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THE FARMER'S SHORT-BOX MEASURING FLUME.[1]

By Carl Rohwer, *Irrigation Engineer,*

Division of Agricultural Engineering, Bureau of Public Roads.

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Many devices have been developed for the measurement of the water delivered to farmers for irrigation, and of these the standard weirs have been most carefully calibrated. When weirs of this type have been correctly designed, installed, and maintained they give accurate results. In some localities, however, especially in the older irrigated sections, types of weirs have come into use that are not standard and that consequently can not give accurate results unless new calibrations are made. For one of the many weirs of this type the following tables and charts have been prepared in order that the structures already installed may be successfully used in the distribution of water.

The farmer's short-box measuring flume, as shown in Figure 1, is a weir with completely suppressed end contractions and a partially suppressed bottom contraction. No provision is made for the aeration and lateral expansion of the nappe, as required in the standard weir without end contractions. The floor of the weir box is level, and is placed at the grade of the ditch in which it is installed. The weir bulkhead is variable in height, depending on the conditions it has to fulfill, and it is usually made from the commercial sizes of 2-inch lumber. No attempt is made to keep a sharp edge at the crest. As shown in the figure, the bulkhead is not fixed, but may be removed, by sliding it out of the grooves in the walls of the weir

[1] The work upon which this bulletin is based was done with the assistance of M. L. Lightburn and A. B. Crosley under the direction of R. L. Parshall, senior irrigation engineer, in charge of the irrigation investigations in Colorado. The bulletin was prepared in cooperation with the Colorado Agricultural Experiment Station.

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box, for the purpose of cleaning the structure of sand and silt. This manipulation makes it difficult to restore the crest of the weir to its former elevation and has led to the practice of measuring the head, for free-flow weirs, on the crest instead of at the standard gauge point, or place for measuring the head. If, however, the weir becomes submerged, as frequently happens when large quantities are measured over low weirs, it is necessary to measure both the upstream and the downstream heads in order to find the discharge. In this case two gauge points, or places for measuring the head,

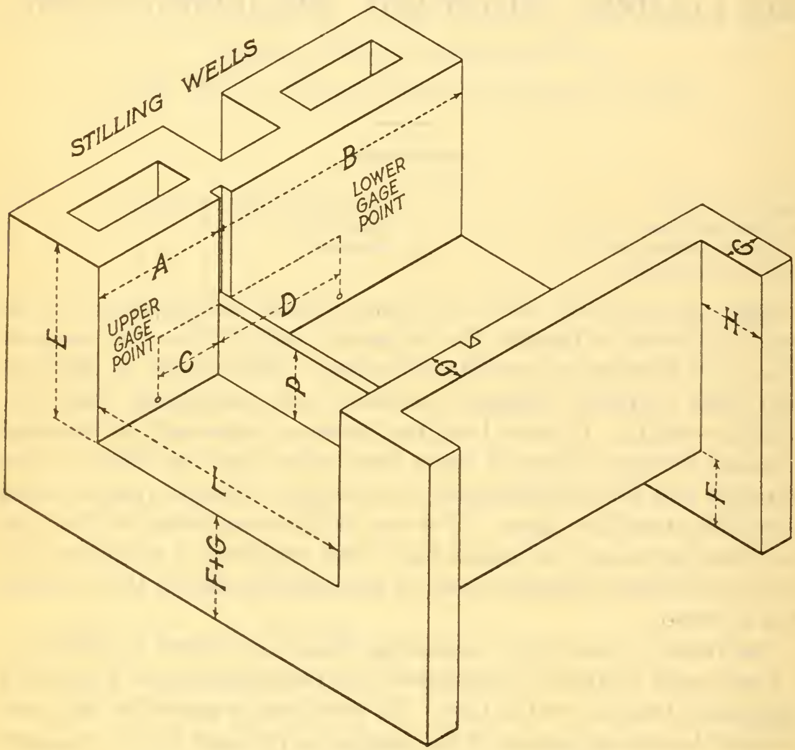

Fig. 1.—Standard plan of farmer's short-box measuring flume.

must be used, one above and one below the weir bulkhead. Both points should be at the same elevation. The floor of the weir box, which is level, may be used in an emergency, but under conditions in which submergence frequently occurs points located at the elevation of the weir crest are more convenient.

METHOD OF CALIBRATION.

For the purpose of simplicity in making the calibrations of the various sizes of flumes and heights of weirs, and in order to make the results comparable, it was necessary to adopt a standard design for the weir box, a definite location for the gauges, and a uniform plan of conducting the tests.

Table 1 gives the standard weir-box dimensions and positions of the gauges. The letters used refer to Figure 1. It will be noted that the location of the gauges is the same for all the sizes of flumes. The discharge over this type of weir is very nearly proportional to the width of the flume, and therefore the condition of the flow is very nearly independent of the width; consequently, the position of the gauges need not be changed for the various sizes of flumes. The gauge point, 1 foot upstream from the weir bulkhead, was so located as to be outside the influence of the contraction lines of the water entering the flume, and not too near the crest. Because of the disturbed condition of the water below the crest the gauge point, 2 feet downstream from the weir bulkhead, was placed as far below the crest as the dimensions of the smallest flume would permit. The elevation of the zero of the gauges is not given. It depends on the height of the weir crest, and for convenience should be at the elevation of the crest.

TABLE 1.—*Standard dimensions for farmer's short-box measuring flumes.*

Size of weir.	Capacity of weir per second.	A Length of box above weir bulkhead.	B Length of box below weir bulkhead.	C Distance from weir bulkhead to upper gauge.	D Distance from weir bulkhead to lower gauge.	E Depth of flume.	F Depth of cut-off wall.	G Thickness of walls and floor.	H Length of wing walls.	L Length of weir crest.	P Height of crest.
Feet.	*Cubic feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Inches.*	*Feet.*	*Feet.*	*Feet.*
1	0.3 to 3.5....	2	2.5	1	2	(1)	0.5	4	0.5	1	(2)
1.5	0.5 to 5......	2	2.5	1	2	(1)	0.5	4	0.5	1.5	(2)
2	0.7 to 7......	2	3	1	2	(1)	0.5	4	0.5	2	(2)
3	1 to 10.......	2	3.5	1	2	(1)	1	6	1	3	(2)
4	1.5 to 14.....	2	4	1	2	(1)	1	6	1	4	(2)

[1] The distance E depends on the height of P and the capacity required.
[2] The height of the crest P depends on the fall available in the lateral.

All the tests upon which the tables and charts are based were made at the hydraulic laboratory at Fort Collins, Colo.[2] The general arrangement of the apparatus used in the calibration is shown in Figure 2. The flume itself is similar to that shown in Figure 1, except that auxiliary walls, with a side slope of 1 to 1, have been attached to the upper end of the structure in order to approach more nearly the condition in a lateral. The points for taking the gauge readings are the same as in the standard measuring flume, but to increase the accuracy the gauge readings above and below the crest were taken by means of hook gauges located in the stilling wells

[2] For a complete description of the hydraulic laboratory, see Engineering News, vol. 70, No. 14, pp. 662–665, Oct. 2, 1913, V. M. Cone.

shown in the figure. At the same time the gauge readings on the crest were taken to the nearest one-sixteenth of an inch, with an ordinary carpenter's folding rule held vertically at the center of the flume and on the upstream edge of the crest. All the weir bulkheads were made of 2-inch material, having the upper edge or crest planed straight and at right angles to the side. Both corners of the crest were slightly rounded with sandpaper in order to approach field

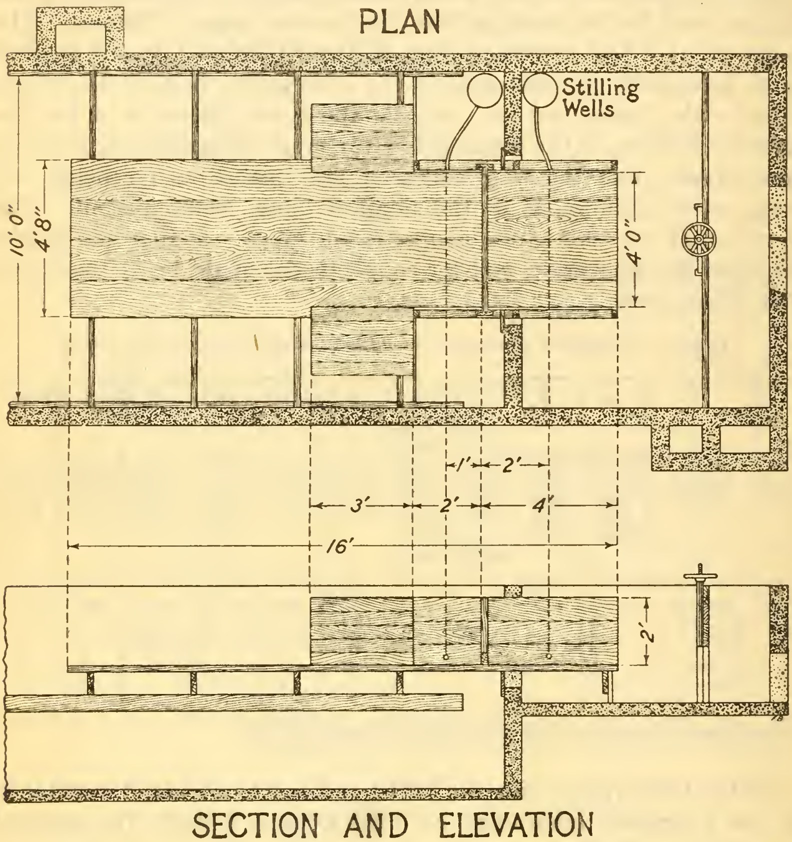

FIG. 2.—The farmer's short-box measuring flume, used at the Fort Collins laboratory.

conditions as nearly as possible. The discharge for each test was determined volumetrically in the calibration tanks at the laboratory.

In all, four sizes of flumes, each with four heights of crest, were calibrated. The flumes were 1, 2, 3, and 4 feet in width and the weirs were nominally 4, 8, 12, and 16 inches in height, but by measurement were found to be $3\frac{11}{16}$, $7\frac{1}{8}$, $10\frac{7}{8}$, and $14\frac{7}{16}$ inches, or 0.307, 0.594, 0.907, and 1.203 feet, respectively, in height. The thickness of the crest was in all cases $1\frac{9}{16}$ inches. For each width of flume and height of crest a sufficient number of tests was made to locate definitely the position of the discharge curves for the free-flow and the submerged-flow conditions. This required a total of 271 tests, or about 17 tests each, for the 16 different settings. In addition, 8 special tests were made to determine the effect of various minor changes in the structure upon the discharge.

DERIVATION OF DISCHARGE FORMULAS.

The formulas for the free flow and for the submerged flow were deduced from these data. The discharge per unit width (1 foot) of flume was first determined for each head and height of weir. By comparing the discharges for unit widths of the different flumes for the same head and height of weir it was noted that there was no uniform difference in the discharges per unit width; therefore, in order to simplify the work, the average values were used. These values were plotted logarithmically, and from the lines drawn through the corresponding points the individual equations were determined. The free-flow and the submerged-flow equations were determined separately on account of the difficulty in determining a general equation for both conditions.

The equations for the two conditions are as follows:

Free flow:

$$Q = \frac{3.566}{(P-0.300)^{0.0164}} LH^{1.525} \qquad \text{(I)}$$

Where Q = discharge in cubic feet per second.
P = height of the weir in feet.
L = width of the flume in feet.
H = head in feet, measured at the upper gauge point.

Submerged flow:

$$Q = 4.12 \frac{H_d^{0.418\,(P-0.300)^{0.0605}}}{P^{0.170}} LH_a^{\frac{1.37\,H_d^{0.091}}{P^{0.123}}} \qquad \text{(II)}$$

Where Q = discharge in cubic feet per second.
P = height of the weir in feet.
L = width of the flume in feet.
H_a = head in feet measured at the upper gauge point.
H_d = difference of head in feet between the upper and the lower head.

Formulas I and II are empirical formulas based on the calibration of 1, 2, 3, and 4 foot flumes, with 4, 8, 12, and 16 inch weirs, for various heads and differences of head. They should not be used for larger or smaller flumes and weirs, nor for heads and differences of head beyond the limits of the experimental data. These limiting heads and differences of head are given in the tables and diagrams computed from the formulas.

The discharge values computed from Formula I agree very closely with the experimental data, except for heads of less than 0.2 foot. Formula II, however, which gives the submerged-flow discharges, does not give values that agree so closely with the experimental data. This is partly due to the variation in the observed discharges caused by the uncertainty of obtaining the true gauge heights. Formula II, like Formula I, does not give accurate results for heads of less than 0.2 foot. The agreement of the discharges computed from Formulas I and II for the free flow and submerged conditions, respectively, with the experimental discharges for the same conditions, is shown graphically in Figure 3. The percentages given in

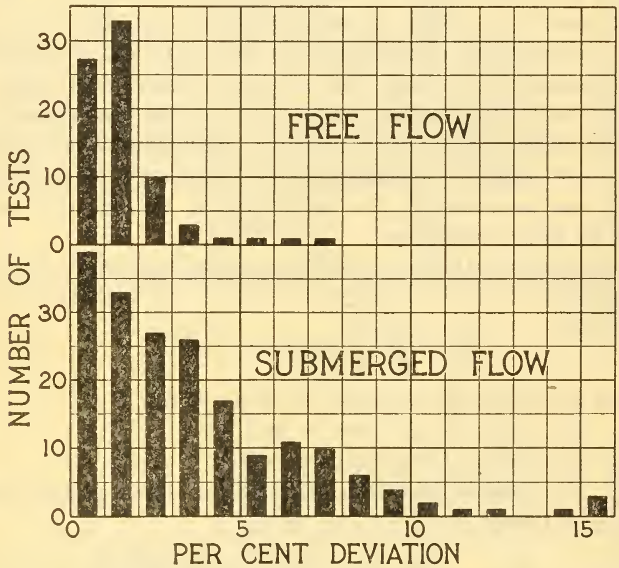

FIG. 3.—Deviation of the computed data from the experimental data for free flow and submerged conditions.

each case represent the deviation of the computed data from the experimental data. These diagrams indicate clearly that where accuracy is required the submerged condition must be avoided.

FREE-FLOW DISCHARGE TABLE.

Table 2 gives the free-flow discharges, in cubic feet per second, per foot in width of flume, for various heads and heights of weirs, computed from Formula I. The head at the upper gauge, which is used in the formula for computing the discharge, is given in both feet and inches at the left of the table. These values should be used to find the discharge in the table when the head is measured at the upper gauge point. If the head is measured on the crest, then the values in inches in the column to the left of the discharge column for the particular height of weir in question should be used. It will be noted that the heads on the crest are not constant for the same upper-gauge head, but vary with the height of weir, and therefore care should be used to choose the proper column for the head. The discharge values given are for a 1-foot width of flume. To find the discharge for any width of flume it is only necessary to multiply the discharge given in the table by the width of the flume in feet. These tables, however, should not be used for flumes less than 1 foot or more than 4 feet in width.

TABLE 2.—*Free-flow discharges in cubic feet per second, per foot in width of farmer's short-box measuring flumes.*

[Computed from the formula $Q=\frac{3.566}{(P-0.300)^{0.0164}}LH^{1.525}$.]

Upper gauge head.		2 by 4 inch weir, 0.307 feet high.		2 by 6 inch weir, 0.450 feet high.		2 by 8 inch weir, 0.594 feet high.		2 by 12 inch weir, 0.907 feet high.		2 by 16 inch weir, 1.203 feet high.	
		Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.
Feet.	*Inches.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*
0.20	2 3/8	2 1/8	0.33	2 1/16	0.32	2 1/16	0.31	2 1/16	0.31	2 1/16	0.31
.21	2 1/2	2 1/4	.36	2 3/16	.34	2 3/16	.34	2 1/8	.33	2 1/8	.33
.22	2 5/8	2 5/16	.38	2 5/16	.37	2 1/4	.36	2 1/4	.36	2 1/4	.35
.23	2 3/4	2 7/16	.41	2 3/8	.39	2 3/8	.39	2 3/8	.38	2 3/8	.38
.24	2 7/8	2 9/16	.44	2 1/2	.42	2 1/2	.41	2 7/16	.41	2 7/16	.41
.25	3	2 11/16	.47	2 5/8	.44	2 5/8	.44	2 9/16	.43	2 9/16	.43
.26	3 1/8	2 3/4	.50	2 11/16	.47	2 11/16	.47	2 5/8	.46	2 5/8	.46
.27	3 1/4	2 7/8	.53	2 13/16	.50	2 13/16	.49	2 3/4	.49	2 3/4	.48
.28	3 3/8	3	.56	2 15/16	.53	2 15/16	.52	2 7/8	.52	2 7/8	.51
.29	3 1/2	3 1/8	.59	3 1/16	.56	3	.55	2 15/16	.54	2 15/16	.54
.30	3 5/8	3 3/16	.62	3 1/8	.59	3 1/8	.58	3 1/16	.57	3 1/16	.57
.31	3 3/4	3 5/16	.65	3 1/4	.62	3 3/16	.61	3 3/16	.60	3 1/8	.60
.32	3 13/16	3 7/16	.68	3 3/8	.65	3 5/16	.64	3 1/4	.63	3 1/4	.63
.33	3 15/16	3 1/2	.71	3 7/16	.68	3 7/16	.67	3 3/8	.66	3 3/8	.66
.34	4 1/16	3 5/8	.75	3 9/16	.71	3 1/2	.70	3 1/2	.69	3 7/16	.69
.35	4 3/16	3 3/4	.78	3 11/16	.74	3 5/8	.73	3 9/16	.73	3 9/16	.72
.36	4 5/16	3 13/16	.82	3 3/4	.78	3 3/4	.77	3 11/16	.76	3 5/8	.75
.37	4 7/16	3 15/16	.85	3 7/8	.81	3 13/16	.80	3 3/4	.79	3 3/4	.78
.38	4 9/16	4 1/16	.88	4	.84	3 15/16	.83	3 7/8	.82	3 7/8	.82
.39	4 11/16	4 3/16	.92	4 1/16	.88	4 1/16	.87	4	.86	3 15/16	.85
.40	4 13/16	4 5/16	.96	4 3/16	.91	4 1/8	.90	4 1/16	.89	4 1/16	.88
.41	4 15/16	4 3/8	.99	4 5/16	.94	4 1/4	.93	4 3/16	.92	4 1/8	.92
.42	5 1/16	4 1/2	1.03	4 3/8	.98	4 3/8	.97	4 5/16	.96	4 1/4	.95
.43	5 3/16	4 5/8	1.07	4 1/2	1.02	4 1/2	1.00	4 3/8	.99	4 3/8	.99
.44	5 1/4	4 11/16	1.11	4 5/8	1.05	4 9/16	1.04	4 1/2	1.03	4 7/16	1.02
.45	5 3/8	4 13/16	1.14	4 11/16	1.09	4 11/16	1.08	4 5/8	1.06	4 9/16	1.06
.46	5 1/2	4 15/16	1.18	4 13/16	1.12	4 3/4	1.11	4 11/16	1.10	4 11/16	1.09
.47	5 5/8	5	1.22	4 15/16	1.16	4 7/8	1.15	4 13/16	1.14	4 3/4	1.13
.48	5 3/4	5 1/8	1.26	5	1.20	4 15/16	1.19	4 7/8	1.17	4 7/8	1.17
.49	5 7/8	5 1/4	1.30	5 1/8	1.24	5 1/16	1.22	5	1.21	5	1.20
.50	6	5 3/8	1.34	5 1/4	1.28	5 3/16	1.26	5 1/16	1.25	5 1/16	1.24
.51	6 1/8	5 1/2	1.39	5 5/16	1.32	5 1/4	1.30	5 3/16	1.29	5 3/16	1.28
.52	6 1/4	5 9/16	1.43	5 7/16	1.36	5 3/8	1.34	5 5/16	1.33	5 1/4	1.32
.53	6 3/8	5 11/16	1.47	5 9/16	1.40	5 1/2	1.38	5 3/8	1.37	5 3/8	1.36
.54	6 1/2	5 13/16	1.51	5 11/16	1.44	5 9/16	1.42	5 1/2	1.40	5 1/2	1.40
.55	6 5/8	5 15/16	1.55	5 3/4	1.48	5 11/16	1.46	5 5/8	1.44	5 9/16	1.44
.56	6 3/4	6	1.60	5 7/8	1.52	5 13/16	1.50	5 11/16	1.48	5 11/16	1.48
.57	6 13/16	6 1/8	1.64	5 15/16	1.56	5 7/8	1.54	5 13/16	1.53	5 3/4	1.52
.58	6 15/16	6 1/4	1.69	6 1/16	1.60	6	1.59	5 15/16	1.57	5 7/8	1.56
.59	7 1/16	6 3/8	1.73	6 3/16	1.64	6 1/8	1.63	6	1.61	6	1.60
.60	7 3/16	6 7/16	1.78	6 5/16	1.69	6 3/16	1.67	6 1/8	1.65	6 1/16	1.64
.61	7 5/16	6 9/16	1.82	6 7/16	1.73	6 5/16	1.71	6 3/16	1.69	6 3/16	1.68
.62	7 7/16	6 11/16	1.87	6 1/2	1.77	6 7/16	1.75	6 5/16	1.73	6 1/4	1.72
.63	7 9/16	6 13/16	1.91	6 5/8	1.82	6 1/2	1.80	6 7/16	1.78	6 3/8	1.77
.64	7 11/16	6 7/8	1.96	6 11/16	1.86	6 5/8	1.84	6 1/2	1.82	6 1/2	1.81
.65	7 13/16	7	2.01	6 13/16	1.91	6 3/4	1.89	6 9/16	1.86	6 9/16	1.85
.66	7 15/16	7 1/8	2.05	6 15/16	1.95	6 13/16	1.93	6 11/16	1.91	6 11/16	1.90
.67	8 1/16	7 1/4	2.10	7 1/16	2.00	6 15/16	1.98	6 13/16	1.95	6 3/4	1.94
.68	8 3/16	7 3/8	2.15	7 1/8	2.04	7 1/16	2.02	6 7/8	2.00	6 7/8	1.98
.69	8 1/4	7 7/16	2.20	7 1/4	2.09	7 1/8	2.07	7	2.04	7	2.03

TABLE 2.—*Free-flow discharges in cubic feet per second, per foot in width of farmer's short-box measuring flumes*—Continued.

Upper gauge head.		2 by 4 inch weir, 0.307 feet high.		2 by 6 inch weir, 0.450 feet high.		2 by 8 inch weir, 0.594 feet high.		2 by 12 inch weir, 0.907 feet high.		2 by 16 inch weir, 1.203 feet high.	
		Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.	Head on crest.	Discharge.
Feet.	*Inches.*	*Inches.*	*Sec-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*	*Inches.*	*Sec.-ft.*
0.70	8 3/8	7 9/16	2.25	7 5/16	2.14	7 1/4	2.11	7 1/16	2.09	7 1/16	2.07
.71	8 1/2	7 11/16	2.29	7 7/16	2.18	7 5/16	2.16	7 3/16	2.13	7 3/16	2.12
.72	8 5/8	7 13/16	2.34	7 9/16	2.23	7 7/16	2.20	7 5/16	2.18	7 1/4	2.16
.73	8 3/4	7 7/8	2.39	7 11/16	2.28	7 9/16	2.25	7 3/8	2.22	7 3/8	2.21
.74	8 7/8	8	2.44	7 3/4	2.32	7 5/8	2.30	7 1/2	2.27	7 7/16	2.26
.75	9	8 1/8	2.49	7 7/8	2.37	7 3/4	2.35	7 9/16	2.32	7 9/16	2.30
.76	9 1/8	8 1/4	2.55	8	2.42	7 7/8	2.39	7 11/16	2.37	7 5/8	2.35
.77	9 1/4	8 3/8	2.60	8 1/8	2.47	7 15/16	2.44	7 13/16	2.41	7 3/4	2.40
.78	9 3/8	8 1/2	2.65	8 3/16	2.52	8 1/16	2.49	7 7/8	2.46	7 13/16	2.45
.79	9 1/2	8 9/16	2.70	8 5/16	2.57	8 3/16	2.54	8	2.51	7 15/16	2.49
.80	9 5/8	8 11/16	2.75	8 3/8	2.62	8 1/4	2.59	8 1/16	2.56	8	2.54
.81	9 3/4	8 13/16	2.81	8 1/2	2.67	8 3/8	2.64	8 3/16	2.61	8 1/8	2.59
.82	9 13/16	8 15/16	2.86	8 5/8	2.72	8 7/16	2.69	8 1/4	2.66	8 3/16	2.64
.83	9 15/16	9	2.91	8 3/4	2.77	8 9/16	2.74	8 3/8	2.71	8 5/16	2.69
.84	10 1/16	9 1/8	2.96	8 7/8	2.82	8 11/16	2.79	8 7/16	2.76	8 7/16	2.74
.85	10 3/16	9 1/4	3.02	8 15/16	2.87	8 3/4	2.84	8 9/16	2.81	8 1/2	2.79
.86	10 5/16	9 3/8	3.07	9 1/16	2.92	8 7/8	2.89	8 5/8	2.86	8 5/8	2.84
.87	10 7/16	9 1/2	3.13	9 3/16	2.97	8 15/16	2.94	8 3/4	2.91	8 11/16	2.89
.88	10 9/16	9 9/16	3.18	9 1/4	3.03	9 1/16	2.99	8 13/16	2.96	8 13/16	2.94
.89	10 11/16	9 11/16	3.24	9 3/8	3.08	9 3/16	3.05	8 15/16	3.01	8 7/8	2.99
.90	10 13/16	9 13/16	3.29	9 1/2	3.13	9 1/4	3.10	9 1/16	3.06	9	3.04
.91	10 15/16	9 15/16	3.35	9 9/16	3.19	9 3/8	3.15	9 1/8	3.11	9 1/16	3.09
.92	11 1/16	10	3.41	9 11/16	3.24	9 7/16	3.20	9 1/4	3.17	9 3/16	3.15
.93	11 3/16	10 1/8	3.46	9 13/16	3.29	9 9/16	3.26	9 5/16	3.22	9 1/4	3.20
.94	11 1/4	10 1/4	3.52	9 15/16	3.35	9 11/16	3.31	9 7/16	3.27	9 3/8	3.25
.95	11 3/8	10 3/8	3.58	10 1/16	3.40	9 3/4	3.36	9 1/2	3.32	9 1/2	3.30
.96	11 1/2	10 1/2	3.63	10 1/8	3.46	9 7/8	3.42	9 5/8	3.38	9 9/16	3.36
.97	11 5/8	10 9/16	3.69	10 1/4	3.51	9 15/16	3.47	9 11/16	3.43	9 11/16	3.41
.98	11 3/4	10 11/16	3.75	10 3/8	3.57	10 1/16	3.53	9 13/16	3.49	9 3/4	3.46
.99	11 7/8	10 13/16	3.81	10 7/16	3.62	10 3/16	3.58	9 15/16	3.54	9 7/8	3.52
1.00	12	10 15/16	3.87	10 9/16	3.68	10 1/4	3.64	10	3.60	9 15/16	3.57

In order to illustrate the use of the table in finding the discharge, assume a 1.5-foot flume with a 2 by 8 inch weir, and a head of 2 3/8 inches measured on the crest. In the column headed "Head on crest" for the 2 by 8 inch weir, find the 2 3/8-inch head, and on the same line, to the right in the column headed "Discharge," read 0.39 cubic feet per second. This is the discharge for a 1-foot flume. To find the discharge for a 1.5-foot flume, multiply 0.39 by 1.5 and get 0.58 cubic feet per second, the discharge for a 1.5-foot flume under conditions given above. Had the 2 3/8-inch head been measured at the upper gauge, then it would have been necessary to find the head in the column headed "Head in inches" for the upper gauge and to read the discharge of 0.31 cubic feet per second on the same line in the discharge column for the 2 by 8 inch weir. The discharge for a 1.5-foot flume is then 1.5 times 0.31, or 0.46 cubic feet per second when the head is measured at the upper gauge. The difference in the two values obtained shows the necessity of using the proper column in finding the head.

TABLE 3.—*Decimals of a foot for each one-sixteenth of an inch.*

Inches.	0	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16
0......	0.000	0.005	0.010	0.016	0.021	0.026	0.031	0.037	0.042	0.047	0.052	0.057	0.063	0.068	0.073	0.078
1......	.083	.089	.094	.099	.104	.109	.115	.120	.125	.130	.135	.141	.146	.151	.156	.162
2......	.167	.172	.177	.182	.188	.193	.198	.203	.208	.214	.219	.224	.229	.234	.240	.245
3......	.250	.255	.260	.266	.271	.276	.281	.287	.292	.297	.302	.307	.313	.318	.323	.328
4......	.333	.339	.344	.349	.354	.359	.365	.370	.375	.380	.385	.391	.396	.401	.406	.412
5......	.417	.422	.427	.432	.438	.443	.448	.453	.458	.464	.469	.474	.479	.484	.490	.495
6......	.500	.505	.510	.516	.521	.526	.531	.537	.542	.547	.552	.557	.563	.568	.573	.578
7......	.583	.589	.594	.599	.604	.609	.615	.620	.625	.630	.635	.641	.646	.651	.656	.662
8......	.667	.672	.677	.682	.688	.693	.698	.703	.708	.714	.719	.724	.729	.734	.740	.745
9......	.750	.755	.760	.766	.771	776	.781	.787	.792	.797	.802	.807	.813	.818	.823	.828
10.....	.833	.839	.844	.849	.854	.859	.865	.870	.875	.880	.885	.891	.896	.901	.906	.912
11.....	.917	.922	.927	.932	.938	.943	.948	.953	.958	.964	.969	.974	.979	.984	.990	.995

SUBMERGED-FLOW DISCHARGE DIAGRAMS.

The discharge diagrams, Figures 4, 5, 6, 7, and 8, for submerged flow, are based on values computed from Formula II. These diagrams were used instead of tables on account of the difficulty of pre-

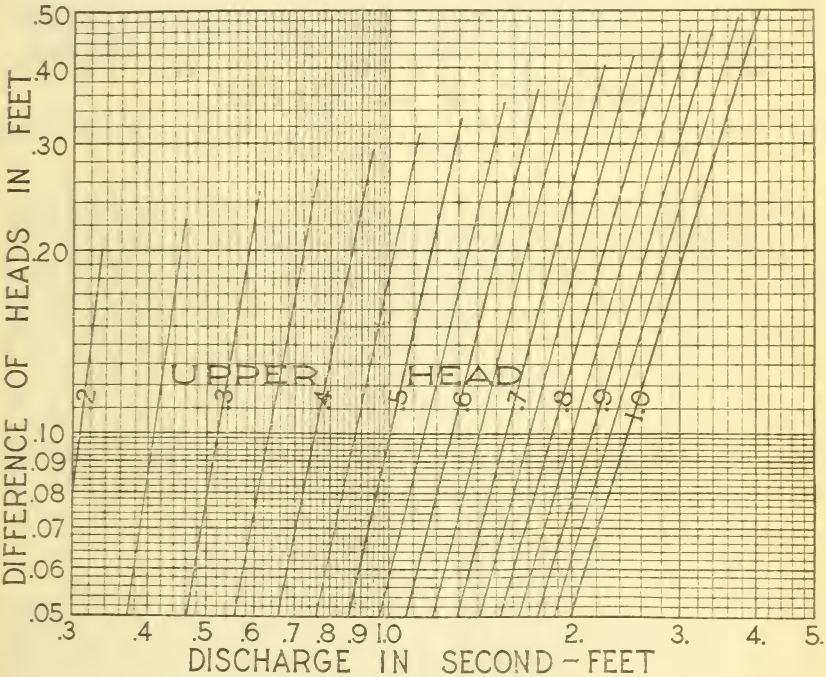

FIG. 4.—Discharge diagram for a 1-foot farmer's short-box measuring flume with a 4-inch weir, plotted from results computed from Formula II.

senting the data in tabular form. The logarithmic scale, which is used for all the diagrams, simplifies the plotting and increases the legibility for small differences in head. To illustrate the use of the diagrams in finding the discharge, assume a 3-foot flume with a 2 by

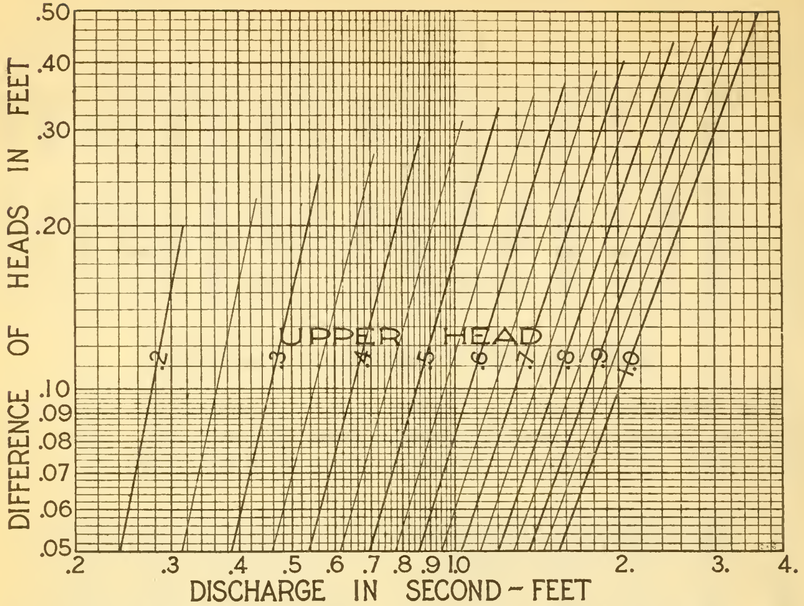

FIG. 5.—Discharge diagram for a 1-foot farmer's short-box measuring flume with a 6 ineh weir, plotted from results computed from Formula II.

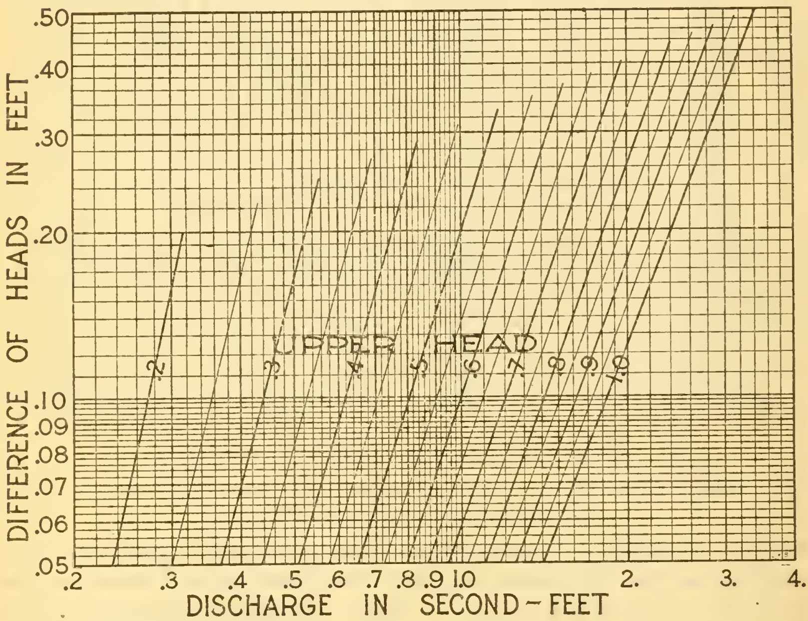

FIG. 6.—Discharge d agram for a 1-foot farmer's short-box measuring flume with an 8-inch weir, plotted from results computed from Formula II.

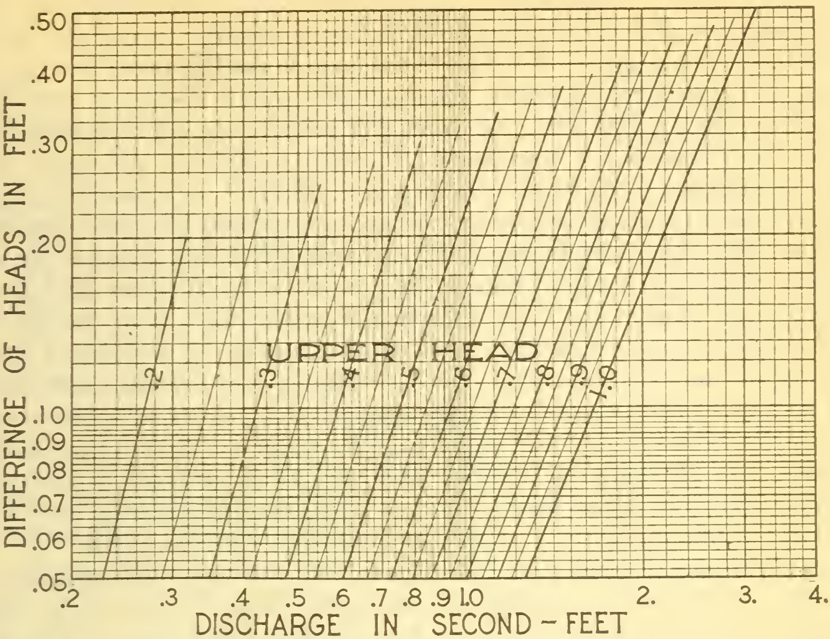

FIG. 7.—Discharge diagram for a 1-foot farmer's short-box measuring flume with a 12-inch weir, plotted from results computed from Formula II.

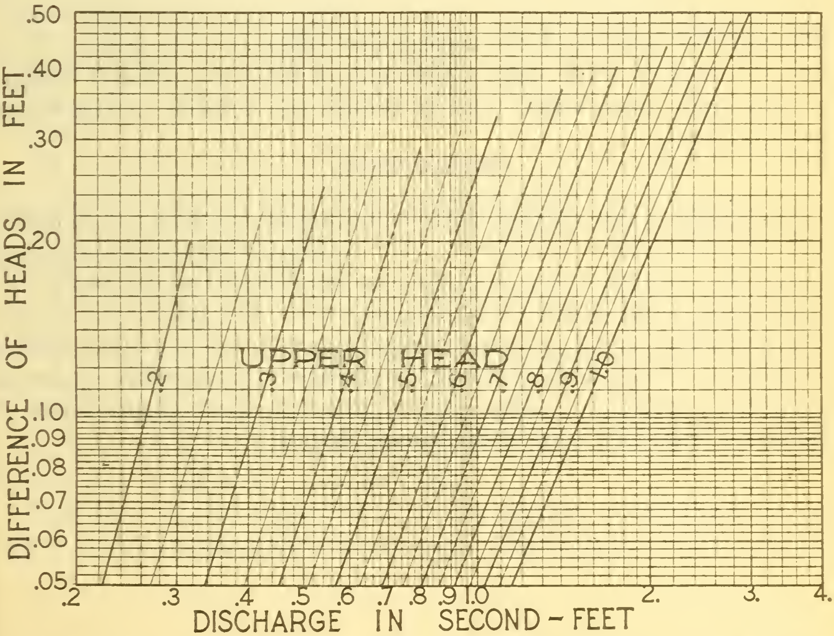

FIG. 8.—Discharge diagram for a 1-foot farmer's short-box measuring flume, with a 16-inch weir, plotted from results computed from Formula II.

16 inch weir, an upper head of 6½ inches and a lower head of 4¼ inches. To find the discharge, it is first necessary to convert the heads in inches into feet. This conversion is readily made with the aid of Table 3, which shows that 6½ inches equals 0.542 foot and 4¼ inches equals 0.354 foot. Of course, if both heads are measured in feet, no conversion is necessary. In order to find the difference of head, subtract 0.354 from 0.542 and get 0.188 foot, or approximately 0.54 and 0.19, respectively, for the upper head and the difference of head. Next turn to Figure 8, which is the discharge diagram for a 2 by 16 inch weir 1 foot long. On the left of the diagram find the horizontal line for the 0.19 difference of head, follow it to the right until the 0.5-upper-head line is reached, estimate the position of the 0.54-line, and then find where the 0.19 difference-of-head line cuts the 0.54-upper-head line, and directly beneath this point read 0.98 cubic feet per second as the discharge for a 1-foot flume. Then for a 3-foot flume, the discharge is 3 times 0.98 or 2.94 cubic feet per second under the conditions given above. These diagrams should not be used for flumes less than 1 foot nor more than 4 feet in width.

It will be observed that the diagrams do not cover the complete range of differences possible for each upper head; in fact, only the small differences are shown except for the small upper heads. This is due to the difficulty in obtaining these heads in practice. Where large flows with large differences in head are measured, the velocity of the water is so great below the crest that there is very little tendency to submerge the weir until the retardation below is quite great. It is doubtful even, if these large differences of head are possible except for very high weirs which tend to reduce the velocity of the water below the crest.

SPECIAL TESTS.

The results of the special tests to determine the effect of changes in the flume are given in Table 4. The results of these tests show that neither the changes in the crest nor the changes in the approach condition cause errors greater than 3.3 per cent. For submerged conditions, the errors would probably be less on account of the lower velocities of flow. This indicates that the changes which ordinarily occur in the field would not cause serious errors in the measurements of discharges from this type of measuring device.

TABLE 4.—*Showing the per cent of error in free flow and discharges due to various changes in the flume.*

Upper gauge head.	Size of flume.	Size of weir bulkhead.	Condition.	Discharge.	Standard experimental discharge.	Difference.	Error
Feet.	*Feet.*	*Inches.*		*Sec.-ft.*	*Sec.-ft.*		*Per cent.*
0.400	1	2 by 12	Both edges of crest rounded to curve of ¼ inch radius	0.926	0.896	0.030	3.3
.800	1	2 by 12		2.698	2.686	.012	0.4
.400	1	2 by 12	Rounded crest replaced by sharp metal crest	.882	.896	−.014	−1.6
.800	1	2 by 12		2.604	2.686	−.082	−3.1
.200	1	2 by 4	Standard crest. Auxiliary walls set vertical at a distance of 3 inches back from the sides of the flume	.333	.336	−.003	−0.9
.800	1	2 by 4		2.786	2.741	.045	1.6
.200	1	2 by 12		.323	[1] .313	.010	3.2
.800	1	2 by 12		2.713	2.686	.027	1.0

[1] Curve value, experimental discharge not determined for this head.

SUMMARY.

The farmer's short-box measuring flume was calibrated in order to make possible the successful use in the distribution of water of the structures of this type already installed.

The accuracy of the device is sufficient for ordinary requirements, but it is not to be recommended in preference to the standard types of weirs.

A comparison of the experimental discharges with the computed discharges for the free flow and for the submerged conditions shows that 77 per cent of all the free-flow computed discharges are in error by less than 2 per cent, and that 74 per cent of all the submerged-flow computed discharges are in error by less than 5 per cent.

The results show that the submerged condition should be avoided if possible.

For free-flow conditions, the gauge height may be measured either on the crest of the weir or 1 foot upstream from it. Care should be taken not to confuse the readings taken at the different points, when using the discharge tables.

For submerged conditions, both the upstream and the downstream heads must be measured. On account of the disturbed condition of the water, it is recommended that, in order to increase the accuracy, the heads be measured in stilling wells placed outside of the flume.

The discharge formulas are not applicable for heads greater or less than those given in the tables and diagrams, nor for flumes greater than 4 feet or less than 1 foot in width.

Changes, such as might occur in the flumes in the field, do not affect the discharge sufficiently to impair the usefulness of the device.

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