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D. R. THEOPHILUS
Director

Farm Water Measurement

MAX C. JENSEN AND MARK R. KULP

COOPERATIVE EXTENSION SERVICE IN AGRICULTURE AND HOME ECONOMICS OF THE STATE OF IDAHO, UNIVERSITY OF IDAHO COLLEGE OF AGRICULTURE AND UNITED STATES DEPARTMENT OF AGRICULTURE COOPERATING

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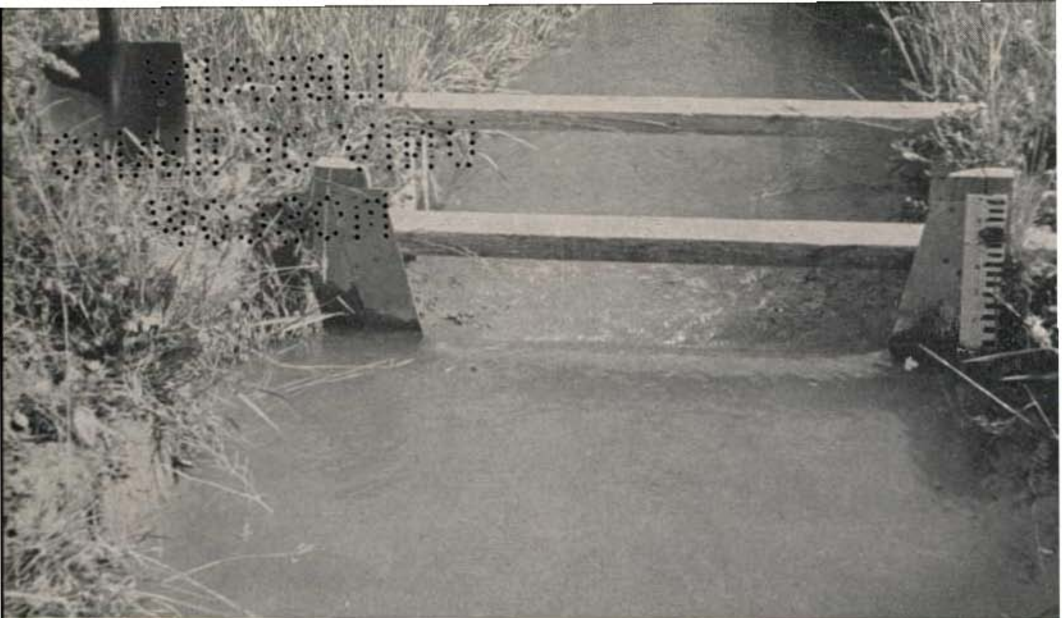

This wooden Cippolletti weir near Jerome is a typical measuring device in use in Idaho. It is easily installed and gives reliable water measurements.

Summary

ACCURATE water measurement is necessary for satisfactory operation of the irrigated farm.

Most farmers are able to make, install, and operate their own measuring devices.

Farm-made devices are accurate when made, installed, and operated properly.

Fully contracted weirs are simple, accurate, and require but one reading of head (h) for determining flow. They need excess fall in the ditch for free-flow measurements.

The suppressed rectangular weir may be used where desirable to measure water in a flume or box not having enough width for complete contractions. It requires excess fall.

Submerged orifices do not require large head loss for operation. They are easily clogged and have a small range of measurable flow.

The Parshall measuring flume combines the advantages of the weir and the submerged orifice. It is more complicated to make than the ordinary weirs or submerged orifice.

A definition of terms used here and listing of equivalents are in the appendix of this bulletin.

Farm Water Measurement

Max C. Jensen* and Mark R. Kulp**

ACCURATE measurement of irrigation water permits more intelligent use of this valuable natural resource. Such measurement reduces excessive waste and allows the water to be distributed among users according to their needs and rights.

The farmer can measure his irrigation water accurately with a device that he can make at home. This bulletin gives him information for making, installing, and operating suitable measuring devices and instruction for measuring water with them.

General†

We measure water in two distinctly different ways, (1) at rest, and (2) in motion.

Water at Rest

We say that water in tanks, in reservoirs, and in the soil is at rest and we measure it in units of volume. The most common units used in expressing volume of irrigation water at rest are the gallon, the cubic foot, the acre inch, and the acre foot.

Water in Motion

When water is flowing in pipes, ditches, and canals, we say it is in motion and measure it in rates of flow, or units of volume passing a point during a unit of time. The more common units used in measuring irrigation water in motion are cubic feet per second, gallons per minute, and miner's inches. We call these rates of flow "discharges."

Do not confuse units of volume with units of rates of flow. The rate of flow always considers the element of time.

Measuring Devices

The measuring devices we discuss in this bulletin are for measuring water in motion.

All accepted farm measuring devices have been developed and proved by thorough study. The conditions under which each device will operate accurately have been determined. These conditions are referred to as "standard conditions." To measure water accurately with these devices, it is necessary to duplicate approximately the "standard conditions."

All common measuring devices require head, or fall in the water surface, for operation. The loss of head required depends on the type and size of the device used and the maximum flow to be measured.

The common measuring devices which you can make on the farm

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*Associate Agricultural Engineer and Irrigationist, Idaho Agricultural Experiment Station.
**Idaho State Reclamation Engineer, State of Idaho, Boise, Idaho.
†Definition of terms will be found in the Appendix, page 28.

include common weirs, submerged orifices, and the Parshall measuring flume. Each measuring device has its advantages, disadvantages, and limitations. You should select the device which will suit your local conditions most economically.

Weirs

A weir is a regularly shaped overpour notch in a vertical wall bulkhead placed across the stream. It is the simplest form of water-measuring device for open channels and is easily constructed on the farm. Under standard conditions it will give reliable results. Discharge tables are given for triangular, rectangular, Cipolletti, and rectangular suppressed weirs.

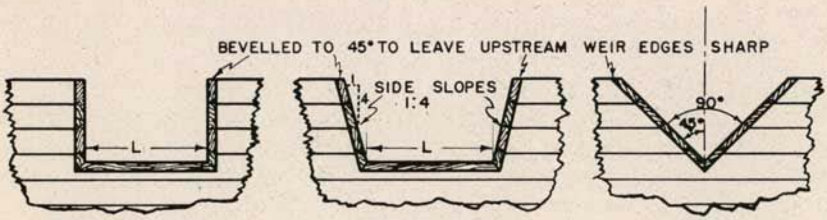


Figure 1.—Downstream side of wooden contracted weir notches.

Standard Conditions for Weirs

The weir wall or bulkhead must be vertical (not leaning upstream or downstream), set at right angles to the direction of flow of the stream, and must extend far enough into the bank to be secure. The weir box, or weir pond, must be large enough to reduce the velocity of the water approaching the weir to less than ½ foot per second (practically still water), and to bring it to the weir in a straight even flow without eddies or swirls. Baffles may be put in the weir pond to reduce velocity and equalize the flow. The weir box or pond must be kept clean of silt accumulations or the velocity of approach will be increased due to the reduction in section, and more water will pass over the weir than the gauge indicates.

The height of the crest above the bottom of the ditch upstream from the weir should be at least twice the maximum head to be measured. The crest being above the ditch bottom is referred to as "bottom contraction." To meet standard conditions, then, the bottom contractions must be 2H or greater.

The side of the weir extending into the stream past the side of the ditch is referred to as "end contraction." Each end contraction must be equal to or greater than twice the head being measured.

The weir notch must be regular in shape and its edges must be rigid, straight, and sharp on the upstream face. The edges need not be knife edges but they must not be rounded nor more than ⅛ inch thick except for large discharges. When cut directly from a wooden bulkhead, the weir notch should be beveled on the downstream side to an angle of 45 degrees so that the water flowing over the weir will not touch the bulkhead or weir notch except at the upstream edge and will have an air pocket under the sheet of falling water. When the edges of the weir notch are made of metal strips nailed to the wall, the wooden notch is beveled or is cut enough larger to obtain the same effect. As wooden weir notches are likely to crack and warp, metal strips are always desirable.

The weir crest must be level and accurate as to length ($\frac{1}{8}$ inch error in the length of a 12-inch weir will change the discharge approximately 1 percent.)

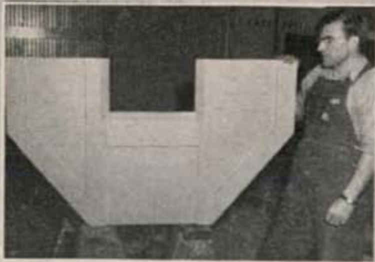
The level of the water downstream from the weir must not be higher than the weir crest at the maximum flow to be measured, or there will be no air pocket under the crest of falling water and free-flow conditions will not result. (All discharge tables in this bulletin are for free-flow conditions although the Parshall measuring flume may be partly submerged without altering the free-flow formula.)

The depth of the water flowing over the crest of the weir should not be less than 2 inches (.17 ft.) for accurate measurement, nor more than one-third the crest width. For heads greater than one-third the crest width special precaution must be taken to insure complete contractions.

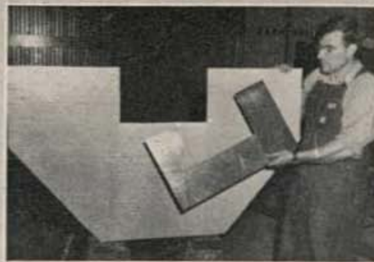
The weir gauge must be set away from the weir notch. It may be set on the weir wall far enough from the side of the notch to be in practically still water. A better place to set the gauge is 3 or 4 feet upstream from the notch and as near the side of the weir pond as possible and yet be in the water at all discharges. The zero of the gauge should be set with a good level at the exact elevation of the weir crest. (Do not set the gauge by filling the pond with water to the point where it starts to flow over the weir crest. Such a setting will not be correct. The water surface raises somewhat above the weir crest before it begins to pour over.)

Construction and Setting of Weirs

Weirs may be constructed of wood, metal, or concrete and may be either portable or permanent. The simplest type of weir installation is a notch cut in a plain wooden bulkhead set across the stream where there is ample fall. When the soil is of a nature that will hold the bulkhead, the installation may be made as shown in Figures 2 and 10.



Downstream face of weir bulkhead without weir plate



Upstream face of weir bulkhead showing metal rectangular weir plate

Looking upstream on installed weir. Note the gravel and rock protecting apron and the staff guage location

Looking downstream on installed weir. Note the end and bottom contractions and staff guage location

Left: The installed weir structure in operation

Figure 2.—This type of weir structure is easy to make, install, and operate and is adapted to use in heavy and medium textured soils.

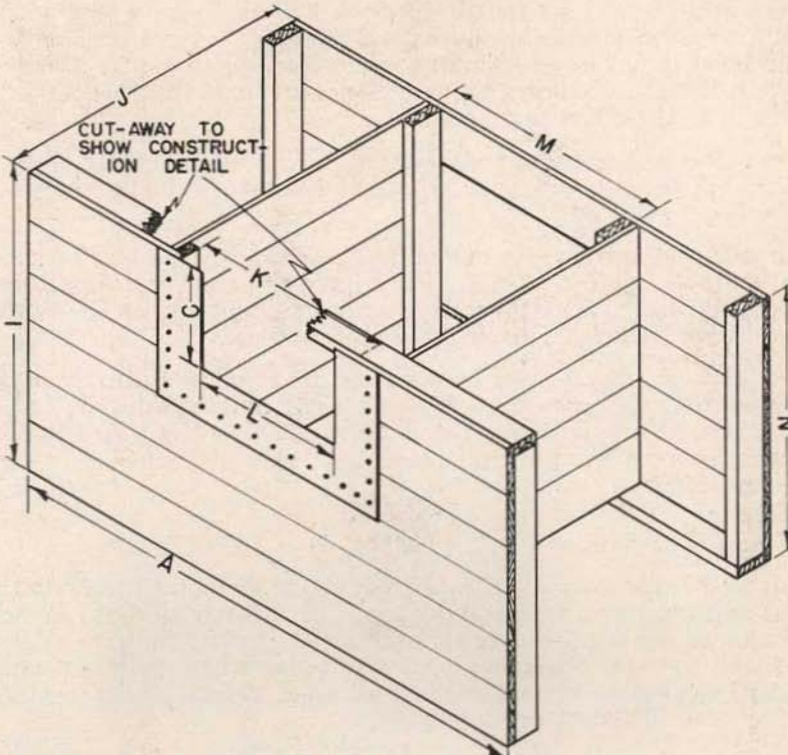


Figure 3.—Structure for rectangular, Cipolletti, and 90° V-notch weir plates . . . suitable for light soils.

Table 1. Symbol dimensions and capacities for weir bulkhead shown in Figure 3.

Crest length L	Recommended range of measurement in C.f.s.		Symbol dimensions														
			C		A		I		J		K		M		N	
ft.	Rectangular	Cipolletti	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
For Rectangular and Cipolletti Weirs																
1	.2 to .6	.2 to .6		8	5		2	4	2	6	1	6	1	10	1	9
1.5	.3 to 1.7	.3 to 1.8	1		6	6	3		3		2		2	6	2	5
2	.4 to 3.5	.4 to 3.7	1	2	8		3	6	3		2	6	3		2	9
3	.6 to 9.5	.6 to 10.0	1	6	11		4	6	3	6	3	6	4	6	3	6
4	.8 to 19.5	.9 to 20.7	2		14		5	8	4		4	6	5	6	4	6
For 90 V-notch Weirs																
2	.02 to 1.5		1		7		3	8	2	6	2	2	2	6	2	5
3	.02 to 4.0		1	6	9	6	5		3		3		3	6	3	4

Very often a weir set in a deep ditch will back the water up far enough to form a suitable weir-pond without further excavation. If the pond is not large enough to cause complete contractions on the weir, it may be enlarged evenly for a distance and then tapered gradually to the ditch section.

When the soil is light and will not hold a simple weir wall or bulkhead, a box is built with wings and cutoff walls as shown in Figure 3.

Portable weirs are usually small and commonly are made of sheet metal suitably reinforced. They may have the weir scales fastened to the bulkhead and, if there is a scale on each side of the notch, the weir can be leveled from the water surface.

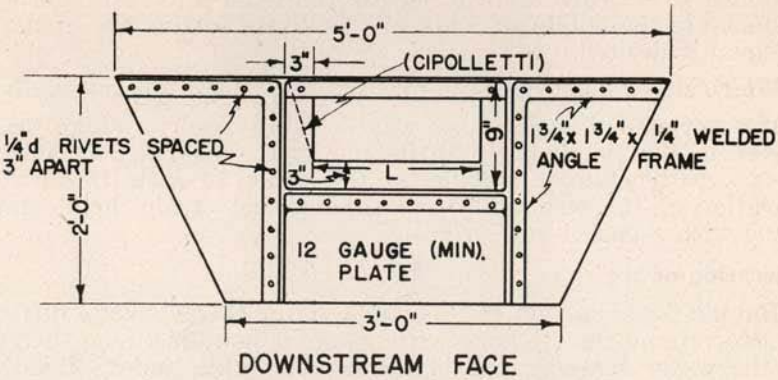
Free-flow conditions can be obtained by setting the weir at an elevation that will give free fall and then building up the banks above the weir; or, if there is excess grade below the weir location, the weir may be set low and the ditch below deepened to obtain the same effect.

Weir Scales or Gauges

The weir scale consists of a strip of wood or metal graduated in inches and fractions, feet and decimals, or directly in units of flow or discharge per minute. A scale graduated directly in units of flow will fit all weirs of the same design and size when operated under standard conditions but will not fit another weir of a different design, or of a different crest length.

The scale or gauge may be set in the weir pond as stated under "standard conditions" or may be set in a stilling well or box at the side of the pond. The stilling well is connected to the weir pond by a small pipe set below the water level. The function of the stilling well is to present a water surface at the same elevation as the water surface of the weir pond completely without turbulence or surges. The connecting pipe must be small in comparison to the area of the well or it will transmit surges. The pipe must be kept freely open or the well will not give a reliable reading.

The practice of reading the head by holding a rule on the crest and allowing the velocity of the water to "pile up" on the rule is not recommended although, with a rule of the right proportion and operated by an expert, it gives very close results. If the rule is not of the proper width or leans from the vertical, the reading will not be correct. Gauges are not read directly on the crest of the weir for the reason that the surface of the water has a decided curve downward as it approaches the weir.



MEASURABLE FLOW IN C.F.S. (APP).		
L	RECTANGULAR	CIPOLLETTI
12"	0.2 TO 0.65	0.2 TO 0.65
18"	0.3 TO 1.7	0.35 TO 1.8
24"	0.45 TO 2.3	0.45 TO 2.4

Figure 4.—Portable weir bulkhead for rectangular or Cipolletti notches.

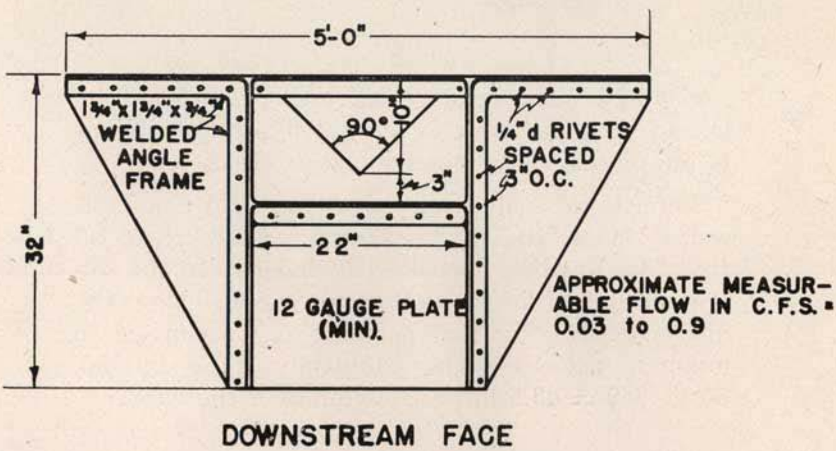


Figure 5.—Portable 90° V-notch weir.

If the scale is to be mounted on the weir bulkhead, it should be fastened to a board slightly longer than the scale and the board fastened to the bulkhead. This will facilitate setting the gauge and removal if desired.

Weir gauges must be set accurately and checked occasionally.

If a permanent scale is not wanted at the weir, a stake may be driven in the weir pond with its top at the elevation of the weir crest, or a block may be nailed to the bulkhead with its top at the elevation of the weir crest and the reading of the head may be made with a pocket rule or scale.

Operation of Weirs

Having made and set the weir and gauge there is little difficulty in determining the discharge. If a gauge is installed, read the gauge at the water surface, look in the correct table under "Head" for that reading, and carry over to the right to the column headed by the length of crest of the weir you are using, and the discharge in cubic feet per second will be found. If the discharge is desired in Idaho miner's inches, multiply by 50. Fifty Idaho miner's inches equal 1 cubic foot per second (c.f.s.).

Be sure to have the right table and the right weir crest length.

Be sure to find the head (H) in the same units in which the measurement of the head was made. Commercial weir scales commonly are made in feet and decimals and most rules are in inches and fractions. Heads in all tables are given both in feet and decimals and in inches and fractions.

Example: The head on an 18-inch (1.5′) crest length Cipolletti weir is read at 3¾ inches. What is the discharge in miner's inches (Idaho)?

Refer to table 5, the discharge table for Cipolletti weirs. Under "In." of the column headed "Head H" find 3¾. Reading opposite this head from the column headed "1.5 feet" is the figure .869. This is the discharge in cubic feet per second. To convert to miner's inches (Idaho) multiply c.f.s. by 50. $50 \times .869 = 43.5$ inches flowing over the weir.

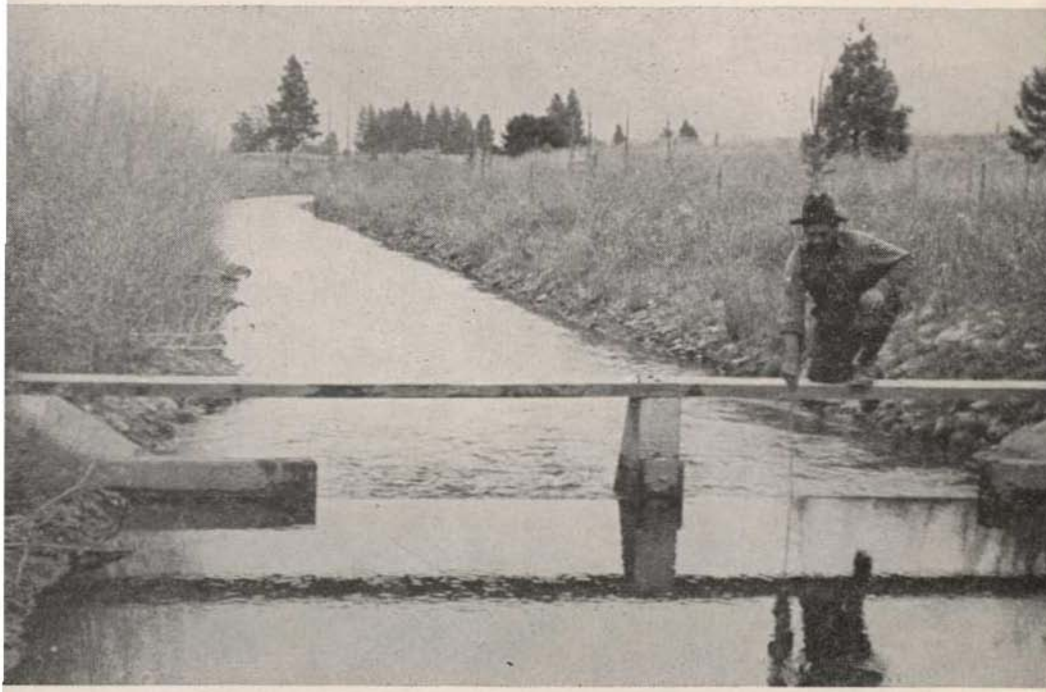


Figure 6.—The operator is measuring the water over a double rectangular weir by the "pile-up" method. This method is not recommended due to the difficulty in getting an accurate head reading. Rather, the head should be measured in still water away from the weir notch.

Advantages of Weirs

Weirs are simple, cheap, and reliable. They require only one reading of the head to determine the discharge. They are not cloggd easily by moss and floating trash.

Disadvantages of Weirs

Weirs require an excess fall in the stream equal to the head of the largest stream to be measured.

Silt accumulates in the weir pond making its cleaning necessary for accurate measurement.

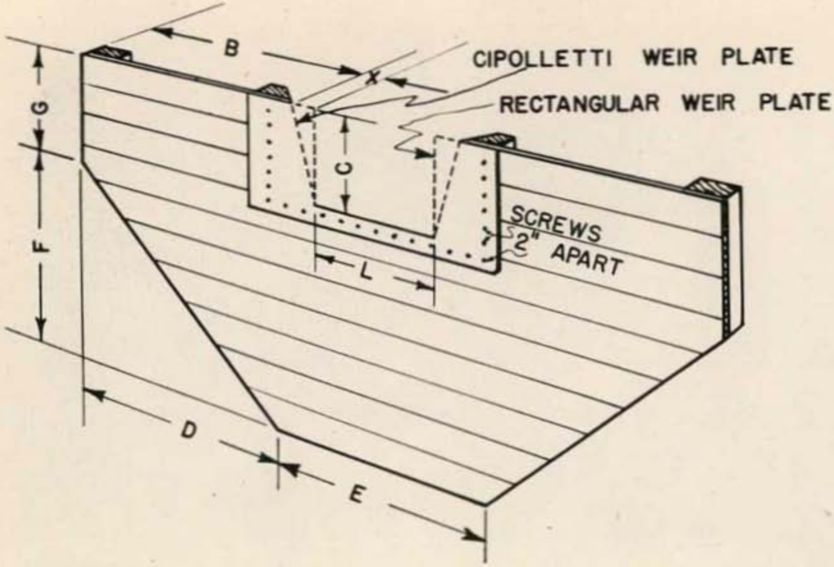


Figure 7.—Bulkhead for rectangular or Cipolletti weirs . . . suitable for medium and heavy soils.

Table 2.—Symbol dimensions and capacities for weir bulkhead shown in Figure 7.

Crest length L	Recommended range of measurement in C.f.s.		Symbol dimensions						
			B	C	D	E	F	G	X
ft.	Rectangular	Cipolletti	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	in.
1.0	.2 to .6	.2 to .6	1 10	8	1 6	2	1 6	10	2
1.5	.3 to 1.7	.3 to 1.8	2 7	1	2 3	2 8	2 3	1 1	3
2.0	.4 to 3.5	.4 to 3.7	3 2½	1 2	2 11	3 2	2 11	1 1	3½
3.0*	.6 to 9.5	.6 to 10.0	4 7½	1 6	4 2	4 8	4 2	1 4	4½
4.0*	.8 to 19.5	.9 to 20.7	6 2	2	5 6	6 4	5 6	1 10	6

*Requires heavier construction than shown in drawing.

The Rectangular Weir

The rectangular weir, as its name suggests, is a weir whose crest is horizontal and whose sides are perpendicular. It is the oldest form of measuring weir and is the most easily farm-made.

Table 4 gives the discharges over rectangular weirs with complete contractions.

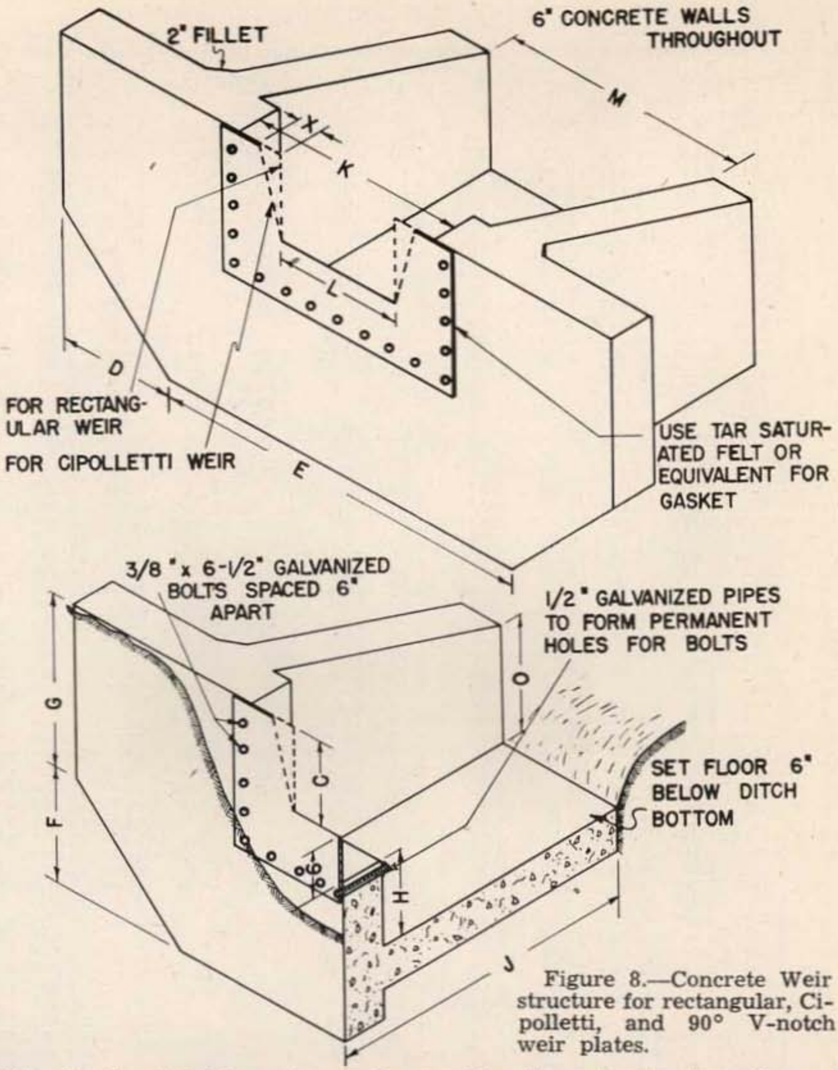


Figure 8.—Concrete Weir structure for rectangular, Cipolletti, and 90° V-notch weir plates.

Table 3.—Symbol dimensions and capacities for weir structure shown in Figure 8.

Crest length L ft.	Recommended range of measurement in C.f.s.		Symbol dimensions										
	Rectangular	Cipolletti	C=H ft. in.	D ft. in.	E ft. in.	F ft. in.	G ft. in.	J ft. in.	K ft. in.	M ft. in.	N ft. in.	O ft. in.	X in.
For Rectangular and Cipolletti Weirs													
1.0	.2 to .6	.2 to .6	8	0	5 8	0	2 7	3	2	2 6	10	1 4	2
1.5	.3 to 1.7	.3 to 1.8	1	1 4	4 6	1 4	2	3 6	2 6	3	10	1 4	3
2.0	.4 to 3.5	.4 to 3.7	1 2	2	5	2	2	4	3	3 6	1	1 6	3½
3.0*	.6 to 9.5	.6 to 10.0	1 6	2 6	7	2 6	2 6	4 6	4 4	5	1 6	2	4½
4.0*	.8 to 19.5	.9 to 20.7	2	3 10	8 4	3 10	2 10	5	5 6	6	2	2 6	6
For 90° V-Notch Weirs													
2.0	.02 to 1.5		1	1 6	5	1 6	2 8	3 6	2 6	3	10	1 4	
3.0*	.02 to 4.0		1 6	2 2	6 2	2 2	3 4	4	3 6	4	1	1 6	

*Use 6" x 6" No. 12 wire mesh reinforcing or equivalent.

Table 4.—Discharge table for rectangular weirs having complete contractions.**

Head H		Discharge, Q, in cubic feet per second				
		Crest length				
Ft.	or In.	1.0 ft.	1.5 ft.	2.0 ft	3.0 ft.	4.0 ft.
0.10	1 3/16	0.105	0.158	0.212	0.319	0.427
0.11	1 5/16	0.121	0.182	0.244	0.367	0.491
0.12	1 7/16	0.137	0.207	0.277	0.418	0.559
0.13	1 9/16	0.155	0.233	0.312	0.470	0.629
0.14	1 11/16	0.172	0.260	0.348	0.524	0.701
0.15	1 13/16	0.191	0.288	0.385	0.581	0.776
0.16	1 15/16	0.210	0.316	0.423	0.638	0.854
0.17	2 1/16	0.229	0.346	0.463	0.698	0.934
0.18	2 3/16	0.249	0.376	0.504	0.760	1.02
0.19	2¼	0.270	0.407	0.546	0.823	1.10
0.20	2⅜	0.291	0.439	0.588	0.887	1.19
0.21	2½	0.312	0.472	0.632	0.954	1.28
0.22	2⅝	0.335	0.505	0.677	1.02	1.37
0.23	2¾	0.358	0.539	0.723	1.09	1.46
0.24	2⅞	0.380	0.574	0.769	1.16	1.55
0.25	3	0.404	0.609	0.817	1.23	1.65
0.26	3⅛	0.428	0.646	0.865	1.31	1.75
0.27	3¼	0.452	0.682	0.914	1.38	1.85
0.28	3⅜	0.477	0.720	0.965	1.46	1.95
0.29	3½	0.502	0.758	1.02	1.53	2.05
0.30	3⅝	0.527	0.796	1.07	1.61	2.16
0.31	3¾	0.553	0.836	1.12	1.69	2.26
0.32	3 13/16	0.580	0.876	1.18	1.77	2.37
0.33	3 15/16	0.606	0.916	1.23	1.86	2.48
0.34	4 1/16	0.634*	0.957	1.28	1.94	2.60
0.35	4 3/16	0.661*	0.999	1.34	2.02	2.71
0.36	4 5/16	0.688*	1.04	1.40	2.11	2.82
0.37	4 7/16	0.717*	1.08	1.45	2.20	2.94
0.38	4 9/16	0.745*	1.13	1.51	2.28	3.06
0.39	4 11/16	0.774*	1.17	1.57	2.37	3.18
0.40	4 13/16	0.804*	1.21	1.63	2.46	3.30
0.41	4 15/16	0.833*	1.26	1.69	2.55	3.42
0.42	5 1/16	0.863*	1.30	1.75	2.65	3.54
0.43	5 3/16	0.893*	1.35	1.81	2.74	3.67
0.44	5¼	0.924*	1.40	1.88	2.83	3.80
0.45	5⅜	0.955*	1.44	1.94	2.93	3.93
0.46	5½	0.986*	1.49	2.00	3.03	4.05
0.47	5⅝	1.02*	1.54	2.07	3.12	4.18
0.48	5¾	1.05*	1.59	2.13	3.22	4.32
0.49	5⅞	1.08*	1.64	2.20	3.32	4.45
0.50	6	1.11*	1.68	2.26	3.42	4.58
0.51	6⅛	1.15*	1.73*	2.33	3.52	4.72
0.52	6¼	1.18*	1.78*	2.40	3.62	4.86
0.53	6⅜	1.21*	1.84*	2.46	3.73	4.99
0.54	6½	1.25*	1.89*	2.53	3.83	5.13
0.55	6⅝	1.28*	1.94*	2.60	3.94	5.27
0.56	6¾	1.31*	1.99*	2.67	4.04	5.42
0.57	6 13/16	1.35*	2.04*	2.74	4.15	5.56
0.58	6 15/16	1.38*	2.09*	2.81	4.26	5.70
0.59	7 1/16	1.42*	2.15*	2.88	4.36	5.85
0.60	7 3/16	1.45*	2.20*	2.96	4.47	6.00
0.61	7 5/16	1.49*	2.25*	3.03	4.59	6.14
0.62	7 7/16	1.52*	2.31*	3.10	4.69	6.29
0.63	7 9/16	1.56*	2.36*	3.17	4.81	6.44
0.64	7 11/16	1.60*	2.42*	3.25	4.92	6.59
0.65	7 13/16	1.63*	2.47*	3.32	5.03	6.75
0.66	7 15/16	1.67*	2.53*	3.40	5.15	6.90
0.67	8 1/16	1.71*	2.59*	3.47*	5.26	7.05
0.68	8 3/16	1.74*	2.64*	3.56*	5.38	7.21
0.69	8¼	1.78*	2.70*	3.63*	5.49	7.36
0.70	8⅜	1.82*	2.76*	3.71*	5.61	7.52
0.71	8½	1.86*	2.81*	3.78*	5.73	7.68
0.72	8⅝	1.90*	2.87*	3.86*	5.85	7.84
0.73	8¾	1.93*	2.93*	3.94*	5.97	8.00
0.74	8⅞	1.97*	2.99*	4.02*	6.09	8.17
0.75	9	2.01*	3.05*	4.10*	6.21	8.33
0.76	9⅛	2.05*	3.11*	4.18*	6.33	8.49
0.77	9¼	2.09*	3.17*	4.26*	6.45	8.66
0.78	9⅜	2.13*	3.23*	4.34*	6.58	8.82
0.79	9½	2.17*	3.29*	4.42*	6.70	8.99
0.80	9⅝	2.21*	3.35*	4.51*	6.83	9.16
0.81	9¾	2.25*	3.41*	4.59*	6.95	9.33
0.82	9 13/16	2.29*	3.47*	4.67*	7.08	9.50
0.83	9 15/16	2.33*	3.54*	4.75*	7.21	9.67
0.84	10 1/16	2.37*	3.60*	4.84*	7.33	9.84
0.85	10 3/16	2.41*	3.66*	4.92*	7.46	10.01
0.86	10 5/16	2.46*	3.72*	5.01*	7.59	10.19
0.87	10 7/16	2.50*	3.79*	5.10*	7.72	10.36
0.88	10 9/16	2.54*	3.85*	5.18*	7.85	10.54
0.89	10 11/16	2.58*	3.92*	5.27*	7.99	10.71
0.90	10 13/16	2.62*	3.98*	5.35*	8.12	10.89
0.91	10 15/16	2.67*	4.05*	5.44*	8.25	11.07
0.92	11 1/16	2.71*	4.11*	5.53*	8.38	11.25
0.93	11 3/16	2.75*	4.18*	5.62*	8.52	11.43
0.94	11¼	2.79*	4.24*	5.71*	8.65	11.61
0.95	11⅜	2.84*	4.31*	5.80*	8.79	11.79
0.96	11½	2.88*	4.37*	5.89*	8.93	11.98
0.98	11⅝	2.93*	4.44*	5.98*	9.06	12.16
0.98	11¾	2.97*	4.51*	6.07*	9.20	12.34
0.99	11⅞	3.01*	4.57*	6.15*	9.34	12.53
1.00	12	3.06*	4.64*	6.25*	9.48	12.72
1.01	12⅛	....	4.71*	6.34*	9.62*	12.91
1.02	12¼	....	4.78*	6.43*	9.76*	13.10
1.03	12⅜	....	4.85*	6.52*	9.90*	13.28
1.04	12½	....	4.92*	6.62*	10.04*	13.47
1.05	12⅝	....	4.98*	6.71*	10.18*	13.66
1.06	12¾	....	5.05*	6.80*	10.32*	13.85
1.07	12 13/16	....	5.12*	6.90*	10.46*	14.04
1.08	12 15/16	....	5.20*	6.99*	10.61*	14.24
1.09	13 1/16	....	5.26*	7.09*	10.75*	14.43
1.10	13 3/16	....	5.34*	7.19*	10.90*	14.64
1.11	13 5/16	....	5.41*	7.28*	11.04*	14.83
1.12	13 7/16	....	5.48*	7.38*	11.19*	15.03
1.13	13 9/16	....	5.55*	7.47*	11.34*	15.22
1.14	13 11/16	....	5.62*	7.57*	11.48*	15.42
1.15	13 13/16	....	5.69*	7.66*	11.64*	15.62
1.16	13 15/16	....	5.77*	7.76*	11.79*	15.82
1.17	14 1/16	....	5.84*	7.86*	11.94*	16.02
1.18	14 3/16	....	5.91*	7.96*	12.09*	16.23
1.19	14¼	....	5.98*	8.06*	12.24*	16.43
1.20	14⅜	....	6.06*	8.16*	12.39*	16.63
1.21	14½	....	6.13*	8.26*	12.54*	16.83
1.22	14⅝	....	6.20*	8.35*	12.69*	17.03
1.23	14¾	....	6.28*	8.46*	12.85*	17.25
1.24	14⅞	....	6.35*	8.56*	12.99*	17.45
1.25	15	....	6.43*	8.66*	13.14*	17.65
1.26	15⅛	....	....	....	13.30*	17.87
1.27	15¼	....	....	....	13.45*	18.07
1.28	15⅜	....	....	....	13.61*	18.28
1.29	15½	....	....	....	13.77*	18.50
1.30	15⅝	....	....	....	13.93*	18.71
1.31	15¾	....	....	....	14.09*	18.92
1.32	15 13/16	....	....	....	14.24*	19.12
1.33	15 15/16	....	....	....	14.40*	19.34
1.34	16 1/16	....	....	....	14.56*	19.55*
1.35	16 3/16	....	....	....	14.72*	19.77*
1.36	16 5/16	....	....	....	14.88*	19.98*
1.37	16 7/16	....	....	....	15.04*	20.20*
1.38	16 9/16	....	....	....	15.20*	20.42*
1.39	16 11/16	....	....	....	15.36*	20.64*
1.40	16 13/16	....	....	....	15.53*	20.86*
1.41	16 15/16	....	....	....	15.69*	21.08*
1.42	17 1/16	....	....	....	15.85*	21.29*
1.43	17 3/16	....	....	....	16.02*	21.52*
1.44	17¼	....	....	....	16.19*	21.74*
1.45	17⅜	....	....	....	16.34*	21.96*
1.46	17½	....	....	....	16.51*	22.18*
1.47	17⅝	....	....	....	16.68*	22.41*
1.48	17¾	....	....	....	16.85*	22.64*
1.49	17⅞	....	....	....	17.01*	22.85*
1.50	18	....	....	....	17.17*	23.08*

****Computed from the formula** $Q=3.247LH^{1.48}-\left(\frac{0.566L^{1.8}}{1+2L^{1.8}}\right)H^{1.9}$

*Discharges are for heads above ⅓ L. Special precautions must be taken for complete contractions for these discharges to be accurate.

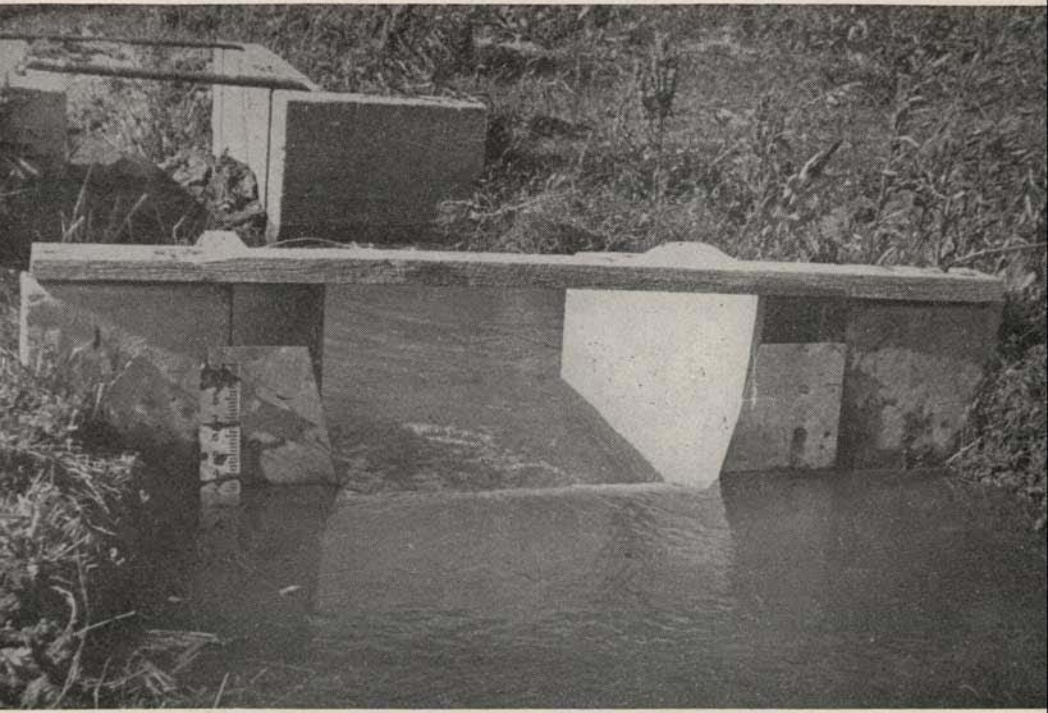


Figure 9.—Concrete structures like this Cipolletti weir near Caldwell, Idaho, are more expensive but longer lived than the ordinary wooden structures.

The Cipolletti Weir

The Cipolletti weir differs from the rectangular in that its sides slope outwardly 1 to 4 (1 inch horizontally to 4 inches vertically). It is the most common weir in general use in Idaho, although it is no more accurate nor convenient than the rectangular weir. It is named after Cesare Cipolletti, the Italian engineer who first proposed its use.

Discharges over Cipolletti weirs with complete contractions are given in Table 5.

The 90° Triangular, or V-Notch Weir

The 90° V-Notch weir has no crest length as the sloping sides come together to form the crest. Each side has an angle of 45° with the vertical or horizontal, making a total notch angle of 90°.

The advantage of the V-notch over other weirs is its ability to measure small flows accurately. Considering the recommendation that the minimum head to be measured over a weir is 2″, this is readily evident by checking the weir discharge tables.

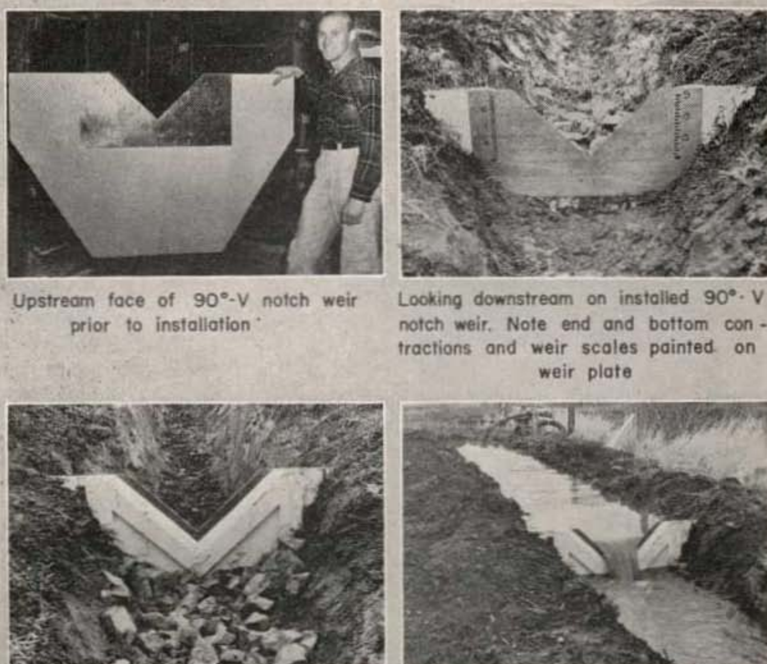
Table 5. Discharge table for Cipolletti weirs with complete contractions.**

Head H		Discharge, Q, in cubic feet per second				
		Crest length				
Ft.	or In.	1.0 ft.	1.5 ft.	2.0 ft	3.0 ft.	4.0 ft.
0.10	1 3/16	0.107	0.160	0.214	0.321	0.429
0.11	1 5/16	0.123	0.185	0.246	0.370	0.494
0.12	1 7/16	0.140	0.210	0.280	0.421	0.562
0.13	1 9/16	0.158	0.237	0.316	0.474	0.632
0.14	1 11/16	0.177	0.264	0.352	0.528	0.706
0.15	1 13/16	0.195	0.293	0.390	0.586	0.782
0.16	1 15/16	0.216	0.322	0.430	0.644	0.860
0.17	2 1/16	0.237	0.353	0.470	0.705	0.941
0.18	2 3/16	0.258	0.384	0.512	0.768	1.024
0.19	2 1/4	0.280	0.417	0.555	0.832	1,110
0.20	2 3/8	0.302	0.450	0.599	0.898	1.20
0.21	2 1/2	0.324	0.484	0.644	0.966	1.29
0.22	2 5/8	0.349	0.519	0.691	1.04	1.38
0.23	2 3/4	0.374	0.555	0.739	1.11	1.47
0.24	2 7/8	0.397	0.591	0.786	1.18	1.57
0.25	3	0.423	0.628	0.836	1.25	1.67
0.26	3 1/8	0.449	0.667	0.886	1.33	1.77
0.27	3 1/4	0.475	0.705	0.937	1.40	1.87
0.28	3 3/8	0.502	0.745	0.990	1.48	1.97
0.29	3 1/2	0.529	0.785	1.04	1.56	2.08
0.30	3 5/8	0.557	0.827	1.10	1.64	2.19
0.31	3 3/4	0.586	0.869	1.15	1.73	2.30
0.32	3 13/16	0.615	0.911	1.21	1.81	2.41
0.33	3 15/16	0.644	0.954	1.27	1.89	2.52
0.34	4 1/16	0.675°	1.00	1.32	1.98	2.64
0.35	4 3/16	0.705°	1.04	1.38	2.07	2.75
0.36	4 5/16	0.735°	1.09	1.44	2.16	2.87
0.37	4 7/16	0.767°	1.13	1.50	2.25	2.99
0.38	4 9/16	0.799°	1.18	1.57	2.34	3.11
0.39	4 11/16	0.832°	1.23	1.63	2.43	3.24
0.40	4 13/16	0.866°	1.28	1.69	2.53	3.36
0.41	4 15/16	0.899°	1.32	1.76	2.62	3.49
0.42	5 1/16	0.932°	1.37	1.82	2.72	3.61
0.43	5 3/16	0.967°	1.42	1.89	2.81	3.74
0.44	5 1/4	1.00°	1.47	1.95	2.91	3.87
0.45	5 3/8	1.04°	1.53	2.02	3.01	4.01
0.46	5 1/2	1.07°	1.58	2.09	3.11	4.14
0.47	5 5/8	1.11°	1.63	2.16	3.21	4.28
0.48	5 3/4	1.15°	1.68	2.23	3.32	4.41
0.49	5 7/8	1.18°	1.74	2.30	3.42	4.55
0.50	6	1.22°	1.79	2.37	3.53	4.69
0.51	6 1/8	1.26°	1.85°	2.44	3.64	4.83
0.52	6 1/4	1.30°	1.90°	2.51	3.74	4.97
0.53	6 3/8	1.34°	1.96°	2.59	3.85	5.12
0.54	6 1/2	1.38°	2.02°	2.66	3.96	5.26
0.55	6 5/8	1.42°	2.07°	2.74	4.07	5.41
0.56	6 3/4	1.46°	2.13°	2.81	4.18	5.56
0.57	6 13/16	1.50°	2.19°	2.89	4.30	5.71
0.58	6 15/16	1.54°	2.25°	2.97	4.41	5.86
0.59	7 1/16	1.58°	2.31°	3.05	4.53	6.01
0.60	7 3/16	1.62°	2.37°	3.13	4.64	6.17
0.61	7 5/16	1.67°	2.43°	3.20	4.76	6.32
0.62	7 7/16	1.71°	2.49°	3.28	4.88	6.47
0.63	7 9/16	1.75°	2.55°	3.37	5.00	6.63
0.64	7 11/16	1.80°	2.62°	3.45	5.12	6.79
0.65	7 13/16	1.84°	2.68°	3.53	5.24	6.95
0.66	7 15/16	1.89°	2.75°	3.61	5.36	7.11
0.67	8 1/16	1.93°	2.81°	3.70°	5.48	7.28
0.68	8 3/16	1.98°	2.87°	3.79°	5.61	7.44
0.69	8 1/4	2.02°	2.94°	3.87°	5.73	7.61
0.70	8 3/8	2.07°	3.01°	3.95°	5.86	7.77
0.71	8 1/2	2.12°	3.07°	4.04°	5.99	7.94
0.72	8 5/8	2.16°	3.14°	4.13°	6.12	8.11
0.73	8 3/4	2.21°	3.21°	4.22°	6.24	8.28
0.74	8 7/8	2.26°	3.28°	4.31°	6.38	8.45
0.75	9	2.31°	3.35°	4.40°	6.51	8.62
0.76	9 1/8	2.36°	3.42°	4.49°	6.64	8.80
0.77	9 1/4	2.41°	3.49°	4.58°	6.77	8.97
0.78	9 3/8	2.46°	3.56°	4.67°	6.90	9.15
0.79	9 1/2	2.51°	3.63°	4.76°	7.04	9.33
0.80	9 5/8	2.56°	3.70°	4.85°	7.18	9.51

Head H		Discharge, Q, in cubic feet per second				
		Crest length				
Ft.	or In.	1.0 ft.	1.5 ft.	2.0 ft	3.0 ft.	4.0 ft.
0.81	9 3/4	2.61°	3.77°	4.95°	7.31	9.69
0.82	9 13/16	2.66°	3.84°	5.04°	7.45	9.87
0.83	9 15/16	2.71°	3.92°	4.14°	7.59	10.05
0.84	10 1/16	2.77°	3.99°	5.23°	7.73	10.23
0.85	10 3/16	2.82°	4.07°	5.33°	7.87	10.42
0.86	10 5/16	2.87°	4.14°	5.43°	8.01	10.60
0.87	10 7/16	2.93°	4.22°	5.52°	8.15	10.79
0.88	10 9/16	2.98°	4.29°	5.62°	8.30	10.98
0.89	10 11/16	3.04°	4.37°	5.72°	8.44	11.17
0.90	10 13/16	3.09°	4.45°	5.82°	8.59	11.36
0.91	10 15/16	3.15°	4.53°	5.92°	8.73	11.55
0.92	11 1/16	3.20°	4.60°	6.02°	8.88	11.74
0.93	11 3/16	3.26°	4.68°	6.13°	9.03	11.94
0.94	11 1/4	3.32°	4.76°	6.23°	9.17	12.13
0.95	11 3/8	3.37°	4.84°	6.33°	9.32	12.33
0.96	11 1/2	3.43°	4.92°	6.44°	9.48	12.53
0.97	11 5/8	3.49°	5.00°	6.55°	9.62	12.72
0.98	11 3/4	3.55°	5.09°	6.64°	9.78	12.92
0.99	11 7/8	3.61°	5.17°	6.75°	9.93	13.12
1.00	12	3.67°	5.25°	6.86°	10.08	13.32
1.01	12 1/8	....	5.33°	6.96°	10.24°	13.53
1.02	12 1/4	....	5.42°	7.07°	10.40°	13.73
1.03	12 3/8	....	5.50°	7.18°	10.55°	13.94
1.04	12 1/2	....	5.59°	7.29°	10.71°	14.15
1.05	12 5/8	....	5.67°	7.40°	10.87°	14.35
1.06	12 3/4	....	5.76°	7.51°	11.03°	14.56
1.07	12 13/16	....	5.84°	7.62°	11.18°	14.76
1.08	12 15/16	....	5.93°	7.73°	11.35°	14.98
1.09	13 1/16	....	6.02°	7.84°	11.51°	15.19
1.10	13 3/16	....	6.11°	7.96°	11.68°	15.41
1.11	13 5/16	....	6.20°	8.07°	11.84°	15.62
1.12	13 7/16	....	6.29°	8.18°	12.00°	15.84
1.13	13 9/16	....	6.37°	8.29°	12.16°	16.04
1.14	13 11/16	....	6.46°	8.41°	12.33°	16.26
1.15	13 13/16	....	6.56°	8.53°	12.50°	16.48
1.16	13 15/16	....	6.65°	8.65°	12.67°	16.70
1.17	14 1/16	....	6.74°	8.76°	12.84°	16.93
1.18	14 3/16	....	6.83°	8.88°	13.01°	17.15
1.19	14 1/4	....	6.93°	9.00°	13.18°	17.37
1.20	14 3/8	....	7.02°	9.12°	13.35°	17.59
1.21	14 1/2	....	7.11°	9.24°	13.52°	17.81
1.22	14 5/8	....	7.20°	9.36°	13.69°	18.03
1.23	14 3/4	....	7.30°	9.48°	13.87°	18.27
1.24	14 7/8	....	7.40°	9.60°	14.04°	18.49
1.25	15	....	7.49°	9.72°	14.21°	18.71
1.26	15 1/8	....	....	....	14.39°	18.95
1.27	15 1/4	....	....	....	14.56°	19.17
1.28	15 3/8	....	....	....	14.74°	19.41
1.29	15 1/2	....	....	....	14.92°	19.65
1.30	15 5/8	....	....	....	15.11°	19.88
1.31	15 3/4	....	....	....	15.29°	20.12
1.32	15 13/16	....	....	....	15.46°	20.34
1.33	15 15/16	....	....	....	15.64°	20.58
1.34	16 1/16	....	....	....	15.82°	20.82°
1.25	16 3/16	....	....	....	16.01°	21.06°
1.36	16 5/16	....	....	....	16.19°	21.29°
1.37	16 7/16	....	....	....	16.37°	21.53°
1.38	16 9/16	....	....	....	16.57°	21.78°
1.39	16 11/16	....	....	....	16.75°	22.02°
1.40	16 13/16	....	....	....	16.94°	22.27°
1.41	16 15/16	....	....	....	17.13°	22.51°
1.42	17 1/16	....	....	....	17.31°	22.75°
1.43	17 3/16	....	....	....	17.51°	23.01°
1.44	17 1/4	....	....	....	17.70°	23.26°
1.45	17 3/8	....	....	....	17.89°	23.50°
1.46	17 1/2	....	....	....	18.08°	23.75°
1.47	17 5/8	....	....	....	18.28°	24.01°
1.48	17 3/4	....	....	....	18.47°	24.26°
1.49	17 7/8	....	....	....	18.66°	24.50°
1.50	18	....	....	....	18.85°	24.75°

****Computed with the formula** $Q = 3.247LH^{1.48} - \left\{\frac{0.566L^{1.8}}{1 + 2L^{1.8}}\right\} H^{1.9} + 0.609H^{2.5}$

° Discharges are for heads above 1/3 L. Special precautions must be taken for complete contractions for these discharges to be accurate.



Upstream face of 90°-V notch weir prior to installation

Looking downstream on installed 90°-V notch weir. Note end and bottom contractions and weir scales painted on weir plate

Looking upstream on installed 90°-V notch weir. Note the gravel and rock protecting apron.

90°-V notch weir being used to measure a pump discharge

Figure 10.—This 90° V-notch weir structure is simple and easy to build and is satisfactory for heavy and medium textured soils. The V-notch is especially adapted to the accurate measurement of small flows.

The sides of the 90° V-notch weir may be determined readily with a carpenter's square as shown in Figure 11. The notch can be marked out by placing the point of the angle of the square at the point as selected for the bottom of the notch, and adjusting the square so that the same figures on both arms are at the edge of the board or metal plate. If the notch is then set with the upper edge level, the sides of the notch will have the same slope as required.

Table 7 gives the discharges over 90° triangular or V-notch weirs.

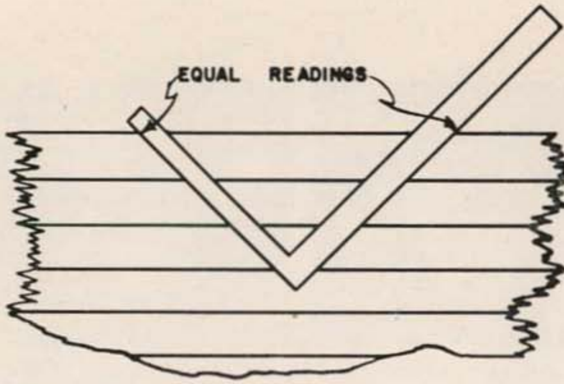


Figure 11.—Method of laying out 90° V-Notch with a steel square.

Table 7. Discharge table for 90° V-notch weirs with complete contractions computed from the formula $Q = 2.49H^{2.48}$

Head H Feet or	Head H Inches	Discharge Q Sec.-feet	Head H Feet or	Head H Inches	Discharge Q Sec.-feet	Head H Feet or	Head H Inches	Discharge Q Sec.-feet
0.10	1 3/16	0.008	.50	6	0.445	.90	10 13/16	1.92
.11	1 5/16	0.010	.51	6 1/8	0.468	.91	10 15/16	1.97
.12	1 7/16	0.012	.52	6 1/4	0.491	.92	11 1/16	2.02
.13	1 9/16	0.016	.53	6 3/8	0.515	.93	11 3/16	2.08
.14	1 11/16	0.019	.54	6 1/2	0.539	.94	11 1/4	2.13
.15	1 13/16	0.022	.55	6 5/8	0.564	.95	11 3/8	2.19
.16	1 15/16	0.026	.56	6 3/4	0.590	.96	11 1/2	2.25
.17	2 1/16	0.031	.57	6 13/16	0.617	.97	11 5/8	2.31
.18	2 3/16	0.035	.58	6 15/16	0.644	.98	11 3/4	2.37
.19	2 1/4	0.040	.59	7 1/16	0.672	.99	11 7/8	2.43
.20	2 3/8	0.046	.60	7 3/16	0.700	1.00	12	2.49
.21	2 1/2	0.052	.61	7 5/16	0.730	1.01	12 1/8	2.55
.22	2 5/8	0.058	.62	7 7/16	0.760	1.02	12 1/4	2.61
.23	2 3/4	0.065	.63	7 9/16	0.790	1.03	12 3/8	2.68
.24	2 7/8	0.072	.64	7 11/16	0.822	1.04	12 1/2	2.74
.25	3	0.080	.65	6 13/16	0.854	1.05	12 5/8	2.81
.26	3 1/8	0.088	.66	7 15/16	0.887	1.06	12 3/4	2.87
.27	3 1/4	0.096	.67	8 1/16	0.921	1.07	12 13/16	2.94
.28	3 3/8	0.106	.68	8 3/16	0.955	1.08	12 15/16	3.01
.29	3 1/2	0.115	.69	8 1/4	0.991	1.09	13 1/16	3.08
.30	3 5/8	0.125	.70	8 3/8	1.03	1.10	13 3/16	3.15
.31	3 3/4	0.136	.71	8 1/2	1.06	1.11	13 5/16	3.22
.32	3 13/16	0.147	.72	8 5/8	1.10	1.12	13 7/16	3.30
.33	3 15/16	0.159	.73	8 3/4	1.14	1.13	13 9/16	3.37
.34	4 1/16	0.171	.74	8 7/8	1.18	1.14	13 11/16	3.44
.35	4 3/16	0.184	.75	9	1.22	1.15	13 13/16	3.52
.36	4 5/16	0.197	.76	9 1/8	1.26	1.16	13 15/16	3.59
.37	4 7/16	0.211	.77	9 1/4	1.30	1.17	14 1/16	3.67
.38	4 9/16	0.225	.78	9 3/8	1.34	1.18	14 3/16	3.75
.39	4 11/16	0.240	.79	9 1/2	1.39	1.19	14 1/4	3.83
.40	4 13/16	0.256	.80	9 5/8	1.43	1.20	14 3/8	3.91
.41	4 15/16	0.272	.81	9 3/4	1.48	1.21	14 1/2	3.99
.42	5 1/16	0.289	.82	9 13/16	1.52	1.22	14 5/8	4.07
.43	5 3/16	0.306	.83	9 15/16	1.57	1.23	14 3/4	4.16
.44	5 1/4	0.324	.84	10 1/16	1.61	1.24	14 7/8	4.24
.45	5 3/8	0.343	.85	10 3/16	1.66	1.25	15	4.33
.46	5 1/2	0.362	.86	10 5/16	1.71			
.47	5 5/8	0.382	.87	10 7/16	1.76			
.48	5 3/4	0.403	.88	10 9/16	1.81			
.49	5 7/8	0.424	.89	10 11/16	1.86			

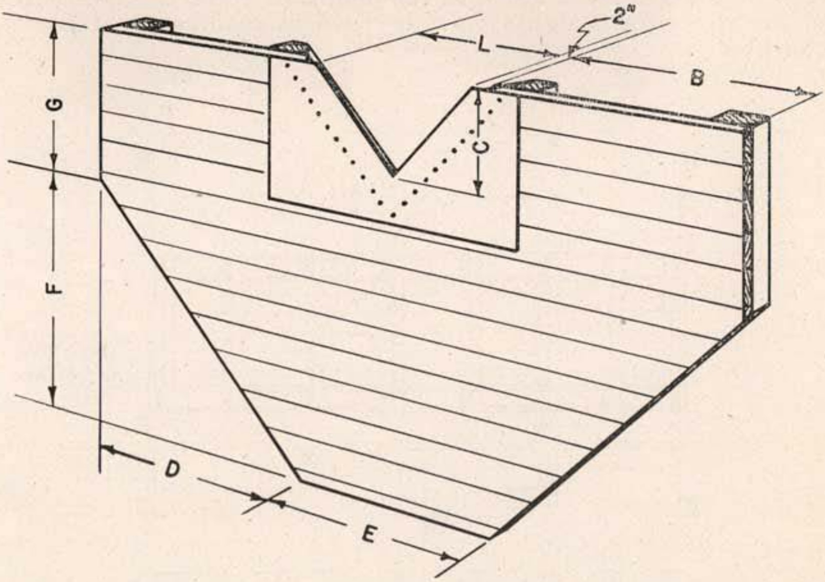


Figure 12.—90° V-notch weir suitable for medium and heavy soils.

Table 6. Symbol dimensions and capacities for weir structure shown in Figure 12.

Length L		Recommended range of measurement in	Symbol dimensions					
			B	C	D	E	F	G
Ft.	In.	C.f.s.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
1	4	.02 to .45	1 8	8	1 5	2 2	1 5	1 3
2		.02 to 1.5	2 10	1	2 8	2 8	2 8	1 6
3*		.02 to 4	4 7	1 6	4 6	3 6	4 6	2

* Requires heavier construction than shown in drawing.

The Suppressed Rectangular Weir

When it is desirable to place the measuring device in a flume or box not large enough to give complete end contractions, the suppressed rectangular weir may be used. This structure consists essentially of a uniform width rectangular flume and a vertical weir plate having a horizontal crest. The sides of the flume form the sides of the weir notch. Hence there are no end contractions on a suppressed rectangular weir.

Weir discharges fluctuate with the height of the crest and therefore, the weir crest heights must be used in reading the table of discharges.

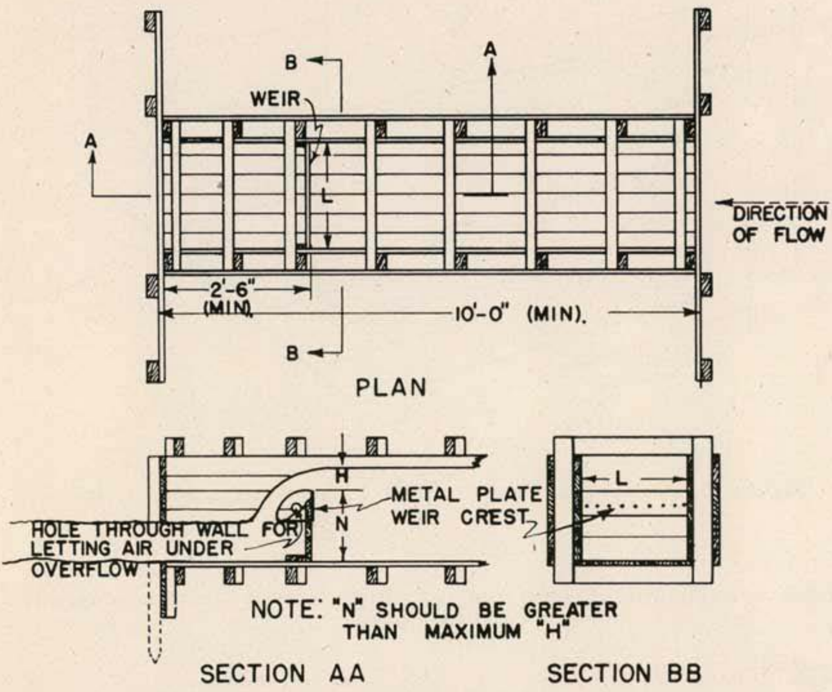


Figure 13.—Suppressed weir structure.

The length of the flume should be at least 10 feet and preferably over 10 times the weir crest length. Holes must be provided immediately below the weir crest to admit air under the sheet of falling water. Openings having an area of ½ square inch per foot length of crest are sufficient for heads up to 1.5 feet.*

Table 8* gives the discharges for rectangular suppressed weirs having various crest heights.

*Taken from *"Measuring Water for Irrigation,"* Bulletin 588, University of California, by J. E. Christiansen.

Table 8. Flow over rectangular suppressed weir.*

Head H		Discharge, Q, in cubic feet per second per foot of weir crest						
Feet or Inches		Weir Height						
		0.5 foot	0.75 foot	1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet
0.10	1 3/16	0.111	0.110	0.109	0.109	0.108	0.108	0.108
0.11	1 5/16	0.127	0.126	0.126	0.125	0.125	0.125	0.124
0.12	1 7/16	0.145	0.144	0.143	0.142	0.142	0.141	0.141
0.13	1 9/16	0.163	0.162	0.161	0.160	0.159	0.159	0.159
0.14	1 11/16	0.182	0.180	0.179	0.178	0.178	0.177	0.177
0.15	1 13/16	0.202	0.200	0.199	0.197	0.197	0.196	0.196
0.16	1 15/16	0.223	0.220	0.219	0.217	0.216	0.216	0.215
0.17	2 1/16	0.244	0.241	0.239	0.238	0.237	0.236	0.235
0.18	2 3/16	0.266	0.263	0.236	0.259	0.257	0.257	0.256
0.19	2 1/4	0.289	0.285	0.283	0.280	0.279	0.277	0.277
0.20	2 3/8	0.312	0.307	0.305	0.302	0.300	0.299	0.299
0.21	2 1/2	0.336	0.331	0.328	0.325	0.324	0.322	0.322
0.22	2 5/8	0.361	0.355	0.352	0.349	0.347	0.345	0.344
0.23	2 3/4	0.387	0.386	0.376	0.372	0.370	0.369	0.368
0.24	2 7/8	0.413	0.406	0.401	0.397	0.395	0.393	0.392
0.25	3	0.440	0.431	0.427	0.422	0.420	0.418	0.416
0.26	3 1/8	0.467	0.458	0.452	0.447	0.445	0.442	0.442
0.27	3 1/4	0.495	0.485	0.479	0.473	0.471	0.468	0.467
0.28	3 3/8	0.524	0.513	0.506	0.500	0.498	0.495	0.493
0.29	3 1/2	0.554	0.541	0.535	0.527	0.524	0.521	0.520
0.30	3 5/8	0.583	0.569	0.562	0.555	0.552	0.548	0.545
0.31	3 11/16	0.614	0.599	0.591	0.583	0.580	0.576	0.574
0.32	3 13/16	0.645	0.629	0.620	0.612	0.608	0.604	0.602
0.33	3 15/16	0.677	0.659	0.650	0.641	0.637	0.633	0.631
0.34	4 1/16	0.709	0.690	0.681	0.670	0.666	0.662	0.660
0.35	4 3/16	0.742	0.722	0.711	0.701	0.696	0.691	0.688
0.36	4 5/16	0.775	0.754	0.743	0.731	0.725	0.721	0.717
0.37	4 7/16	0.810	0.787	0.774	0.762	0.757	0.751	0.748
0.38	4 9/16	0.844	0.819	0.807	0.793	0.788	0.782	0.778
0.39	4 11/16	0.881	0.853	0.840	0.826	0.819	0.813	0.809
0.40	4 13/16	0.916	0.888	0.873	0.858	0.851	0.844	0.840
0.41	4 15/16	0.952	0.922	0.907	0.890	0.883	0.876	0.872
0.42	5 1/16	0.990	0.958	0.942	0.924	0.917	0.908	0.904
0.43	5 1/8	1.03	0.994	0.976	0.958	0.950	0.941	0.937
0.44	5 1/4	1.07	1.03	1.01	0.993	0.983	0.974	0.969
0.45	5 3/8	1.10	1.07	1.05	1.03	1.02	1.01	1.00
0.46	5 1/2	1.14	1.10	1.08	1.06	1.05	1.04	1.04
0.47	5 5/8	1.18	1.14	1.12	1.10	1.09	1.08	1.07
0.48	5 3/4	1.22	1.18	1.16	1.13	1.12	1.11	1.10
0.49	5 7/8	1.27	1.22	1.19	1.17	1.16	1.15	1.14
0.50	6	1.31	1.26	1.23	1.21	1.20	1.18	1.18
0.51	6 1/8	1.35	1.30	1.27	1.24	1.23	1.22	1.21
0.52	6 1/4	1.39	1.34	1.31	1.28	1.27	1.25	1.25
0.53	6 3/8	1.44	1.38	1.35	1.32	1.30	1.29	1.28
0.54	6 1/2	1.48	1.42	1.39	1.36	1.34	1.33	1.32
0.55	6 5/8	1.52	1.46	1.43	1.40	1.38	1.36	1.36
0.56	6 11/16	1.57	1.50	1.47	1.44	1.42	1.40	1.39
0.57	6 13/16	1.61	1.54	1.51	1.48	1.46	1.44	1.43
0.58	6 15/16	1.66	1.59	1.55	1.52	1.50	1.48	1.47
0.59	7 1/16	1.71	1.63	1.60	1.56	1.54	1.52	1.51
0.60	7 3/16	1.76	1.68	1.64	1.60	1.58	1.56	1.55
0.61	7 5/16	1.80	1.72	1.68	1.64	1.62	1.59	1.58
0.62	7 7/16	1.85	1.77	1.72	1.68	1.66	1.63	1.62
0.63	7 9/16	1.90	1.81	1.77	1.72	1.70	1.68	1.67
0.64	7 11/16	1.95	1.86	1.81	1.76	1.74	1.72	1.71
0.65	7 13/16	2.00	1.90	1.86	1.81	1.78	1.76	1.75
0.66	7 15/16	2.05	1.95	1.90	1.85	1.82	1.80	1.79
0.67	8 1/16	2.10	2.00	1.95	1.90	1.87	1.84	1.83
0.68	8 1/8	2.15	2.05	1.99	1.94	1.91	1.88	1.87
0.69	8 1/4	2.21	2.09	2.04	1.98	1.95	1.93	1.91
0.70	8 3/8	2.26	2.14	2.08	2.03	2.00	1.97	1.95
0.71	8 1/2	2.31	2.19	2.13	2.07	2.04	2.01	2.00
0.72	8 5/8	2.37	2.24	2.18	1.12	2.08	2.05	2.04
0.73	8 3/4	2.42	2.29	2.23	2.16	2.13	2.10	2.08
0.74	8 7/8	2.48	2.34	2.28	2.21	2.18	2.14	2.12
0.75	9	2.53	2.39	2.32	2.25	2.22	2.18	2.17
0.76	9 1/8	2.59	2.45	2.37	2.30	2.27	2.23	2.21
0.77	9 1/4	2.65	2.50	2.43	2.35	2.31	2.27	2.26
0.78	9 3/8	2.70	2.55	2.48	2.40	2.36	2.32	2.30
0.79	9 1/2	2.76	2.60	2.52	2.45	2.41	2.37	2.35
0.80	9 5/8	2.82	2.66	2.58	2.49	2.45	2.41	2.39
0.81	9 11/16	2.88	2.71	2.63	2.54	2.50	2.46	2.44
0.82	9 13/16	2.94	2.76	2.68	2.59	2.55	2.51	2.48
0.83	9 15/16	3.00	2.82	2.73	2.64	2.60	2.55	2.53
0.84	10 1/16	3.06	2.87	2.78	2.69	2.64	2.60	2.58

(Continued on page 22)

Table 8. Flow over rectangular suppressed weir.* (Continued)

Head H		Discharge, Q, in cubic feet per second per foot of weir crest						
		Weir Height						
Feet or Inches		0.5 foot	0.75 foot	1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet
0.85	10 3/16	3.12	2.93	2.84	2.74	2.69	2.65	2.62
0.86	10 5/16	3.18	2.99	2.89	2.79	2.74	2.69	2.67
0.87	10 7/16	3.25	3.04	2.94	2.84	2.80	2.74	2.72
0.88	10 9/16	3.31	3.10	3.00	2.90	2.84	2.79	2.76
0.89	10 11/16	3.37	3.16	3.05	2.95	2.89	2.84	2.81

*Computed from the simplified form of Rehbock's formula $Q=2/3mL\sqrt{2g}h^{3/2}$, where $m = 0.605+\frac{0.0028}{h}+0.08\frac{h}{P}$ and P = height of weir crest above bottom of channel approach.

The Submerged Orifice

The submerged orifice is a regularly shaped opening in a bulkhead through which the water flows, the level of the water surface both upstream and downstream from the bulkhead being above the top of the hole. The orifice should be rectangular and have sharp edges and complete contractions the same as a weir.

The head (denoted by h for the submerged orifice) causing the flow is obtained by subtracting the reading of the downstream water surface from the reading of the upstream water surface. The downstream gauge and the upstream gauge must be set on the same level. Measurements should not be made on flows giving an effective head of less than 2 inches.

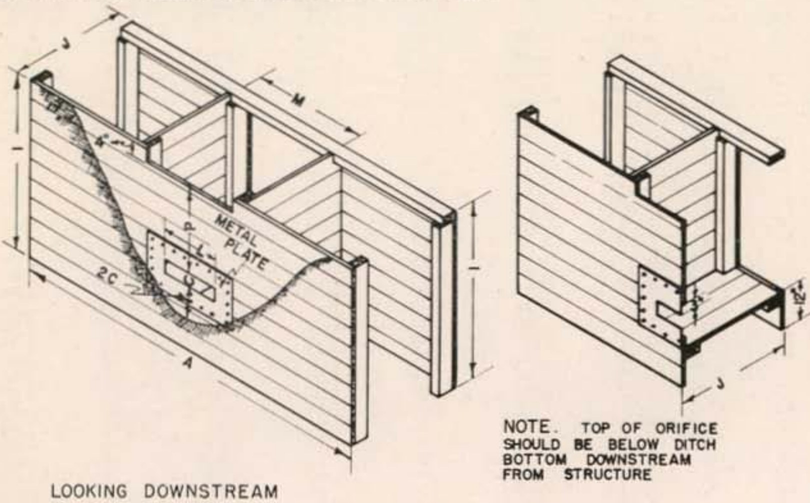


Figure 14.*—Submerged orifice structure.

Table 9.—Symbol dimensions and capacities for submerged orifice structure shown in Figure 14.

Size of orifice				Recommended range of measurement in C.f.s.	Symbol dimensions									
L		C	Area in		A		I		J		M		P	
Ft.	In.	in.	sq. ft.		Ft.	In.	Ft.	In.	Ft.	In	Ft.	In.	Ft.	In.
1		3	.25	.4 to 1.0	8	4	4		3		2	6	1	11
1	4	3	.33	.5 to 1.4	9	8	4		3		3		1	11
2		3	.50	.8 to 2.1	9	10	4	3	3		3	6	2	2
		4	.33	.5 to 1.4	9		4	4	3		2	6	2	
1	6	4	.50	.8 to 2.1	10		4	7	3		3		2	3
2	3	4	.75	1.0 to 3.2	11	3	4	10	3	6	3	6	2	6
1		6	.50	.8 to 2.1	10	6	5	1	3		2	6	2	3
1	6	6	.75	1.0 to 3.2	11	6	5	4	3	6	3		2	6
	*	6	1.00	1.5 to 4.3	12		5	4	3	6	3	6	2	6
3	*	6	1.50	2.3 to 6.5	14		5	10	4		4	6	3	
1	4*	9	1.00	1.5 to 4.3	12	6	5	11	3	6	3		2	6
2	*	9	1.50	2.3 to 6.5	14	6	6	7	4		3	6	3	
2	8*	9	2.00	3.0 to 8.7	16		7		4		4		3	6

* Requires heavier construction than shown in drawing.

Table 10. Discharge table for submerged orifices.*

Effective Head H		Discharge in cubic feet per second						
		Cross-secional area, A, of orifice						
In feet	In inches	0.25 sq.ft.	0.333 sq. ft.	0.50 sq.ft.	0.75 sq. ft.	1.00 sq. ft.	1.50 sq. ft.	2.00 sq. ft.
0.01	1/8	0.122	0.163	0.245	0.367	0.489	0.73	0.98
0.02	1/4	0.173	0.230	0.346	0.518	0.691	1.04	1.38
0.03	3/8	0.212	0.282	0.424	0.635	0.847	1.27	1.69
0.04	1/2	0.245	0.326	0.489	0.734	0.978	1.47	1.96
0.05	5/8	0.273	0.364	0.546	0.820	1.09	1.64	2.19
0.06	3/4	0.300	0.399	0.599	0.899	1.20	1.80	2.40
0.07	13/16	0.324	0.431	0.647	0.971	1.29	1.94	2.59
0.08	15/16	0.346	0.461	0.691	1.04	1.38	2.07	2.77
0.09	1 1/16	0.367	0.489	0.734	1.10	1.47	2.20	2.94
0.10	1 3/16	0.387	0.518	0.773	1.16	1.56	2.32	3.09
0.11	1 5/16	0.406	0.540	0.811	1.22	1.62	2.43	3.24
0.12	1 7/16	0.424	0.564	0.847	1.27	1.69	2.54	3.39
0.13	1 9/16	0.441	0.587	0.882	1.32	1.76	2.65	3.53
0.14	1 11/16	0.458	0.609	0.915	1.37	1.83	2.75	3.66
0.15	1 13/16	0.474	0.631	0.947	1.42	1.90	2.84	3.79
0.16	1 15/16	0.489	0.651	0.978	1.47	1.96	2.93	3.91
0.17	2 1/16	0.504	0.671	1.01	1.51	2.02	3.02	4.03
0.18	2 3/16	0.519	0.691	1.04	1.56	2.08	3.11	4.15
0.19	2 1/4	0.533	0.710	1.07	1.60	2.13	3.20	4.26
0.20	2 3/8	0.547	0.729	1.09	1.64	2.19	3.28	4.38
0.21	2 1/2	0.561	0.746	1.12	1.68	2.24	3.36	4.48
0.22	2 5/8	0.574	0.765	1.15	1.72	2.30	3.46	4.59
0.23	2 3/4	0.587	0.781	1.17	1.76	2.35	3.52	4.69
0.24	2 7/8	0.600	0.798	1.20	1.80	2.40	3.60	4.79
0.25	3	0.612	0.815	1.22	1.83	2.45	3.67	4.89
0.26	3 1/8	0.624	0.831	1.25	1.87	2.49	2.74	4.99
0.27	3 1/4	0.636	0.846	1.27	1.91	2.54	3.81	5.08
0.28	3 3/8	0.646	0.862	1.29	1.94	2.59	3.88	5.18
0.29	3 1/2	0.659	0.878	1.32	1.98	2.64	3.96	5.28
0.30	3 5/8	0.670	0.892	1.34	2.01	2.68	4.02	5.36
0.31	3 3/4	0.681	0.908	1.36	2.05	2.73	4.09	5.45
0.32	3 13/16	0.692	0.920	1.38	2.07	2.76	4.15	5.53
0.33	3 15/16	0.703	0.936	1.41	2.11	2.81	4.22	5.62
0.34	4 1/16	0.713	0.950	1.43	2.14	2.85	4.28	5.70
0.35	4 3/16	0.724	0.963	1.45	2.17	2.89	4.34	5.78
0.36	4 5/16	0.734	0.976	1.47	2.20	2.93	4.40	5.87
0.37	4 7/16	0.745	0.991	1.49	2.23	2.98	4.46	5.95
0.38	4 9/16	0.754	1.00	1.51	2.26	3.02	4.52	6.03
0.39	4 11/16	0.764	1.02	1.53	2.29	3.05	4.58	6.11
0.40	4 13/16	0.774	1.03	1.55	2.32	3.09	4.64	6.19
0.41	4 15/16	0.783	1.04	1.57	2.35	3.13	4.70	6.27
0.42	5 1/16	0.792	1.06	1.59	2.38	3.17	4.75	6.34
0.43	5 3/16	0.802	1.07	1.60	2.41	3.21	4.81	6.42
0.44	5 1/4	0.811	1.08	1.62	2.43	3.24	4.87	6.49
0.45	5 3/8	0.820	1.09	1.64	2.46	3.28	4.92	6.56
0.46	5 1/2	0.829	1.10	1.66	2.49	3.32	4.98	6.64
0.47	5 5/8	0.839	1.12	1.68	2.52	3.36	5.04	6.71
0.48	5 3/4	0.847	1.13	1.70	2.54	3.39	5.08	6.78
0.49	5 7/8	0.856	1.14	1.71	2.57	3.42	5.14	6.85
0.50	6	0.865	1.15	1.73	2.59	3.46	5.19	6.92
0.51	6 1/8	0.873	1.16	1.75	2.62	3.49	5.24	6.99
0.52	6 1/4	0.882	1.17	1.76	2.65	3.53	5.29	7.05
0.53	6 3/8	0.890	1.19	1.78	2.67	3.56	5.34	7.12
0.54	6 1/2	0.898	1.20	1.80	2.70	3.59	5.39	7.19
0.55	6 5/8	0.907	1.21	1.81	2.72	3.63	5.44	7.25
0.56	6 3/4	0.915	1.22	1.83	2.75	3.66	5.49	7.32
0.57	6 13/16	0.923	1.23	1.85	2.77	3.69	5.54	7.38
0.58	6 15/16	0.931	1.24	1.86	2.79	3.73	5.59	7.45
0.59	7 1/16	0.939	1.25	1.88	2.82	3.76	5.64	7.51
0.60	7 3/16	0.947	1.26	1.90	2.84	3.79	5.68	7.58
0.61	7 5/16	0.955	1.27	1.91	2.87	3.82	5.73	7.64
0.62	7 7/16	0.963	1.28	1.93	2.89	3.85	5.78	7.70
0.63	7 9/16	0.971	1.29	1.94	2.91	3.88	5.82	7.76
0.64	7 11/16	0.978	1.30	1.96	2.93	3.91	5.87	7.82
0.65	7 13/16	0.986	1.31	1.97	2.96	3.94	5.92	7.89
0.66	7 15/16	0.993	1.32	1.99	2.98	3.97	5.96	7.95
0.67	8 1/16	1.00	1.33	2.00	3.00	4.00	6.01	8.01
0.68	8 3/16	1.01	1.34	2.02	3.02	4.03	6.05	8.06
0.69	8 1/4	1.02	1.35	2.03	3.05	4.06	6.10	8.13
0.70	8 3/8	1.02	1.36	2.05	3.07	4.09	6.14	8.18
0.71	8 1/2	1.03	1.37	2.06	3.09	4.12	6.19	8.25
0.72	8 5/8	1.04	1.38	2.08	3.11	4.15	6.23	8.30
0.73	8 3/4	1.05	1.39	2.09	3.14	4.18	6.27	8.36
0.74	8 7/8	1.05	1.40	2.10	3.16	4.21	6.31	8.42
0.75	9	1.06	1.41	2.12	3.18	4.24	6.36	8.48
0.76	9 1/8	1.07	1.42	2.13	3.20	4.26	6.40	8.53
0.77	9 1/4	1.07	1.43	2.15	3.22	4.29	6.43	8.58
0.78	9 3/8	1.08	1.44	2.16	3.24	4.32	6.48	8.64
0.79	9 1/2	1.09	1.45	2.17	3.26	4.35	6.52	8.70
0.80	9 5/8	1.09	1.46	2.19	3.28	4.38	6.56	8.75

*Computed from the formulae $Q = 0.61\ A\sqrt{2gh}$.

The Parshall Measuring Flume

The Parshall flume combines many of the advantages of the weir and submerged orifice. There is no need for a pond above the flume as the velocity of approach has little effect on the accuracy of the measurement. It uses a small amount of head as it can have a high degree of submergence without the necessity of reading

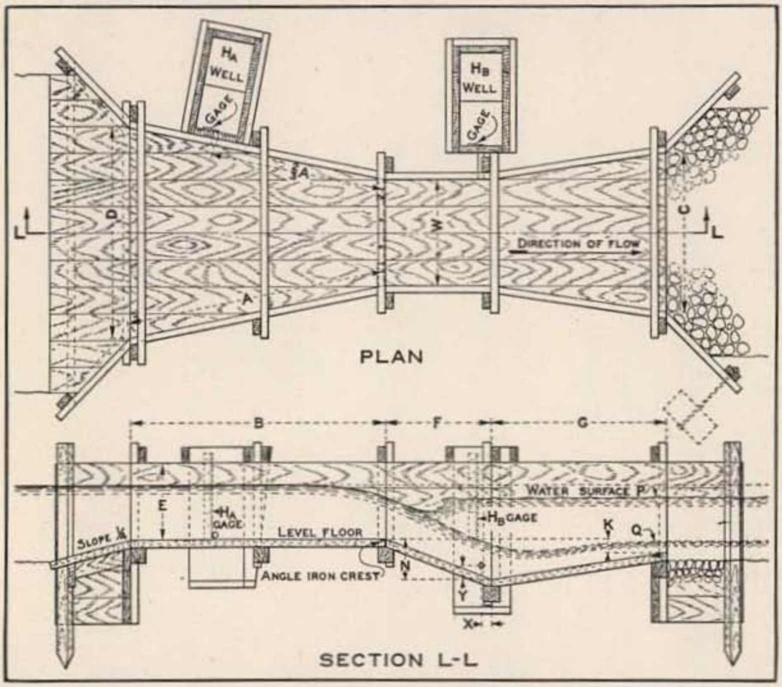


Figure 15.—Parshall measuring flume.

Table 11. Symbol dimensions and capacities of Parshall measuring flume. (Letters refer to Figure 15.)

Free-flow capacity		SYMBOL DIMENSION																		
Maximum	Minimum	W	A		2/3A		B		C		D		E		F	G	K	N	X	Y
Sec. ft.	Sec. ft.	Feet	Ft.	in.	Ft.	in	Ft.	in	Ft.	in.	Ft.	in.	Ft.	in.	Ft.	Ft.	In.	In.	In.	In.
1.2	0.03	0.25	1	6⅜	1	¼	1	6		7		10 3/16	1	3	½	1	1	2¼	1	1½
2.9	.05	.50	2	7/16	1	4 5/16	2		1	3½	1	3½	1	6	1	2	3	4½	2	3
5.7	.1	.75	2	10⅝	1	11⅛	2	10	1	3	1	10⅝	2		1	1½	3	4½	2	3
16	.4	1	4	6	3		4	4⅞	2		2	9¼	3		2	3	3	9	2	3
33	.7	2	5		3	4	4	10⅞	3		3	11½	3		2	3	3	9	2	3
50	1.0	3	5	6	3	8	5	4¾	4		5	1⅞	3		2	3	3	9	2	3
68	1.3	4	6		4		5	10⅝	5		6	4¼	3		2	3	3	9	2	3

two heads or making corrections in the free-flow formula. It does not readily clog with floating trash and it keeps itself clean of sand and silt. It requires but one reading of head (H_A) for determining the discharge except in case of extreme submergence.

Table 12. Free flow discharge through Parshall measuring flume.*

Head H_A		Discharge, Q, for throat widths, W, of—						
		0.25 foot	0.50 foot	0.75 foot	1.00 feet	2.00 feet	3.00 feet	4.00 feet
Inches	Feet	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
1 3/16	0.10	0.028	0.05	0.09				
1 5/16	.11	.033	.06	.10				
1 7/16	.12	.037	.07	.12				
1 9/16	.13	.042	.08	.14				
1 11/16	.14	.047	.09	.15				
1 13/16	.15	.053	.10	.17				
1 15/16	.16	.058	.11	.19				
2 1/16	.17	.064	.12	.20				
2 3/16	.18	.070	.14	.22				
2 1/4	.19	.076	.15	.24				
2 3/8	.20	.082	.16	.26	0.35	0.66	0.97	1.26
2 1/2	.21	.089	.18	.28	.37	.71	1.04	1.36
2 5/8	.22	.095	.19	.30	.40	.77	1.12	1.47
2 3/4	.23	.102	.20	.32	.43	.82	1.20	1.58
2 7/8	.24	.109	.22	.35	.46	.88	1.28	1.68
3	.25	.117	.23	.37	.49	.93	1.37	1.80
3 1/8	.26	.124	.25	.39	.51	.99	1.46	1.91
3 1/4	.27	.131	.26	.41	.54	1.05	1.55	2.03
3 3/8	.28	.138	.28	.44	.58	1.11	1.64	2.15
3 1/2	.29	.146	.29	.46	.61	1.18	1.73	2.27
3 5/8	.30	.154	.31	.49	.64	1.24	1.82	2.39
3 3/4	.31	.162	.32	.51	.68	1.30	1.92	2.52
3 13/16	.32	.170	.34	.54	.71	1.37	2.02	2.65
3 15/16	.33	.179	.36	.56	.74	1.44	2.12	2.78
4 1/16	.34	.187	.38	.59	.77	1.50	2.22	2.92
4 3/16	.35	.196	.39	.62	.80	1.57	2.32	3.06
4 5/16	.36	.205	.41	.64	.84	1.64	2.42	3.19
4 7/16	.37	.213	.43	.67	.88	1.72	2.53	3.34
4 9/16	.38	.222	.45	.70	.92	1.79	2.64	3.48
4 11/16	.39	.231	.47	.73	.95	1.86	2.75	3.62
4 13/16	.40	.241	.48	.76	.99	1.93	2.86	3.77
4 15/16	.41	.250	.50	.78	1.03	2.01	2.97	3.92
5 1/16	.42	.260	.52	.81	1.07	2.09	3.08	4.07
5 3/16	.43	.269	.54	.84	1.11	2.16	3.20	4.22
5 1/4	.44	.279	.56	.87	1.15	2.24	3.32	4.38
5 3/8	.45	.289	.58	.90	1.19	2.32	3.44	4.54
5 1/2	.46	.299	.61	.94	1.23	2.40	3.56	4.70
5 5/8	.47	.309	.63	.97	1.27	2.48	3.68	4.86
5 3/4	.48	3.19	.65	1.00	1.31	2.57	3.80	5.03
5 7/8	.49	3.29	.67	1.03	1.35	2.65	3.92	5.20
6	.50	.339	.69	1.06	1.39	2.73	4.05	5.36
6 1/8	.51	.350	.71	1.10	1.44	2.82	4.18	5.53
6 1/4	.52	.361	.73	1.13	1.48	2.90	4.31	5.70
6 3/8	.53	.371	.76	1.16	1.52	2.99	4.44	5.88
6 1/2	.54	.382	.78	1.20	1.57	3.08	4.57	6.05
6 5/8	.55	.393	.80	1.23	1.62	3.17	4.70	6.23
6 3/4	.56	.404	.82	1.26	1.66	3.26	4.84	6.41
6 13/16	.57	.415	.85	1.30	1.70	3.35	4.98	6.59
6 15/16	.58	.427	.87	1.33	1.75	3.44	5.11	6.77
7 1/16	.59	.438	.89	1.37	1.80	3.53	5.25	6.96
7 3/16	.60	.450	.92	1.40	1.84	3.62	5.39	7.15
7 5/16	.61	.462	.94	1.44	1.88	3.72	5.53	7.34
7 7/16	.62	.474	.97	1.48	1.93	3.81	5.68	7.53
7 9/16	.63	.485	.99	1.51	1.98	3.91	5.82	7.72
7 11/16	.64	.497	1.02	1.55	2.03	4.01	5.97	7.91
7 13/16	.65	.509	1.04	1.59	2.08	4.11	6.12	8.11
7 15/16	.66	.522	1.07	1.63	2.13	4.20	6.26	8.31
8 1/16	.67	.534	1.10	1.66	2.18	4.30	6.41	8.51
8 3/16	.68	.546	1.12	1.70	2.23	4.40	6.56	8.71
8 1/4	.69	.558	1.15	1.74	2.28	4.50	6.71	8.91
8 3/8	.70	.571	1.17	1.78	2.33	4.60	6.86	9.11
8 1/2	.71	.584	1.20	1.82	2.38	4.70	7.02	9.32
8 5/8	.72	.597	1.23	1.86	2.43	4.81	7.17	9.53
8 3/4	.73	.610	1.26	1.90	2.48	4.91	7.33	9.74
8 7/8	.74	.623	1.28	1.94	2.53	5.02	7.49	9.95
9	.75	....	1.31	1.98	2.58	5.12	7.65	10.2
9 1/8	.76	....	1.34	2.02	2.63	5.23	7.81	10.4
9 1/4	.77	....	1.36	2.06	2.68	5.34	7.97	10.6
9 3/8	.78	....	1.39	2.10	2.74	5.44	8.13	10.8
9 1/2	.79	....	1.42	2.14	2.80	5.55	8.30	11.0
9 5/8	.80	....	1.45	2.18	2.85	5.66	8.46	11.2

(Continued on page 26)

Table 12. Free flow discharge through Parshall measuring flume.* (Cont'd.)

Head H_A		Discharge, Q, for throat widths, W, of–						
		0.25 foot	0.50 foot	0.75 foot	1.00 feet	2.00 feet	3.00 feet	4.00 feet
Inches	Feet	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.	Sec.-ft.
9¾	.81	....	1.48	2.22	2.90	5.77	9.63	11.5
9 13/16	.82	....	1.50	2.27	2.96	5.88	8.79	11.7
9 15/16	.83	....	1.53	2.31	3.02	6.00	8.96	11.9
10 1/16	.84	....	1.56	2.35	3.07	6.11	9.13	12.2
10 3/16	.85	....	1.59	2.39	3.12	6.22	9.30	12.4
10 5/16	.86	....	1.62	2.44	3.18	6.33	9.48	12.6
10 7/16	.87	....	1.65	2.48	3.24	6.44	9.65	12.8
10 9/16	.88	....	1.68	2.52	3.29	6.56	9.82	13.1
10 11/16	.89	....	1.71	2.57	3.35	6.68	10.0	13.3
10 13/16	.90	....	1.74	2.61	3.41	6.80	10.2	13.6
10 15/16	.91	....	1.77	2.66	3.46	6.92	10.4	13.8
11 1/16	.92	....	1.81	2.70	3.52	7.03	10.5	14.0
11 3/16	.93	....	1.84	2.75	3.58	7.15	10.7	14.3
11¼	.94	....	1.87	2.79	3.64	7.27	10.9	14.5
11⅜	.95	....	1.90	2.84	3.70	7.39	11.1	14.8
11½	.96	....	1.93	2.88	3.76	7.51	11.3	15.0
11⅝	.97	....	1.97	2.93	3.82	7.63	11.4	15.2
11¾	.98	....	2.00	2.98	3.88	7.75	11.6	15.5
11⅞	.99	....	2.03	3.02	3.94	7.88	11.8	15.8
12	1.00	....	2.06	3.07	4.00	8.00	12.0	16.0
12⅛	1.01	....	2.09	3.12	4.06	8.12	12.2	16.2
12¼	1.02	....	2.12	3.17	4.12	8.25	12.4	16.5
12⅜	1.03	....	2.16	3.21	4.18	8.38	12.6	16.8
12½	1.04	....	2.19	3.26	4.25	8.50	12.8	17.0
12⅝	1.05	....	2.22	3.31	4.31	8.63	13.0	17.3
12¾	1.06	....	2.26	3.36	4.37	8.76	13.2	17.5
12 13/16	1.07	....	2.29	3.40	4.43	8.88	13.3	17.8
12 15/16	1.08	....	2.32	3.45	4.50	9.01	13.5	18.1
13 1/16	1.09	....	2.36	3.50	4.56	9.14	13.7	18.3
13 3/16	1.10	....	2.40	3.55	4.62	9.27	13.9	18.6
13 5/16	1.11	....	2.43	3.60	4.68	9.40	14.1	18.9
13 7/16	1.12	....	2.46	3.65	4.75	9.54	14.3	19.1
13 9/16	1.13	....	2.50	3.70	4.82	9.67	14.5	19.4
13 11/16	1.14	....	2.53	3.75	4.88	9.80	14.7	19.7
13 13/16	1.15	....	2.57	3.80	4.94	9.94	14.9	19.9
13 15/16	1.16	....	2.60	3.85	5.01	10.1	15.1	20.2
14 1/16	1.17	....	2.64	3.90	5.08	10.2	15.3	20.5
14 3/16	1.18	....	2.68	3.95	5.15	10.3	15.6	20.8
14¼	1.19	....	2.71	4.01	5.21	10.5	15.8	21.0
14⅜	1.20	....	2.75	4.06	5.28	10.6	16.0	21.3
14½	1.21	....	2.78	4.11	5.34	10.8	16.2	21.6
14⅝	1.22	....	2.82	4.16	5.41	10.9	16.4	21.9
14¾	1.23	....	2.86	4.22	5.48	11.0	16.6	22.2
14⅞	1.24	....	2.89	4.27	5.55	11.2	16.8	22.5
15	1.25	....	....	4.32	5.62	11.3	17.0	22.8
15⅛	1.26	....	....	4.37	5.69	11.4	17.2	23.0
15¼	1.27	....	....	4.43	5.76	11.6	17.4	23.3
15⅜	1.28	....	....	4.48	5.82	11.7	17.7	23.6
15½	1.29	....	....	4.53	5.89	11.9	17.9	23.9
15⅝	1.30	....	....	4.59	5.96	12.0	18.1	24.2
15¾	1.31	....	....	4.64	6.03	12.2	18.3	24.5
15 13/16	1.32	....	....	4.69	6.10	12.3	18.5	24.8
15 15/16	1.33	....	....	4.75	6.18	12.4	18.8	25.1
16 1/16	1.34	....	....	4.80	6.25	12.6	19.0	25.4
16 3/16	1.35	....	....	4.86	6.32	12.7	19.2	25.7
16 5/16	1.36	....	....	4.92	6.39	12.9	19.4	26.0
16 7/16	1.37	....	....	4.97	6.46	13.0	19.6	26.3
16 9/16	1.38	....	....	5.03	6.53	13.2	19.9	26.6
16 11/16	1.39	....	....	5.08	6.60	13.3	20.1	26.9

*Letters H_A and W refer to Figure 15.

Setting and Size of Parshall Measuring Flume*

Successful operation of the Parshall flume depends upon setting the crest at the correct elevation with reference to the bed of the channel. Free-flow conditions are desirable so that computations for submergence of flow need not be made. The smallest practical size of flume should be selected as a matter of economy, but as the size of the flume decreases the loss of head increases.

The dimensions as given in Table 11 which correspond to the same letter in Figure 15, must be followed accurately. The crest must be straight and level and the floor of the converging section must be level in both directions.

Measurement of head should be made in a stilling well with the zero of the gauge level with the crest of the flume. The connection from the flume to the stilling well should take out of the flume at a point exactly two thirds of the length of the converging section back from the crest and about 1½ inches above the floor line.

Combined Regulating and Measuring Devices

There are several manufactured devices which combine regulating and measuring facilities into one structure. These devices have been calibrated so that they accurately measure the water as regulated if they are installed and operated as directed. A special table is necessary for each size and type of device.

You cannot easily make these devices on the farm. They are ordinarily installed and operated by the canal company and are not treated in this bulletin.

*Complete instructions for setting, size, construction, and operation of Parshall measuring flume are given in USDA Farmers' Bulletin No. 1683, "*Measuring Water in Irrigation Channels,*" by R. L. Parshall.

Appendix I

Equivalents

1 cubic foot = 7.48 gallons or approximately 7.5 gallons.

1 cubic foot of water weighs about 62.4 pounds.

1 cubic foot per second (c.f.s.) = 448.8 gallons per minute or approximately 450 gallons per minute = 50 miner's inches (Idaho).

1 cubic foot per second flowing 24 hours = 1.9835 acre-feet or approximately 2 acre-feet.

1 cubic foot per second flowing 12 hours = .9917 acre-feet or approximately 1 acre-foot.

1 cubic foot per second flowing 1 hour = .9917 acre-inches or approximately 1 acre-inch.

The table of equivalents may be used to determine the depth of water applied to a field when the time and flow are known.

Example: A flow of 60 miner's inches (Idaho) has been running on a 20-acre field for 48 hours. How much water has been applied if it is evenly distributed:

(a) From the table of equivalents, 1 cubic foot per second equals 50 miner's inches; therefore, 60 inches will equal

$$\frac{60}{50} \times 1 \text{ cfs or } 1.2 \text{ c.f.s.}$$

(b) From the table of equivalents, 1 cubic foot per second flowing 1 hour equals 1 acre inch; 1.2 c.f.s. flowing for 1 hour will equal 1.2 × 1 acre inches = 1.2 acre inches per hour.

(c) 1.2 acre inches per hour × 48 hours equals 57.6 acre inches in 48 hours.

(d) As the field is 20 acres in size and the 57.6 acre inches are uniformly distributed over it, there will be a uniform application of 57.6 ÷ 20 inches, or, 2.88 (about 2⅞ inches) inches depth applied.

If a certain depth is assumed, the time it will take for a given size stream to apply the depth can be computed.

Example: A stream of 40 miner's inches (Idaho) is being delivered. How long will it take to apply 4 inches of water to a 15 acre field?

(a) 15 acres to a depth of 4 inches = 4 × 15 acre inches = 60 acre inches.

(b) From the table of equivalents, 1 cfs equals 50 miner's inches; also 1 cfs equals one acre-inch per hour; therefore, 40 miner's inches will apply $\frac{40}{50} \times 1$ acre inches per hour = 4/5 or 0.8 acre inches per hour.

(c) As 60 acre inches are required, 60 ÷ 0.8 hours will be required = 75 hours to irrigate the the field to the required depth of 4 inches.

Note: The average waste runoff from irrigated fields is 11 per cent. If allowance is to be made for waste, the length of time will be increased by this amount. Hence, 75 hours equals 89% of the time. 1% equals $\frac{75}{89} = 0.843$ hrs. Total time required equals 100% = *84.3 hours.*

Appendix II

Definition of Terms

Gallon: The gallon is 231 cubic inches.

Cubic foot: A volume equal to that of a cube 12 inches in length, 12 inches in breadth, and 12 inches in thickness. (1,728 cubic inches)

Acre foot: The volume necessary to cover 1 acre to a depth of 1 foot. (43,560 cubic feet).

Acre inch: The volume necessary to cover 1 acre to a depth of 1 inch. (3,630 cubic feet)

Gallon per minute: A continuous flow amounting to 1 gallon passing a point each minute.

Cubic foot per second: (c.f.s., or second foot) A continuous flow amounting to 1 cubic foot passing a point each second.

Miner's inch (Idaho): A continuous flow equal to 1/50 cubic foot per second. The Idaho miner's inch originally was the amount of water that would flow through an orifice 1 inch square under a head of 4 inches above the center of the opening. It has been defined by court decision as 1/50 cubic foot per second.

Weir wall or weir bulkhead: A wall or bulkhead placed across the channel of a stream to check the stream and cause it to flow through a weir notch.

Weir crest: The horizontal edge or the bottom point of a weir notch.

Weir pond: The enlarged section of the stream bed immediately above the weir wall.

Head: The depth of the water above the weir crest measured at a distance from the weir notch so as to be unaffected by the curve of the water surface as the water flows over the weir. In the submerged orifice the head is the difference in elevation between the water surfaces above and below the orifice. In the Parshall measuring flume it is the elevation of the water surface above the floor of the flume measured at a definite distance from the throat. Symbols used to denote head on measuring structures are generally "H" for a weir, "h" for a submerged orifice and "H_A" for the Parshall measuring flume.

Free flow: The condition of flow over a weir wherein the sheet of falling water falls freely into the air and meets no obstruction above the elevation of the weir crest.

End contraction: The horizontal distance from the side of the weir notch or orifice to the side of the weir pond. To have end contractions, the wier pond must be wider than the weir notch.

Bottom contractions: The vertical distance from the weir crest down to the bottom of the weir pond.

Complete contractions: End and bottom contractions large enough to give practically a still-water condition in the weir pond. To accomplish this, each end contraction and the bottom contraction should be at least twice the head being measured.

Baffles: Obstructions placed in a stream to reduce turbulence or velocity or to equalize the flow throughout the section of the stream.

Velocity of approach: The actual movement of the water toward the structure in feet per second.

Submergence or submerged flow: The condition of flow wherein the elevation of the water surface below the measuring device is higher than (a) the crest of the weir, or, (b) the top of the orifice, or, (c) the bottom of the Parshall measuring flume.

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