in this chapter. If a gage is not provided, estimate by other means, such as using a pole, or a rope with a rock or other heavy object tied to the end.

To get the velocity (V) or speed of the water, mark off a distance parallel to the Flow of the stream and measure in seconds the amount of time it takes a piece of floating debris to get from one point to the other of the marked-off distance. For example: if you marked off a distance of 100' and saw a piece of debris coming down the stream and clocked it through the 100' at 20 seconds, that would calculate to: (Example V)

$$\frac{100 \text{ ft.}}{20 \text{ sec.}} \qquad 20\overline{)100} \quad = \quad 5 \text{ ft./sec. (velocity)}$$

That means the surface velocity is 5' per second. The reason surface velocity is underlined is to draw the necessary attention to the fact that surface velocity is not necessarily a true indication of the average or mean velocity of the entire cross-sectional area (A). It has been the experience of the Hydrology Division of the SRVWUA that the actual mean velocity (or average velocity) of the area (A) is much closer to 80% of the surface velocity. Therefore, in order to obtain an accurate indication of velocity (V) for our formula, the 5' per second in our example would have to be recalculated to 5 x .80 = 4.0 feet per second before it is applied to the Q = A V.

Now, take the examples and apply them to the formula Q = A V. Example A calculated to 42 sq. ft. for A. Example V calculated to 4' per second after the 80% factor was applied for V.

Therefore: $Q = A V$

$$Q = A \times V$$

$$Q = 42 \text{ sq. ft.} \times 4 \text{ ft. per second}$$

$$Q = 168 \text{ cu. ft. per second}$$

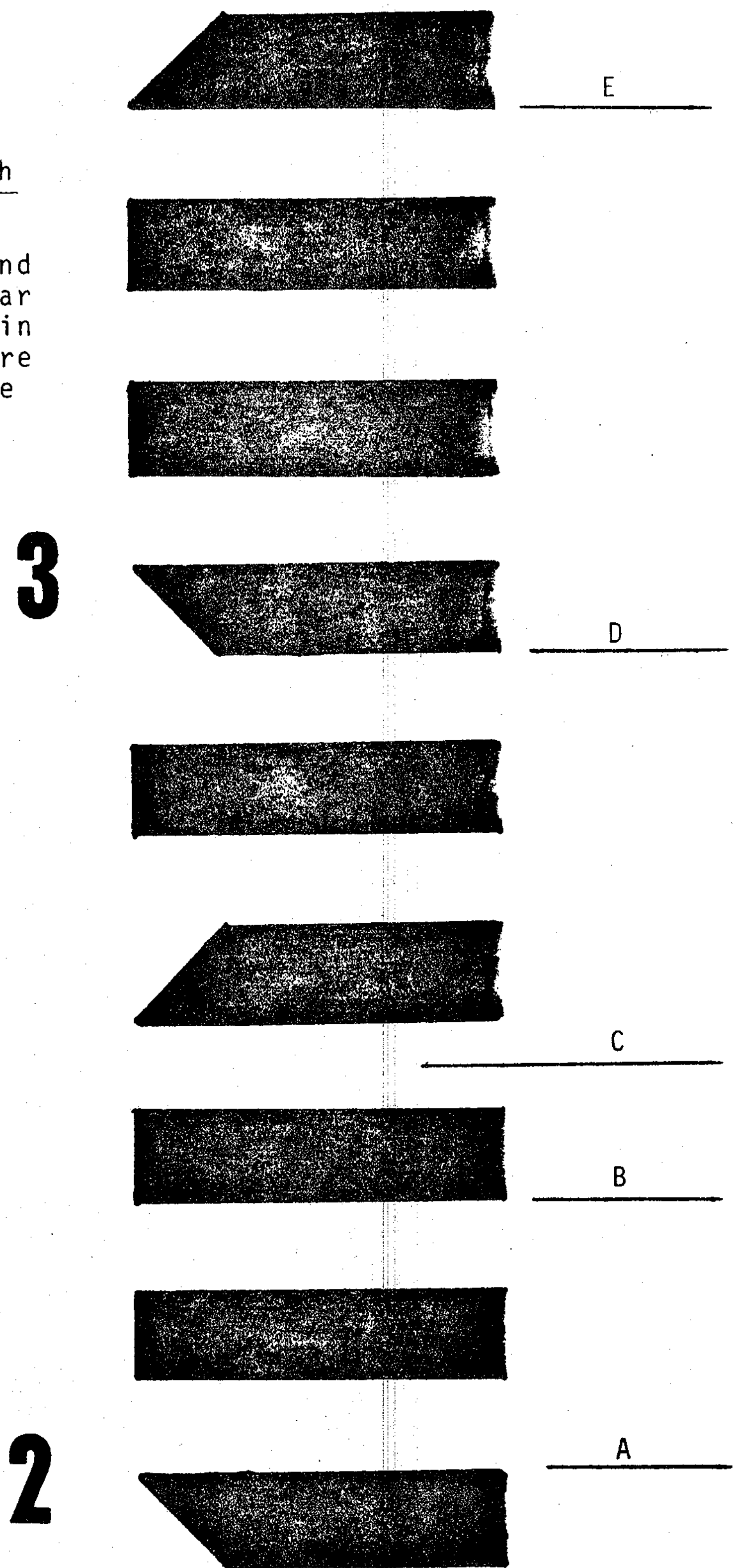
The standard gauge used by the SRVWUA looks similar to the example at the right. Each horizontal line is .10' (one tenth of a foot) from the next.

The numbering starts at a reference point (usually the ground or surface level of that particular stream bed) and continues upward in 1 (one) foot increments. Below are some examples of readings from one of these gauges.

if the water level is at:	it is read as:
A	2.00'
B	2.30'
C	2.45'
D	2.90'
E	3.50'

If the water level is **"bouncing"** take an average between the high bounce and the low bounce. That will be considered a good mean (average) reading. For instance:

if the water is **"bouncing"** from	to	the mean is
A	B	2.15'
A	D	2.45'
B	D	2.60'
B	E	2.90'



C O N C L U S I O N S

It is difficult, if not impossible, to establish definite rules which apply generally to water measurement procedures and equipment. Similarly, one measurement device cannot be recommended over any other device until all variables at the particular installation site are considered and properly weighed. It is therefore necessary for each operator to learn as much as possible about the device he is using and to evaluate the effect of each variable (at the particular site) on the measurement he is making.

Each operator must learn to look objectively at his equipment and procedures. He must be able to "see" that his equipment is run down and in need of maintenance or that his measurement procedures are not compatible with what he is trying to measure. He should become familiar with various types of measuring equipment, learn the advantages and disadvantages of each, and decide whether the existing equipment is the best for the job at hand. He should try to find deficiences with his equipment and every step he uses to make a discharge measurement, and try to improve wherever possible. This means that he must understand the basic measurement he is trying to make and then modify, if necessary, his methods of getting it. He should try to understand why he is doing the things he does and develop confidence in his knowledge. He should read available literature as much as possible to get background information on water measurement. He will thereby not only obtain more meaningful information, but will also have the satisfaction of knowing his job is well done.