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AGRICULTURAL EXPERIMENT STATION

# Improving the Distribution of Water to Farmers by Use of the Parshall Measuring Flume

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United States Department of Agriculture
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# Improving the Distribution of Water To Farmers by Use of the Parshall Measuring Flume[1]

Ralph L. Parshall[2]

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## Introduction

THE present development of irrigation throughout the West has reached the point where the water supply, under normal conditions, falls somewhat short of serving adequately all the areas intended to be watered. This experience of limited supplies, in stretching the service to reach all the water users efficiently, shows the importance of improving the facilities of distribution to the farmer so that each one will be justly considered and have his fair share of the common water supply. It is believed that less than one-half the water diverted into the farmer's lateral is measured accurately in accordance with his just claim or legal right in sharing the supply with his neighbors. In fairness to all the users there should be provided suitable and accurate measuring devices to permit proper and equitable apportionment of this all-important asset. For mutually owned irrigation systems the water service to the farmer is met by annual assessments, or some other form of charge, and, since the water users' proportionate share of the maintenance and operation costs to cover this water delivery is one of the major items of farm expense, it follows that the amount of water delivered

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should be commensurate with this charge. Many irrigation organizations withhold deliveries of water to those in arrears in the payment of assessments, or other water charges, and some require the payment of water tolls in advance of delivery.

The discussion of irrigation conditions and the operation of methods of measuring water to farmers is based largely upon experience in Colorado, particularly in the Cache la Poudre Valley, supplemented by observations madé in various other western communities.

The principal purpose of this bulletin is to encourage the betterment of delivery of water to the farmer by the adoption of improved methods of measuring the discharge of small streams from canals and ditches into the lateral serving the farm. The main advantage of gaging accurately the rate of delivery to the user is to assure that at the conclusion of the season the total amount of water delivered is in keeping with the dollars paid for this service. The wealth produced on the farm is disposed of in sales based on unit values, but often the water necessary in the production of crop values is paid for with little or no concern as to the actual amount delivered. For economical operation of the farm, it should be recognized that the cost of water for production is as important as the return in revenue through the sale of the crops. The equitable parceling out of the common water supply throughout the entire irrigation system will make possible a closer relation between the assessments paid for water service and the return from crop production.

To approach the problem of fair allocation of the water supply, careful measurement of the rate of delivery is basic and fundamental. Better measurements of the discharge into the farmer's lateral will tend to reduce the waste of water in such cases where over-delivery occurs through mere estimation of the rate of flow, which is usually in excess of the rightful or proper amount, will increase the efficiency of irrigation on the farm, especially where the delivery is for a short period of time, and ultimately will result in harmony among the farmers being served because all are subject to a uniform and equitable plan of distributing the common water supply. Accurate measurement of water delivery over many irrigation systems will result in an apparent increase of 10 to 20 percent in the available supply. Where irrigation systems have been improved by the installation of new methods of measurement, it is to be expected at the start that a considerable number of complaints will be made by the farmers, since, in comparison with their past experiences, some will find themselves served with a much smaller head of water than formerly. Their claims may be unquestioned. In such case it is probable that the farmer heretofore was using a portion of his neighbor's water because of improper measurement of the flow into his own lateral.

Several types of measuring devices of practical design are available for use in making possible the better distribution of the water supply. Both the rectangular and Cipolletti types of

weirs may be used. However, experience shows that these devices are not particularly well suited in meeting all the conditions ordinarily found along a ditch system. The loss of head required for a free flow over the weir crest is often not attainable because the grade of the farmer's lateral is flat, and often sand and silt fill the weir pond or pool upstream from the weir bulkhead and change the approach conditions to the extent of causing erroneous measurements.

Turn-out gates at the head of the lateral are sometimes calibrated to measure the delivery to the farmer. Measurements of this kind are usually for submerged-flow conditions, and the loss of head is therefore held to a minimum.

The Parshall measuring flume, now recognized as a practical device for gaging the rate of delivery to farmers, is quite widely used. The sizes of flume best suited for this purpose range from 3- to 18-inch throat widths for capacities of from 1 to about 10 second-feet. Recent developments in the method of observing the rate of flow through these flumes are believed to be an advancement in the use of this particular measuring device, especially for small flumes such as would be used in a farmer's lateral.

The circular or rectangular orifice is a type of measuring device commonly used for the measurement of diversion to the farmer in laterals of flat grade.

The rating flume, another device suitable for a small lateral, is relatively inexpensive and requires the least loss of head for measurement of any of the devices in common use. Unfortunately, such a device is not dependable in the indication of the rate of discharge and therefore is not recommended except where the condition of the channel does not change because of scouring out or filling in with debris, effects of vegetative growth in the channel or along the banks, or other causes which would affect the flow through the calibrated structure.

## The Problem of Distributing Water

The mutual or cooperative irrigation company is widely used as an organization through which water is delivered to the farmer for the irrigation of his crops. The water user holds shares of stock in the company and, in most instances, pays for water service in the form of annual assessments proportioned according to his holding of stock or acres irrigated. Some mutual companies, particularly in southern California, make toll charges for part, and in a few cases for all, of the water they provide based upon the quantities of water actually delivered. However, under the general practice followed in Colorado and various other states, the number of shares or rights held by the farmer in proportion to the total outstanding shares of the company determines the ratio or percentage of the available supply which is to be rightfully diverted for his use on the farm. Under ordinary seasonal conditions the amount or extent of the supply

of water in the canal or reservoir is variable in serving a community under a particular distribution system. At the beginning of the season when the runoff is normal, the system may be fully supplied and the delivery to the farmer is at a maximum, at times even to the point of free water delivery. Variations in the flow of the stream or source of supply are related directly to the amount of water available for distribution. When the total supply is reduced, say to about one-half, it is usual to attempt delivery to all the users in this same ratio. Where the total supply in the canal is less than one-half, deliveries are then made either along the upper or lower half of the canal, thus holding to a maximum delivery, but for half the time. For further reductions in supply, the service to the farmers may be restricted to thirds or quarters of the length of the canal. For such restrictions, the distribution is commonly referred to in various communities as "by sections."

If the total water supply is inadequate for simultaneous deliveries out of the upper and lower portions of the canal, making it necessary to divide the system into sections, the entire supply is rotated in turns from one section to another. Deliveries are thus restricted to one section at a time for a fixed period of time. For such cases the superintendent determines the days, hours, or other period of delivery to the users under the particular section of the canal being served. On a time basis, the farmer may receive water continuously for 24 or 36 hours and then his head gate is closed to permit delivery along another section of the system. Under extreme conditions, the delivery may be for only a few consecutive hours each week or 10-day period.

Under the ordinary mutual or cooperative ditch system, the water supply at the head is reckoned as a flow in cubic feet per second or in miner's inches or statutory inches and forms the basis for distribution at that particular time. Certain deductions are made from this supply to cover losses caused by seepage, waste, leakage from faulty structures, evaporation, growth of vegetation along the canal, and other causes. Experience dictates the total percentage of reduction necessary to make the available water supply reach all the users drawing water at the time. Prevailing weather conditions for the day also play an important part in the final estimated amount of water to be made available for distribution.

Where the source of supply is largely that of stored water in reservoirs, the seasonal delivery is usually in units of volume such as acre-feet, acre-inches, or cubic feet. For irrigation systems deriving their supply from streams under decreed rights, based on rate of flow in cubic feet per second, the distribution to the user is then measured in second-feet, statutory inches, or some other convenient unit of flow.

As is now evident, any scheme of the delivery of water to the user involves the problem of measuring the rate of flow into the farmer's lateral. A number of practical devices are avail-

able for measuring water, as described in this bulletin, but experience shows that, because of the many advantages in meeting the various conditions in the field, the Parshall measuring flume is especially well suited for the purpose of measuring irrigation supplies, not only the large flows at the head of the system, but also the small streams turned out to the farmer.

A typical example of distributing water from the Lake Canal, a mutually owned enterprise near Fort Collins, Colorado, is given as a practical plan for the delivery of water to the farmers under this particular irrigation system. This canal has priority No. 54, November 1, 1872, for 158 second-feet from the Cache la Poudre River. The inflow from the river ranges from a minimum of about 50 second-feet during the summer months to the full appropriation of 158 second-feet or the capacity of the canal during the peak spring runoff. The canal is about 15 miles in length and serves approximately 10,000 acres of land. For the first few miles this canal traverses an area that contributes a small inflow of seepage return from an irrigated section at higher elevation. Also, waste and surface water from the adjacent irrigated lands are collected, which amount in the aggregate to a substantial accumulation or inflow of water into the canal that is available for diversion to the users. In addition to the river supply, this canal is also served by three small reservoirs. The stored water is used for irrigation of late crops at a time when the supply in the river is insufficient to permit drawing on its decreed appropriation. When stored water is being used, the shares held by the farmer are of the same value as for water from the river. For the smaller available supplies, either river or stored water, the canal is sectionized as a means of improving the efficiency of distribution.

This canal system was equipped completely with small Parshall measuring flumes of reinforced concrete construction for proportioning accurately the water supply to the farmers. Prior to the use of the measuring flume, unserviceable wooden weirs were used, with the result that many of the users at the lower end of the canal received little or no water in comparison with those farther upstream.

The measuring flumes were provided with a suitable staff gage fixed at the proper place in the converging section of the structure to indicate the rate of discharge through the flume. Because of the favorable slope of the laterals, practically all measurements of delivery were free flow.

There are 260 shares held by the users under this canal, which form the basis for proportioning the amount of water to be turned out to each farmer. Table 1 serves as a guide to enable the ditch rider to distribute the supply properly. The scope of this table covers the range of diversion from the river in amounts varying by 5 second-feet up to full capacity of the canal and gives the corresponding rates of delivery in second-feet for both fractional and unit shares. As an example, in the delivery of

TABLE 1.—DISCHARGE IN SECOND-FEET PER SHARE OR FRACTION THEREOF ACCORDING TO VARIOUS QUANTITIES OF FLOW DIVERTED INTO THE LAKE CANAL FROM THE CACHE LA POUDRE RIVER. THIS TABLE IS BASED ON A TOTAL OF 260 SHARES.

| Flow at head of canal | Shares | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ⅛ | ¼ | ½ | ¾ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* | *Sec.-ft.* |
| 50 | 0.02 | 0.05 | 0.10 | 0.14 | 0.19 | 0.38 | 0.58 | 0.77 | 0.96 | 1.15 | 1.35 | 1.54 | 1.73 | 1.92 |
| 55 | .03 | .05 | .11 | .16 | .21 | .42 | .63 | .85 | 1.06 | 1.27 | 1.48 | 1.69 | 1.91 | 2.12 |
| 60 | .03 | .06 | .12 | .17 | .23 | .46 | .69 | .92 | 1.15 | 1.39 | 1.62 | 1.85 | 2.08 | 2.31 |
| 65 | .03 | .06 | .13 | .19 | .25 | .50 | .75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 |
| 70 | .03 | .07 | .13 | .20 | .27 | .54 | .81 | 1.08 | 1.35 | 1.62 | 1.89 | 2.16 | 2.43 | 2.69 |
| 75 | .04 | .07 | .14 | .22 | .29 | .58 | .87 | 1.16 | 1.44 | 1.73 | 2.02 | 2.31 | 2.60 | 2.88 |
| 80 | .04 | .08 | .15 | .23 | .31 | .62 | .92 | 1.23 | 1.54 | 1.85 | 2.16 | 2.46 | 2.77 | 3.08 |
| 85 | .04 | .08 | .16 | .25 | .33 | .65 | .98 | 1.31 | 1.64 | 1.96 | 2.29 | 2.62 | 2.94 | 3.27 |
| 90 | .04 | .09 | .17 | .26 | .35 | .69 | 1.04 | 1.38 | 1.73 | 2.08 | 2.42 | 2.77 | 3.12 | 3.46 |
| 95 | .05 | .09 | .18 | .27 | .37 | .73 | 1.10 | 1.46 | 1.83 | 2.19 | 2.56 | 2.92 | 3.29 | 3.66 |
| 100 | .05 | .10 | .19 | .29 | .38 | .77 | 1.15 | 1.54 | 1.92 | 2.31 | 2.69 | 3.08 | 3.46 | 3.84 |
| 105 | .05 | .10 | .20 | .30 | .40 | .81 | 1.21 | 1.61 | 2.02 | 2.42 | 2.82 | 3.23 | 3.63 | 4.04 |
| 110 | .05 | .11 | .21 | .32 | .42 | .85 | 1.27 | 1.69 | 2.12 | 2.54 | 2.96 | 3.38 | 3.81 | 4.23 |
| 115 | .06 | .11 | .22 | .33 | .44 | .89 | 1.33 | 1.77 | 2.21 | 2.66 | 3.10 | 3.54 | 3.96 | 4.42 |
| 120 | .06 | .12 | .23 | .35 | .46 | .92 | 1.38 | 1.85 | 2.31 | 2.77 | 3.23 | 3.69 | 4.15 | 4.61 |
| 125 | .06 | .12 | .24 | .36 | .48 | .96 | 1.44 | 1.92 | 2.40 | 2.88 | 3.36 | 3.84 | 4.32 | 4.80 |
| 130 | .06 | .13 | .25 | .38 | .50 | 1.00 | 1.50 | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 | 4.50 | 5.00 |
| 135 | .06 | .13 | .26 | .39 | .52 | 1.04 | 1.56 | 2.08 | 2.60 | 3.12 | 3.63 | 4.15 | 4.67 | 5.19 |
| 140 | .07 | .13 | .27 | .40 | .54 | 1.08 | 1.61 | 2.16 | 2.69 | 3.23 | 3.77 | 4.30 | 4.84 | 5.38 |
| 145 | .07 | .14 | .28 | .42 | .56 | 1.12 | 1.67 | 2.23 | 2.79 | 3.34 | 3.90 | 4.46 | 5.02 | 5.58 |
| 150 | .07 | .14 | .29 | .43 | .58 | 1.15 | 1.73 | 2.31 | 2.88 | 3.46 | 4.04 | 4.61 | 5.19 | 5.76 |
| 155 | .07 | .15 | .30 | .45 | .60 | 1.19 | 1.79 | 2.38 | 2.97 | 3.58 | 4.17 | 4.77 | 5.36 | 5.96 |
| 158 | .08 | .15 | .30 | .46 | .61 | 1.22 | 1.83 | 2.44 | 3.05 | 3.66 | 4.26 | 4.87 | 5.48 | 6.09 |

water from this canal under the improved conditions, assume that the inflow from the river for the day was found to be 125 second-feet. The base flow for distribution is taken at 5 to 10 percent less than the river diversion to account for waste, seepage, and evaporation losses, and it is otherwise corrected by an estimated inflow at various points down the canal. The experienced superintendent estimates 115 second-feet should be taken as the most probable flow at the time to serve all users in accordance with their equitable share of the common supply. Each ditch rider is then informed early in the morning of the base flow for distribution. This information, together with the record of the number of shares of water held by each of the users in his division, enables him to divert properly the canal supply into the farmer's lateral. As an example, supposing that Farmer Brown holds four and one-fourth shares, how much water should be delivered? For a base flow of 115 second-feet, his four shares entitle him to a flow of 1.77 second-feet and the quarter share entitles him to 0.11 second-feet, or a total of 1.88 second-feet (see table 1). Since Mr. Brown's measuring flume is a 1-foot size, the ditch rider opens the head gate until the staff gage reading is just 0.61 foot (see table 3), thus showing a delivery of 1.88 second-feet or his share of the supply for that day. It may happen, however, that a sudden rise in the river, caused by a freshet or a heavy shower over a part of the irrigated district, may cause a revision in the base flow and make necessary an adjustment in rate of deliveries to the users during the remaining portion of the day.

If the user has a small tract and a fractional share of water, it is the usual thing to double or quadruple the indicated flow and cut the time of delivery proportionately. This plan of delivering water has been found satisfactory.

The Pleasant Valley and Lake Canal, also near Fort Collins, has equipped all farmers' laterals drawing water from this source with small reinforced concrete Parshall measuring flumes, to distribute properly and equitably among the users the available water supply. The plan of distributing the water in this case is essentially the same as for the Lake Canal except that the rate of flow of delivery is in Colorado statutory inches. One second-foot is equivalent to 38.4 such inches. Table 2, as an illustration, shows the lateral diversions in statutory inches for various amounts of water drawn from the Cache la Poudre River in accordance with the number of shares held by the farmer.

TABLE 2.—DISCHARGE IN COLORADO STATUTORY INCHES PER SHARE OR FRACTION THEREOF ACCORDING TO VARIOUS QUANTITIES OF FLOW DIVERTED INTO THE PLEASANT VALLEY AND LAKE CANAL FROM THE CACHE LA POUDRE RIVER. THIS TABLE IS BASED ON A TOTAL OF 260 SHARES.

| Canal | Supply | Shares | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ¼ | ½ | ¾ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| *Colo. Inch* | *Sec. Ft.* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 400 | 10.4 | .... | 1 | 1 | 2 | 3 | 5 | 6 | 8 | 9 | 11 | 12 | 14 | 15 |
| 420 | 10.9 | .... | 1 | 1 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 15 | 16 |
| 440 | 11.5 | .... | 1 | 1 | 2 | 3 | 5 | 7 | 8 | 10 | 12 | 14 | 15 | 17 |
| 460 | 12.0 | .... | 1 | 1 | 2 | 4 | 5 | 7 | 9 | 11 | 12 | 14 | 16 | 18 |
| 480 | 12.5 | .... | 1 | 1 | 2 | 4 | 6 | 7 | 9 | 11 | 13 | 15 | 17 | 18 |
| 1100 | 28.6 | 1 | 2 | 3 | 4 | 8 | 13 | 17 | 21 | 25 | 30 | 34 | 38 | 42 |
| 1120 | 29.2 | 1 | 2 | 3 | 4 | 9 | 13 | 17 | 22 | 26 | 30 | 34 | 39 | 43 |
| 1140 | 29.7 | 1 | 2 | 3 | 4 | 9 | 13 | 18 | 22 | 26 | 31 | 35 | 39 | 44 |
| 1160 | 30.2 | 1 | 2 | 3 | 4 | 9 | 13 | 18 | 22 | 27 | 31 | 36 | 40 | 45 |
| 1180 | 30.7 | 1 | 2 | 3 | 5 | 9 | 14 | 18 | 23 | 27 | 32 | 36 | 41 | 45 |
| 2400 | 62.5 | 2 | 5 | 7 | 9 | 18 | 28 | 37 | 46 | 55 | 65 | 74 | 83 | 92 |
| 2420 | 63.0 | 2 | 5 | 7 | 9 | 19 | 28 | 37 | 47 | 56 | 65 | 74 | 84 | 93 |
| 2440 | 63.6 | 2 | 5 | 7 | 9 | 19 | 28 | 38 | 47 | 56 | 66 | 75 | 84 | 94 |
| 2460 | 64.1 | 2 | 5 | 7 | 9 | 19 | 28 | 38 | 47 | 57 | 66 | 76 | 85 | 95 |
| 2480 | 64.6 | 2 | 5 | 7 | 10 | 19 | 29 | 38 | 48 | 57 | 67 | 76 | 86 | 95 |
| 2500 | 65.1 | 2 | 5 | 7 | 10 | 19 | 29 | 39 | 48 | 58 | 67 | 77 | 87 | 96 |

## TABLE 3.—FREE-FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUME.

| Head Ha | Discharge, Q, for throat widths, W, of— | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3-inch | | 6-inch | | 9-inch | | 12-inch | | 18-inch | |
| *Feet* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* |
| 0.10 | 0.028 | 1.1 | 0.05 | 1.9 | 0.09 | 3.5 | 0.11 | 4.6 | 0.15 | 5.8 |
| .11 | .033 | 1.3 | .06 | 2.3 | .10 | 3.8 | .12 | 5.4 | .18 | 6.9 |
| .12 | .037 | 1.4 | .07 | 2.7 | .12 | 4.6 | .14 | 6.1 | .21 | 8.1 |
| .13 | .042 | 1.6 | .08 | 3.1 | .14 | 5.4 | .16 | 6.9 | .24 | 9.2 |
| .14 | .047 | 1.8 | .09 | 3.5 | .15 | 5.8 | .18 | 7.7 | .27 | 10 |
| .15 | .053 | 2.0 | .10 | 3.8 | .17 | 6.5 | .20 | 8.8 | .30 | 12 |
| .16 | .058 | 2.2 | .11 | 4.2 | .19 | 7.3 | .23 | 9.6 | .34 | 13 |
| .17 | .064 | 2.5 | .12 | 4.6 | .20 | 7.7 | .26 | 10 | .38 | 15 |
| .18 | .070 | 2.7 | .14 | 5.4 | .22 | 8.4 | .29 | 11 | .42 | 16 |
| .19 | .076 | 2.9 | .15 | 5.8 | .24 | 9.2 | .32 | 12 | .46 | 18 |
| .20 | .082 | 3.1 | .16 | 6.1 | .26 | 10 | .35 | 13 | .50 | 19 |
| .21 | .089 | 3.4 | .18 | 6.9 | .28 | 11 | .37 | 14 | .54 | 21 |
| .22 | .095 | 3.6 | .19 | 7.3 | .30 | 12 | .40 | 15 | .58 | 22 |
| .23 | .102 | 3.9 | .20 | 7.7 | .32 | 12 | .43 | 17 | .63 | 24 |
| .24 | .109 | 4.2 | .22 | 8.4 | .35 | 13 | .46 | 18 | .67 | 26 |
| .25 | .117 | 4.5 | .23 | 8.8 | .37 | 14 | .49 | 19 | .71 | 27 |
| .26 | .124 | 4.8 | .25 | 9.6 | .39 | 15 | .51 | 20 | .76 | 29 |
| .27 | .131 | 5.0 | .26 | 10 | .41 | 16 | .54 | 21 | .80 | 31 |
| .28 | .138 | 5.3 | .28 | 11 | .44 | 17 | .58 | 22 | .85 | 33 |
| .29 | .146 | 5.6 | .29 | 11 | .46 | 18 | .61 | 23 | .90 | 35 |
| .30 | .154 | 5.9 | .31 | 12 | .49 | 19 | .64 | 25 | .94 | 36 |
| .31 | .162 | 6.2 | .32 | 12 | .51 | 20 | .68 | 26 | .99 | 38 |
| .32 | .170 | 6.5 | .34 | 13 | .54 | 21 | .71 | 27 | 1.04 | 40 |
| .33 | .179 | 6.9 | .36 | 14 | .56 | 22 | .74 | 28 | 1.09 | 42 |
| .34 | .187 | 7.2 | .38 | 15 | .59 | 23 | .77 | 30 | 1.14 | 44 |
| .35 | .196 | 7.5 | .39 | 15 | .62 | 24 | .80 | 31 | 1.19 | 46 |
| .36 | .205 | 7.9 | .41 | 16 | .64 | 25 | .84 | 32 | 1.25 | 48 |
| .37 | .213 | 8.2 | .43 | 17 | .67 | 26 | .88 | 34 | 1.30 | 50 |
| .38 | .222 | 8.5 | .45 | 17 | .70 | 27 | .92 | 35 | 1.36 | 52 |
| .39 | .231 | 8.9 | .47 | 18 | .73 | 28 | .95 | 36 | 1.41 | 54 |

TABLE 3.—FREE-FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUME.—Continued.

| Head Ha | Discharge, Q, for throat widths, W, of— | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3-inch | | 6-inch | | 9-inch | | 12-inch | | 18-inch | |
| *Feet* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* |
| .40 | .241 | 9.3 | .48 | 18 | .76 | 29 | .99 | 38 | 1.47 | 56 |
| .41 | .250 | 9.6 | .50 | 19 | .78 | 30 | 1.03 | 40 | 1.53 | 59 |
| .42 | .260 | 10 | .52 | 20 | .81 | 31 | 1.07 | 41 | 1.58 | 61 |
| .43 | .269 | 10 | .54 | 21 | .84 | 32 | 1.11 | 43 | 1.64 | 63 |
| .44 | .279 | 11 | .56 | 22 | .87 | 33 | 1.15 | 44 | 1.70 | 65 |
| .45 | .289 | 11 | .58 | 22 | .90 | 35 | 1.19 | 46 | 1.76 | 68 |
| .46 | .299 | 11 | .61 | 23 | .94 | 36 | 1.23 | 47 | 1.82 | 70 |
| .47 | .309 | 12 | .63 | 24 | .97 | 37 | 1.27 | 49 | 1.88 | 72 |
| .48 | .319 | 12 | .65 | 25 | 1.00 | 38 | 1.31 | 50 | 1.94 | 74 |
| .49 | .329 | 13 | .67 | 26 | 1.03 | 40 | 1.35 | 52 | 2.00 | 77 |
| .50 | .339 | 13 | .69 | 26 | 1.06 | 41 | 1.39 | 53 | 2.06 | 79 |
| .51 | .350 | 13 | .71 | 27 | 1.10 | 42 | 1.44 | 55 | 2.13 | 82 |
| .52 | .361 | 14 | .73 | 28 | 1.13 | 43 | 1.48 | 57 | 2.19 | 84 |
| .53 | .371 | 14 | .76 | 29 | 1.16 | 45 | 1.52 | 58 | 2.25 | 86 |
| .54 | .382 | 15 | .78 | 30 | 1.20 | 46 | 1.57 | 60 | 2.32 | 89 |
| .55 | .393 | 15 | .80 | 31 | 1.23 | 47 | 1.62 | 62 | 2.39 | 92 |
| .56 | .404 | 16 | .82 | 31 | 1.26 | 48 | 1.66 | 64 | 2.45 | 94 |
| .57 | .415 | 16 | .85 | 33 | 1.30 | 50 | 1.70 | 65 | 2.52 | 97 |
| .58 | .427 | 16 | .87 | 33 | 1.33 | 51 | 1.75 | 67 | 2.59 | 99 |
| .59 | .438 | 17 | .89 | 34 | 1.37 | 53 | 1.80 | 69 | 2.66 | 102 |
| .60 | .450 | 17 | .92 | 35 | 1.40 | 54 | 1.84 | 71 | 2.73 | 105 |
| .61 | .462 | 18 | .94 | 36 | 1.44 | 55 | 1.88 | 72 | 2.80 | 108 |
| .62 | .474 | 18 | .97 | 37 | 1.48 | 57 | 1.93 | 74 | 2.87 | 110 |
| .63 | .485 | 19 | .99 | 38 | 1.51 | 58 | 1.98 | 76 | 2.95 | 113 |
| .64 | .497 | 19 | 1.02 | 39 | 1.55 | 60 | 2.03 | 78 | 3.02 | 116 |
| .65 | .509 | 20 | 1.04 | 40 | 1.59 | 61 | 2.08 | 80 | 3.09 | 119 |
| .66 | .522 | 20 | 1.07 | 41 | 1.63 | 63 | 2.13 | 82 | 3.17 | 122 |
| .67 | .534 | 20 | 1.10 | 42 | 1.66 | 64 | 2.18 | 84 | 3.24 | 124 |
| .68 | .546 | 21 | 1.12 | 43 | 1.70 | 65 | 2.23 | 86 | 3.31 | 127 |
| .69 | .558 | 21 | 1.15 | 44 | 1.74 | 67 | 2.28 | 88 | 3.39 | 130 |
| .70 | .571 | 22 | 1.17 | 45 | 1.78 | 68 | 2.33 | 89 | 3.46 | 133 |
| .71 | .584 | 22 | 1.20 | 46 | 1.82 | 70 | 2.38 | 91 | 3.54 | 136 |
| .72 | .597 | 23 | 1.23 | 47 | 1.86 | 71 | 2.43 | 93 | 3.62 | 139 |
| .73 | .610 | 23 | 1.26 | 48 | 1.90 | 73 | 2.48 | 95 | 3.69 | 142 |
| .74 | .623 | 24 | 1.28 | 49 | 1.94 | 74 | 2.53 | 97 | 3.77 | 145 |
| .75 | .636 | 24 | 1.31 | 50 | 1.98 | 76 | 2.58 | 99 | 3.85 | 148 |
| .76 | .649 | 25 | 1.34 | 51 | 2.02 | 78 | 2.63 | 101 | 3.93 | 151 |
| .77 | .662 | 25 | 1.36 | 52 | 2.06 | 79 | 2.68 | 103 | 4.01 | 154 |
| .78 | .675 | 26 | 1.39 | 53 | 2.10 | 81 | 2.74 | 105 | 4.09 | 157 |
| .79 | .689 | 26 | 1.42 | 55 | 2.14 | 82 | 2.80 | 107 | 4.17 | 160 |

TABLE 3.—FREE-FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUME.—Continued.

| Head Ha | Discharge, Q, for throat widths, W, of— | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3-inch | | 6-inch | | 9-inch | | 12-inch | | 18-inch | |
| *Feet* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* |
| .80 | .702 | 27 | 1.45 | 56 | 2.18 | 84 | 2.85 | 109 | 4.26 | 164 |
| .81 | .716 | 27 | 1.48 | 57 | 2.22 | 85 | 2.90 | 111 | 4.34 | 167 |
| .82 | .730 | 28 | 1.50 | 58 | 2.27 | 87 | 2.96 | 114 | 4.42 | 170 |
| .83 | .744 | 29 | 1.53 | 59 | 2.31 | 89 | 3.02 | 116 | 4.50 | 173 |
| .84 | .757 | 29 | 1.56 | 60 | 2.35 | 90 | 3.07 | 118 | 4.59 | 176 |
| .85 | .771 | 30 | 1.59 | 61 | 2.39 | 92 | 3.12 | 120 | 4.67 | 179 |
| .86 | .786 | 30 | 1.62 | 62 | 2.44 | 94 | 3.18 | 122 | 4.76 | 183 |
| .87 | .800 | 31 | 1.65 | 63 | 2.48 | 95 | 3.24 | 124 | 4.84 | 186 |
| .88 | .814 | 31 | 1.68 | 65 | 2.52 | 97 | 3.29 | 126 | 4.93 | 189 |
| .89 | .828 | 32 | 1.71 | 66 | 2.57 | 99 | 3.35 | 129 | 5.01 | 192 |
| .90 | .843 | 32 | 1.74 | 67 | 2.61 | 100 | 3.41 | 131 | 5.10 | 196 |
| .91 | .858 | 33 | 1.77 | 68 | 2.66 | 102 | 3.46 | 133 | 5.19 | 199 |
| .92 | .872 | 33 | 1.81 | 70 | 2.70 | 104 | 3.52 | 135 | 5.28 | 203 |
| .93 | .887 | 34 | 1.84 | 71 | 2.75 | 106 | 3.58 | 137 | 5.37 | 206 |
| .94 | .902 | 35 | 1.87 | 72 | 2.79 | 107 | 3.64 | 140 | 5.46 | 210 |
| .95 | .916 | 35 | 1.90 | 73 | 2.84 | 109 | 3.70 | 142 | 5.55 | 213 |
| .96 | .931 | 36 | 1.93 | 74 | 2.88 | 111 | 3.76 | 144 | 5.64 | 217 |
| .97 | .946 | 36 | 1.97 | 76 | 2.93 | 113 | 3.82 | 147 | 5.73 | 220 |
| .98 | .961 | 37 | 2.00 | 77 | 2.98 | 114 | 3.88 | 149 | 5.82 | 223 |
| .99 | .977 | 38 | 2.03 | 78 | 3.02 | 116 | 3.94 | 151 | 5.91 | 227 |
| 1.00 | .992 | 38 | 2.06 | 79 | 3.07 | 118 | 4.00 | 154 | 6.00 | 230 |
| 1.01 | 1.01 | 39 | 2.09 | 80 | 3.12 | 120 | 4.06 | 156 | 6.09 | 234 |
| 1.02 | 1.02 | 39 | 2.12 | 81 | 3.17 | 122 | 4.12 | 158 | 6.19 | 238 |
| 1.03 | 1.04 | 40 | 2.16 | 83 | 3.21 | 123 | 4.18 | 161 | 6.28 | 241 |
| 1.04 | 1.05 | 40 | 2.19 | 84 | 3.26 | 125 | 4.25 | 163 | 6.37 | 245 |
| 1.05 | 1.07 | 41 | 2.22 | 85 | 3.31 | 127 | 4.31 | 166 | 6.47 | 248 |
| 1.06 | 1.09 | 42 | 2.26 | 87 | 3.36 | 129 | 4.37 | 168 | 6.56 | 252 |
| 1.07 | 1.10 | 42 | 2.29 | 88 | 3.40 | 131 | 4.43 | 170 | 6.66 | 256 |
| 1.08 | 1.12 | 43 | 2.32 | 89 | 3.45 | 132 | 4.50 | 173 | 6.75 | 259 |
| 1.09 | 1.13 | 43 | 2.36 | 91 | 3.50 | 134 | 4.56 | 175 | 6.85 | 263 |
| 1.10 | 1.15 | 44 | 2.40 | 92 | 3.55 | 136 | 4.62 | 177 | 6.95 | 267 |
| 1.11 | 1.16 | 45 | 2.43 | 93 | 3.60 | 138 | 4.68 | 180 | 7.04 | 270 |
| 1.12 | 1.18 | 45 | 2.46 | 94 | 3.65 | 140 | 4.75 | 182 | 7.14 | 274 |
| 1.13 | 1.20 | 46 | 2.50 | 96 | 3.70 | 142 | 4.82 | 185 | 7.24 | 278 |
| 1.14 | 1.21 | 46 | 2.53 | 97 | 3.75 | 144 | 4.88 | 187 | 7.34 | 282 |

TABLE 3.—FREE-FLOW DISCHARGE TABLE FOR PARSHALL MEASURING FLUME.—Continued.

| Head Ha | Discharge, Q, for throat widths, W, of— | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 3-inch | | 6-inch | | 9-inch | | 12-inch | | 18-inch | |
| *Feet* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* | *Sec.-ft.* | *Colo. Inch* |
| 1.15 | 1.23 | 47 | 2.57 | 99 | 3.80 | 146 | 4.94 | 190 | 7.44 | 286 |
| 1.16 | 1.25 | 48 | 2.60 | 100 | 3.85 | 148 | 5.01 | 192 | 7.54 | 290 |
| 1.17 | 1.26 | 48 | 2.64 | 101 | 3.90 | 150 | 5.08 | 195 | 7.64 | 293 |
| 1.18 | 1.28 | 49 | 2.68 | 103 | 3.95 | 152 | 5.15 | 198 | 7.74 | 297 |
| 1.19 | 1.30 | 50 | 2.71 | 104 | 4.01 | 154 | 5.21 | 200 | 7.84 | 301 |
| 1.20 | 1.32 | 51 | 2.75 | 106 | 4.06 | 156 | 5.28 | 203 | 7.94 | 305 |
| 1.21 | 1.33 | 51 | 2.78 | 107 | 4.11 | 158 | 5.34 | 205 | 8.05 | 309 |
| 1.22 | 1.35 | 52 | 2.82 | 108 | 4.16 | 160 | 5.41 | 208 | 8.15 | 313 |
| 1.23 | 1.37 | 53 | 2.86 | 110 | 4.22 | 162 | 5.48 | 210 | 8.25 | 317 |
| 1.24 | 1.38 | 53 | 2.89 | 111 | 4.27 | 164 | 5.55 | 213 | 8.36 | 321 |
| 1.25 | 1.40 | 54 | 2.93 | 113 | 4.32 | 166 | 5.62 | 216 | 8.46 | 325 |
| 1.26 | 1.42 | 55 | 2.97 | 114 | 4.37 | 168 | 5.69 | 218 | 8.56 | 329 |
| 1.27 | 1.44 | 55 | 3.01 | 116 | 4.43 | 170 | 5.76 | 221 | 8.67 | 333 |
| 1.28 | 1.45 | 56 | 3.04 | 117 | 4.48 | 172 | 5.82 | 223 | 8.77 | 337 |
| 1.29 | 1.47 | 56 | 3.08 | 118 | 4.53 | 174 | 5.89 | 226 | 8.88 | 341 |
| 1.30 | 1.49 | 57 | 3.12 | 120 | 4.59 | 176 | 5.96 | 229 | 8.99 | 345 |
| 1.31 | 1.50 | 58 | 3.16 | 121 | 4.64 | 178 | 6.03 | 232 | 9.09 | 349 |
| 1.32 | 1.52 | 58 | 3.19 | 122 | 4.69 | 180 | 6.10 | 234 | 9.20 | 353 |
| 1.33 | 1.54 | 59 | 3.23 | 124 | 4.75 | 182 | 6.18 | 237 | 9.30 | 357 |
| 1.34 | 1.56 | 60 | 3.27 | 126 | 4.80 | 184 | 6.25 | 240 | 9.41 | 361 |
| 1.35 | 1.58 | 61 | 3.31 | 127 | 4.86 | 187 | 6.32 | 243 | 9.52 | 366 |
| 1.36 | 1.59 | 61 | 3.35 | 129 | 4.92 | 189 | 6.39 | 245 | 9.63 | 370 |
| 1.37 | 1.61 | 62 | 3.39 | 130 | 4.97 | 191 | 6.46 | 248 | 9.74 | 374 |
| 1.38 | 1.63 | 63 | 3.43 | 132 | 5.03 | 193 | 6.53 | 251 | 9.85 | 378 |
| 1.39 | 1.65 | 63 | 3.47 | 133 | 5.08 | 195 | 6.60 | 253 | 9.96 | 382 |
| 1.40 | 1.67 | 64 | 3.51 | 135 | 5.14 | 197 | 6.68 | 256 | 10.1 | 388 |
| 1.41 | 1.69 | 65 | 3.55 | 136 | 5.19 | 199 | 6.75 | 259 | 10.2 | 392 |
| 1.42 | 1.70 | 65 | 3.59 | 138 | 5.25 | 202 | 6.82 | 262 | 10.3 | 396 |
| 1.43 | 1.72 | 66 | 3.63 | 139 | 5.31 | 204 | 6.89 | 265 | 10.4 | 399 |
| 1.44 | 1.74 | 67 | 3.67 | 141 | 5.37 | 206 | 6.97 | 268 | 10.5 | 403 |
| 1.45 | 1.76 | 68 | 3.71 | 142 | 5.42 | 208 | 7.04 | 270 | 10.6 | 407 |
| 1.46 | 1.78 | 68 | 3.75 | 144 | 5.48 | 210 | 7.12 | 273 | 10.7 | 411 |
| 1.47 | 1.80 | 69 | 3.79 | 146 | 5.54 | 213 | 7.19 | 276 | 10.8 | 415 |
| 1.48 | 1.82 | 70 | 3.83 | 147 | 5.59 | 215 | 7.26 | 279 | 11.0 | 422 |
| 1.49 | 1.84 | 71 | 3.87 | 149 | 5.65 | 217 | 7.34 | 282 | 11.1 | 426 |
| 1.50 | 1.86 | 72 | 3.91 | 150 | 5.71 | 219 | 7.41 | 285 | 11.2 | 430 |

## Measuring Deliveries to the Farmer

There are a number of types of measuring devices used as a means of gaging the rate of small flow, such as would apply to farm deliveries.

One of the most commonly used of these several schemes of measurement is the ordinary weir. This device under standard dimensions of setting is one of the simplest and most accurate of the several practical methods used to measure small to moderate amounts of flowing water for irrigation purposes. The weir is essentially a watertight bulkhead placed at right angles across the channel, causing the approaching stream to fill the basin upstream to the point of overflow through the notched opening at the top side of the barrier. This opening is usually rectangular in shape with the bottom side or crest fixed in a level position. The weir crest should be sharp-edged and straight. The length of the crest in inches, or preferably in feet, specifies the size of the weir. Where the sides are vertical, the device is known as a rectangular weir; where the sides slope outward at a ratio of 1 to 4 it is called a Cipolletti weir. The minimum practical head over these types of weirs is about 0.1 foot, and the minimum length of crest is limited to 6 inches. To measure small flows, less than can be accommodated by the standard rectangular or the Cipolletti weir, the triangular notch is used. This type of weir has the sides inclined outward, usually 45 degrees from the vertical, in which case they form a 90-degree notch; the point of intersection is the reference datum for measuring the head or depth of water flowing through the opening. The rate of flow or discharge over weirs is determined by the head or depth, in feet or inches, of the water passing through the opening. This head should be measured at a point upstream from the bulkhead at a distance of at least four times the maximum head or depth expected over the crest. To accomplish this head measurement, a flat-topped stake is driven at the proper distance upstream into the bed of the weir pool near the bank and within easy reach, until the top is just level with the weir crest. The depth of water over this stake will then be the effective head or depth of flow over the weir.

Because of certain limitations in the use of this type of measuring device under field conditions, the weir in many areas is becoming obsolete. The required loss of head for free-flow measurement is often objectionable, and the filling of the weir pond with debris, which results in over-registration, is also a disadvantage.[3]

[3] Discharge tables for various sizes and kinds of weirs may be found in U. S. Farmers' Bulletin 1683, "Measuring Water in Irrigation Channels."

TABLE 4.—DIMENSIONS AND CAPACITIES OF THE PARSHALL MEASURING FLUME, FOR VARIOUS THROAT WIDTHS, W.

(Letters refer to dimensions, Fig. 1.)

| W | A | 2/3 A | B | C | D | E | F | G | K | N | X | Y | Free-flow capacity | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | Max. | Min. |
| *Inch* | *Ft. In.* | *Ft. In.* | *Ft. In.* | *Ft. In.* | *Ft. In.* | *Ft. In.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | *In.* | *Sec.-ft* | *Sec.-ft* |
| 3 | 1— 6 3/8 | 1— 1/4 | 1— 6 | 0—7 | 0—10 3/16 | 1—6 | 1/2 | 1 | 1 | 2 1/4 | 1 | 1 1/2 | 1.9 | 0.03 |
| 6 | 2— 7/16 | 1— 4 5/16 | 2— 0 | 1—3 5/8 | 1— 3 5/8 | 1—6 | 1 | 2 | 3 | 4 1/2 | 2 | 3 | 3.9 | .05 |
| 9 | 2—10 5/8 | 1—11 1/8 | 2—10 | 1—3 | 1—10 5/8 | 1—6 | 1 | 1 1/2 | 3 | 4 1/2 | 2 | 3 | 5.7 | .09 |
| 12 | 4— 6 | 3— 0 | 4— 4 7/8 | 2—0 | 2— 9 1/4 | 1—6 | 2 | 3 | 3 | 9 | 2 | 3 | 7.4 | .11 |
| 18 | 4— 9 | 3— 2 | 4— 7 7/8 | 2—6 | 3— 4 3/8 | 1—6 | 2 | 3 | 3 | 9 | 2 | 3 | 11.2 | .15 |

## Features of the Parshall Measuring Flume

The Parshall measuring flume consists of a converging section, a throat, and a diverging section, with vertical side walls and the floor in the throat inclined downward as shown in figure 1, section M-M.

The discharge through the Parshall measuring flume is called free flow when the elevation of the water surface downstream from the throat is not high enough to cause the flow to be retarded by the effect of backwater. However, when the surface elevation of the water downstream is sufficiently high to affect the rate of flow, the critical point of submergence has been

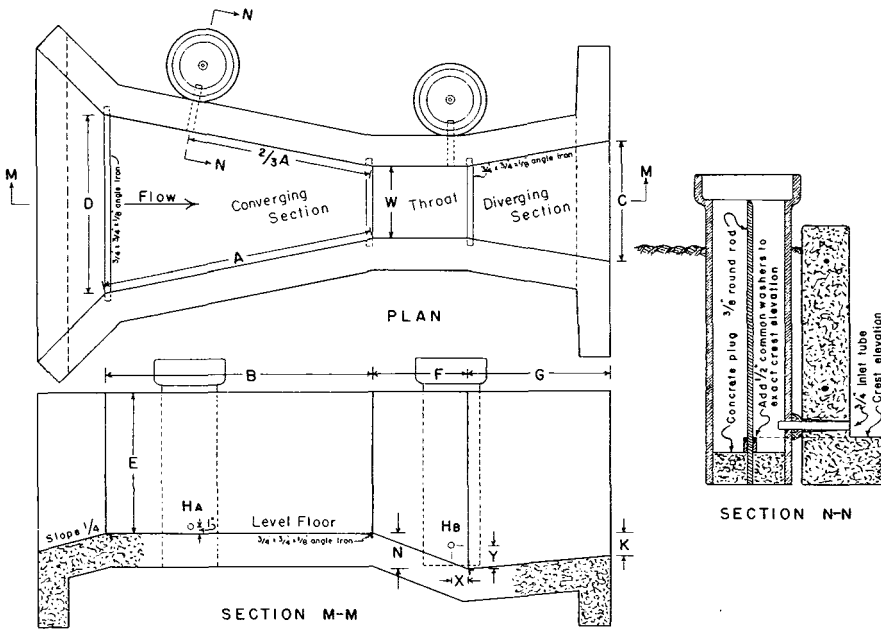


**FIGURE 1.—Plan and elevation of the Parshall measuring flume showing dimensions of W, size of flume, in inches or feet; A, length of side wall of converging section; ⅔ A, distance back from end of crest to gage point; B, axial length of converging section; C, width of downstream end of flume; D, width of upstream end of flume; E, depth of flume; F, length of throat; G, length of diverging section; K, difference in elevation between lower end of flume and crest; N, depth of depression in throat below crest; X, horizontal distance to $H_b$ gage point upstream from lower edge of throat; Y, vertical distance to $H_b$ gage point from low point in throat. See table 4 for actual dimensions for various sizes of flume.**

reached and the condition of submerged flow begins. At first the flow is only slightly reduced, but as the degree of submergence increases, a greater reduction in the discharge results. If the water surface downstream were to have the same elevation as the water surface upstream, submergence would be complete and the rate of flow reduced to zero—that is, the water would be standing in the ditch, not flowing. But so long as there is a difference in the elevation of the water surfaces upstream and downstream, submergence is not complete and the water will then flow through the throat of the Parshall measuring flume.

The two principal advantages of this type of measuring device are that its accuracy is not appreciably affected by a moderately high degree of submergence, and the relatively high velocity of the water passing through the converging section prevents the accumulation of sand and silt on the floor of the structure. Numerous laboratory and field experiments have proved this device to be sufficiently accurate and dependable in meeting practical irrigation requirements. Table 4 gives the required dimensions for small Parshall measuring flumes. The lettered columns refer to the corresponding dimensions in figure 1. The size of flume (W) is taken as the horizontal distance between the vertical parallel walls of the throat section, and is identical with the length of the crest, which is the line where the level floor of the converging section joins the inclined floor of the throat. The floor of the converging part of the structure is level both transversely and longitudinally.

The rate of flow is determined by the head or depth in feet of the water in the $H_a$ stilling well where the discharge is free from submergence, and in both the $H_a$ and $H_b$ wells for submerged flow. The datum points in the $H_a$ and $H_b$ wells must be set accurately to the elevation of the crest of the flume.

## Free Flow

Free flow is the condition under which the rate of discharge is dependent only upon the length of crest and the depth or head $H_a$ in the converging section. The Parshall measuring flume can withstand a relatively high degree of submergence without reduction in the rate of flow; therefore a free-flow discharge is obtained over a rather wide range of downstream backwater conditions. The stream passing through the throat can assume two different stages of flow: first, where the water moves at a high velocity in a thin sheet conforming closely with the dip at the lower end of the throat; and second, where the backwater raises the water surface to the point where a ripple or wave is formed at or near the downstream end of the throat. For this higher stage there is a marked reduction in the velocity of the

water as it leaves the lower end of the flume. This upper limit of stage, just bordering on the condition of submerged flow, can be determined by observing the depths in both stilling wells and then determining the ratio of these values. If the ratio of the $H_b$ head to the $H_a$ head is 0.6 or less for the 3-, 6-, and 9-inch flumes, and 0.7 or less for the 12- and 18-inch flumes, then the rate of discharge is that of free flow. Should the ratio of the heads exceed these limits for the respective sizes of flume, then the flow is submerged.

Table 3 gives the rate of free-flow discharge in second-feet and Colorado statutory inches through the 3-, 6-, 9-, 12-, and 18-inch flumes for $H_a$ heads ranging from 0.1 to 1.5 feet. The 3-inch flume is intended for the more precise measurement of small flows down to approximately 1/30 second-foot as a minimum.

## Submerged Flow

When the ratio of the $H_b$ to $H_a$ readings exceeds these limits, as just enumerated, the condition of flow has reached the point where a negative correction must be applied to the free-flow discharge as indicated by the upper head $H_a$. To facilitate the determination of the rate of submerged flow discharge through these smaller sized flumes, tables 5 to 9 inclusive have been prepared in units of Colorado statutory inches. Accompanying these tables are diagrams, figures 2 to 6, in condensed form, which may be applied to the solution of the submerged flow problem.

To use these tables, enter at the left side at the value of $H_a$ and then read to the right to the column headed by the ratio of $H_b$ to $H_a$, expressed as a percentage. The observed columnar value is the rate of flow in statutory inches. If the discharge is desired in second-feet, divide this tabular value by 38.4. As an example, suppose the flow through a 9-inch Parshall measuring flume shows the $H_a$ head to be 0.89 foot and the $H_b$ head 0.81 foot. For this condition, what is the discharge in statutory inches and also in second-feet? By dividing 0.81 by 0.89, the ratio of the two heads is found to be 0.91. For the 9-inch flume (table 7), the $H_a$ value lies between 0.88 and 0.90 and the ratio between 0.90 and 0.92. For $H_a$ 0.88 foot, the interpolated value of the flow for a submergence of 91 percent is 69.5 inches; for $H_a$ 0.90 foot and the same submergence, the flow is 71.5 inches. Then for the actual $H_a$ head of 0.89, the discharge will be the average of these two discharges, or 70.5 statutory inches. This flow of 70.5 inches divided by 38.4 gives 1.84 second-feet.

The use of the diagrams is quite simple. First, estimate the location of the $H_a$ head curve for 0.89 foot at the point between the horizontal parallel submergence lines, namely 88 and 90 percent. Vertically below on the base of the diagram is to be found the rate of submerged flow in statutory inches.

## TABLE 5.—SUBMERGED-FLOW DISCHARGE TABLE FOR 3-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 0.10 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.8 | 0.8 | 0.7 | 0.6 | 0.5 |
| .12 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.1 | 1.1 | 1.0 | 0.8 | 0.6 |
| .14 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.7 | 1.6 | 1.5 | 1.4 | 1.4 | 1.2 | 1.0 | 0.8 |
| .16 | 2.2 | 2.2 | 2.2 | 2 2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.0 | 2.0 | 1.8 | 1.7 | 1.7 | 1.5 | 1.3 | 1.1 |
| .18 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.6 | 2.6 | 2.6 | 2.6 | 2.5 | 2.5 | 2.4 | 2.3 | 2.1 | 2.0 | 2.0 | 1.8 | 1.5 | 1.3 |
| .20 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 | 2.9 | 2.8 | 2.8 | 2.6 | 2.5 | 2.4 | 2.3 | 2.1 | 1.8 | 1.5 |
| .22 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.5 | 3.5 | 3.4 | 3.3 | 3.3 | 3.1 | 2.9 | 2.8 | 2.7 | 2.4 | 2.1 | 1.8 |
| .24 | 4.2 | 4.2 | 4.2 | 4.1 | 4.1 | 4.1 | 4.1 | 4.0 | 4.0 | 3.9 | 3.8 | 3.7 | 3.5 | 3.3 | 3.1 | 3.0 | 2.7 | 2.4 | 2.1 |
| .26 | 4.8 | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 | 4.6 | 4.5 | 4.5 | 4.4 | 4.3 | 4.2 | 4.0 | 3.8 | 3.6 | 3.5 | 3.1 | 2.7 | 2.4 |
| .28 | 5.3 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.1 | 5.0 | 5.0 | 4.9 | 4.8 | 4.7 | 4.5 | 4.2 | 4.0 | 3.8 | 3.5 | 3.0 | 2.6 |
| .30 | 5.9 | 5.9 | 5.9 | 5.8 | 5.8 | 5.8 | 5.8 | 5.7 | 5.6 | 5.5 | 5.3 | 5.2 | 5.0 | 4.8 | 4.5 | 4.3 | 3.9 | 3.5 | 2.9 |
| 32 | 6.5 | 6.5 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 | 6.2 | 6.1 | 5.9 | 5.7 | 5.5 | 5.2 | 5.0 | 4.7 | 4.3 | 3.8 | 3.3 |
| .34 | 7.2 | 7.1 | 7.1 | 7.0 | 7.0 | 7.0 | 7.0 | 6.8 | 6.7 | 6.6 | 6.4 | 6.2 | 6.1 | 5.7 | 5.5 | 5.1 | 4.7 | 4.1 | 3.6 |
| .36 | 7.9 | 7.8 | 7.8 | 7.7 | 7.7 | 7.6 | 7.6 | 7.5 | 7.4 | 7.2 | 7.0 | 6.8 | 6.6 | 6.2 | 6.0 | 5.6 | 5.1 | 4.5 | 4.0 |
| .38 | 8.5 | 8.5 | 8.5 | 8.4 | 8.4 | 8.3 | 8.3 | 8.2 | 8.0 | 7.8 | 7.6 | 7.4 | 7.2 | 6.8 | 6.5 | 6.1 | 5.5 | 4.8 | 4.3 |
| .40 | 9.3 | 9.2 | 9.2 | 9.1 | 9.1 | 9.0 | 8.9 | 8.8 | 8.7 | 8.5 | 8.2 | 8.0 | 7.8 | 7.4 | 7.0 | 6.6 | 6.0 | 5.2 | 4.6 |
| .42 | 10 | 10 | 10 | 9.7 | 9.7 | 9.7 | 9.6 | 9.5 | 9.3 | 9.2 | 8.8 | 8 5 | 8.4 | 7.8 | 7.5 | 7.0 | 6.4 | 5.6 | 5.0 |
| .44 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 9.9 | 9.4 | 9.2 | 9.0 | 8.4 | 8.0 | 7.5 | 6.8 | 6.0 | 5.3 |
| .46 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 10 | 9.8 | 9.6 | 8.9 | 8.6 | 8.1 | 7.3 | 6.4 | 5.7 |
| .48 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 11 | 11 | 11 | 11 | 10 | 10 | 9.4 | 9.2 | 8.6 | 7.8 | 6.8 | 6.0 |
| .50 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 12 | 12 | 12 | 11 | 11 | 11 | 10 | 9.8 | 9.1 | 8.3 | 7.3 | 6.4 |
| .52 | 14 | 14 | 14 | 14 | 14 | 13 | 13 | 13 | 13 | 13 | 12 | 12 | 11 | 11 | 10 | 9.7 | 8.8 | 7.7 | 6.8 |
| .54 | 15 | 15 | 15 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 13 | 12 | 12 | 11 | 11 | 10 | 9.2 | 8.2 | 7.2 |
| .56 | 16 | 16 | 16 | 15 | 15 | 15 | 15 | 14 | 14 | 14 | 14 | 13 | 13 | 12 | 12 | 11 | 9.7 | 8.7 | 7.5 |
| .58 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 15 | 15 | 15 | 14 | 14 | 13 | 13 | 12 | 11 | 10 | 9.1 | 7.9 |

(Continued)

TABLE 5.—SUBMERGED-FLOW DISCHARGE TABLE FOR 3-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| .60 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 16 | 16 | 16 | 15 | 15 | 14 | 13 | 13 | 12 | 11 | 9.6 | 8.3 |
| .62 | 18 | 18 | 18 | 18 | 18 | 17 | 17 | 17 | 17 | 17 | 16 | 15 | 15 | 14 | 13 | 12 | 11 | 10 | 8.7 |
| .64 | 19 | 19 | 19 | 19 | 19 | 18 | 18 | 18 | 18 | 17 | 16 | 16 | 16 | 15 | 14 | 13 | 12 | 10 | 9.2 |
| .66 | 20 | 20 | 20 | 20 | 20 | 19 | 19 | 19 | 18 | 18 | 17 | 17 | 16 | 15 | 15 | 14 | 12 | 11 | 9.6 |
| .68 | 21 | 21 | 21 | 21 | 21 | 20 | 20 | 19 | 19 | 19 | 18 | 18 | 17 | 16 | 15 | 14 | 13 | 11 | 10 |
| .70 | 22 | 22 | 22 | 22 | 21 | 21 | 21 | 20 | 20 | 20 | 19 | 18 | 18 | 17 | 16 | 15 | 13 | 12 | 10 |
| .72 | 23 | 23 | 23 | 23 | 22 | 22 | 22 | 21 | 21 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 12 | 11 |
| .74 | 24 | 24 | 24 | 24 | 23 | 23 | 23 | 22 | 22 | 22 | 20 | 20 | 19 | 18 | 17 | 16 | 14 | 13 | 12 |
| .76 | 25 | 25 | 25 | 25 | 24 | 24 | 24 | 23 | 23 | 22 | 21 | 21 | 20 | 19 | 18 | 17 | 15 | 13 | 12 |
| .78 | 26 | 26 | 26 | 25 | 25 | 25 | 25 | 24 | 24 | 23 | 22 | 22 | 21 | 20 | 19 | 17 | 15 | 14 | 12 |
| .80 | 27 | 27 | 27 | 26 | 26 | 26 | 26 | 25 | 24 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 16 | 14 | 12 |
| .82 | 28 | 28 | 28 | 27 | 27 | 27 | 27 | 26 | 25 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 17 | 15 | 13 |
| .84 | 29 | 29 | 29 | 29 | 28 | 28 | 28 | 27 | 26 | 26 | 25 | 24 | 23 | 22 | 21 | 19 | 17 | 15 | 13 |
| .86 | 30 | 30 | 30 | 30 | 29 | 29 | 29 | 28 | 27 | 27 | 26 | 25 | 24 | 23 | 21 | 20 | 18 | 16 | 14 |
| .88 | 31 | 31 | 31 | 31 | 30 | 30 | 30 | 29 | 28 | 28 | 27 | 26 | 25 | 23 | 22 | 21 | 18 | 16 | 14 |
| .90 | 32 | 32 | 32 | 32 | 31 | 31 | 30 | 30 | 29 | 28 | 28 | 27 | 25 | 24 | 23 | 21 | 19 | 17 | 15 |
| .92 | 33 | 33 | 33 | 33 | 32 | 32 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 23 | 22 | 19 | 17 | 15 |
| .94 | 35 | 34 | 34 | 34 | 33 | 33 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 26 | 24 | 22 | 20 | 18 | 15 |
| .96 | 36 | 35 | 35 | 35 | 34 | 34 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 27 | 25 | 23 | 21 | 18 | 16 |
| .98 | 37 | 36 | 36 | 36 | 35 | 35 | 35 | 34 | 33 | 32 | 31 | 30 | 29 | 27 | 26 | 24 | 21 | 19 | 16 |
| 1.00 | 38 | 38 | 37 | 37 | 37 | 36 | 36 | 35 | 34 | 33 | 32 | 31 | 30 | 28 | 26 | 25 | 22 | 20 | 17 |
| 1.02 | 39 | 39 | 38 | 38 | 38 | 37 | 37 | 36 | 35 | 34 | 33 | 32 | 30 | 29 | 27 | 25 | 22 | 20 | 17 |
| 1.04 | 40 | 40 | 39 | 39 | 39 | 38 | 38 | 37 | 36 | 35 | 34 | 33 | 31 | 30 | 28 | 26 | 23 | 21 | 17 |
| 1.06 | 42 | 41 | 40 | 40 | 40 | 39 | 39 | 38 | 37 | 36 | 35 | 34 | 32 | 31 | 28 | 27 | 24 | 21 | 18 |
| 1.08 | 43 | 42 | 41 | 41 | 41 | 40 | 40 | 39 | 38 | 37 | 36 | 35 | 33 | 31 | 29 | 27 | 24 | 22 | 18 |

(Continued)

TABLE 5.—SUBMERGED-FLOW DISCHARGE TABLE FOR 3-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 1.10 | 44 | 43 | 43 | 43 | 42 | 42 | 41 | 40 | 39 | 38 | 37 | 36 | 34 | 32 | 30 | 28 | 25 | 22 | 19 |
| 1.12 | 45 | 45 | 44 | 44 | 43 | 43 | 42 | 41 | 40 | 39 | 38 | 37 | 35 | 33 | 31 | 29 | 25 | 23 | 19 |
| 1.14 | 46 | 46 | 45 | 45 | 44 | 44 | 43 | 42 | 41 | 40 | 39 | 37 | 35 | 34 | 32 | 29 | 26 | 23 | 20 |
| 1.16 | 48 | 47 | 46 | 46 | 45 | 45 | 44 | 43 | 42 | 41 | 40 | 38 | 36 | 35 | 32 | 30 | 27 | 24 | 20 |
| 1.18 | 49 | 48 | 47 | 47 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 39 | 37 | 35 | 33 | 31 | 27 | 24 | 20 |
| 1.20 | 51 | 50 | 49 | 49 | 48 | 47 | 47 | 45 | 44 | 43 | 42 | 40 | 38 | 36 | 34 | 31 | 28 | 25 | 21 |
| 1.22 | 52 | 51 | 50 | 50 | 49 | 48 | 48 | 47 | 45 | 44 | 43 | 41 | 39 | 37 | 35 | 32 | 29 | 25 | 21 |
| 1.24 | 53 | 52 | 51 | 51 | 50 | 50 | 49 | 48 | 46 | 45 | 44 | 42 | 40 | 38 | 36 | 33 | 29 | 26 | 22 |
| 1.26 | 55 | 53 | 52 | 52 | 52 | 51 | 50 | 49 | 47 | 46 | 45 | 43 | 41 | 39 | 36 | 33 | 30 | 26 | 22 |
| 1.28 | 56 | 55 | 54 | 54 | 53 | 52 | 51 | 50 | 49 | 47 | 46 | 44 | 42 | 39 | 37 | 34 | 30 | 27 | 22 |
| 1.30 | 57 | 56 | 55 | 55 | 54 | 53 | 52 | 51 | 50 | 48 | 47 | 45 | 43 | 40 | 38 | 35 | 31 | 27 | 23 |
| 1.32 | 58 | 57 | 56 | 56 | 55 | 54 | 53 | 52 | 51 | 49 | 48 | 46 | 44 | 41 | 39 | 36 | 32 | 28 | 23 |
| 1.34 | 60 | 58 | 58 | 58 | 57 | 56 | 55 | 53 | 52 | 50 | 49 | 47 | 45 | 42 | 40 | 36 | 32 | 28 | 24 |
| 1.36 | 61 | 60 | 59 | 59 | 58 | 57 | 56 | 54 | 53 | 51 | 50 | 48 | 45 | 42 | 40 | 37 | 33 | 29 | 24 |
| 1.38 | 63 | 61 | 60 | 60 | 59 | 58 | 57 | 55 | 54 | 52 | 51 | 49 | 46 | 43 | 41 | 38 | 33 | 29 | 25 |
| 1.40 | 64 | 63 | 62 | 61 | 60 | 59 | 58 | 56 | 55 | 53 | 52 | 50 | 47 | 44 | 42 | 38 | 34 | 30 | 25 |
| 1.42 | 65 | 64 | 63 | 63 | 62 | 60 | 59 | 57 | 56 | 54 | 53 | 51 | 48 | 45 | 43 | 39 | 35 | 30 | 25 |
| 1.44 | 67 | 65 | 64 | 64 | 63 | 61 | 60 | 59 | 57 | 56 | 54 | 52 | 49 | 46 | 44 | 40 | 35 | 31 | 26 |
| 1.46 | 68 | 66 | 65 | 65 | 64 | 63 | 62 | 60 | 58 | 57 | 55 | 53 | 50 | 46 | 44 | 40 | 36 | 31 | 26 |
| 1.48 | 70 | 68 | 67 | 67 | 66 | 64 | 63 | 61 | 60 | 58 | 56 | 54 | 51 | 47 | 45 | 41 | 36 | 32 | 27 |
| 1.50 | 72 | 69 | 68 | 68 | 67 | 65 | 64 | 62 | 61 | 59 | 57 | 55 | 52 | 48 | 46 | 42 | 37 | 33 | 27 |

## TABLE 6.—SUBMERGED-FLOW DISCHARGE TABLE FOR 6-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 0.10 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| .12 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| .14 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 |
| .16 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| .18 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 |
| .20 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 3 | 3 | 3 |
| .22 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 4 | 4 | 3 | 3 |
| .24 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 5 | 5 | 4 | 3 |
| .26 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 6 | 6 | 5 | 4 | 4 |
| .28 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 7 | 7 | 6 | 5 | 4 |
| .30 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 7 | 6 | 5 |
| .32 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 11 | 11 | 11 | 11 | 10 | 10 | 9 | 9 | 8 | 7 | 7 | 5 |
| .34 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 12 | 12 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 8 | 8 | 6 |
| .36 | 15 | 15 | 15 | 14 | 14 | 14 | 14 | 13 | 13 | 13 | 13 | 12 | 12 | 12 | 11 | 10 | 9 | 9 | 7 |
| .38 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 15 | 15 | 14 | 14 | 13 | 13 | 13 | 12 | 11 | 10 | 10 | 7 |
| .40 | 18 | 18 | 18 | 17 | 17 | 17 | 17 | 16 | 16 | 15 | 15 | 15 | 14 | 14 | 13 | 12 | 11 | 10 | 8 |
| .42 | 19 | 19 | 19 | 18 | 18 | 18 | 18 | 17 | 17 | 16 | 16 | 16 | 15 | 15 | 14 | 13 | 12 | 10 | 9 |
| .44 | 20 | 20 | 20 | 20 | 20 | 20 | 19 | 18 | 18 | 18 | 18 | 17 | 16 | 16 | 15 | 14 | 13 | 11 | 10 |
| .46 | 22 | 22 | 22 | 21 | 21 | 21 | 21 | 20 | 20 | 19 | 19 | 18 | 17 | 17 | 16 | 15 | 14 | 12 | 10 |
| .48 | 23 | 23 | 23 | 23 | 23 | 23 | 22 | 21 | 21 | 21 | 20 | 20 | 19 | 18 | 17 | 16 | 15 | 13 | 11 |
| .50 | 25 | 25 | 25 | 24 | 24 | 24 | 24 | 23 | 23 | 22 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 14 | 12 |
| .52 | 27 | 27 | 26 | 26 | 26 | 26 | 25 | 24 | 24 | 23 | 23 | 22 | 21 | 21 | 20 | 18 | 17 | 15 | 13 |
| .54 | 28 | 28 | 28 | 28 | 27 | 27 | 26 | 26 | 26 | 25 | 25 | 24 | 23 | 22 | 21 | 19 | 18 | 16 | 14 |
| .56 | 30 | 30 | 30 | 29 | 29 | 29 | 28 | 28 | 27 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 19 | 17 | 15 |
| .58 | 32 | 32 | 31 | 31 | 30 | 30 | 30 | 29 | 29 | 28 | 27 | 27 | 26 | 25 | 24 | 22 | 20 | 18 | 16 |

(Continued)

TABLE 6.—SUBMERGED-FLOW DISCHARGE TABLE FOR 6-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| .60 | 34 | 34 | 33 | 33 | 32 | 32 | 31 | 31 | 30 | 30 | 29 | 28 | 27 | 26 | 25 | 23 | 21 | 19 | 17 |
| .62 | 36 | 36 | 35 | 35 | 34 | 34 | 33 | 33 | 32 | 31 | 31 | 30 | 29 | 27 | 26 | 24 | 23 | 20 | 18 |
| .64 | 37 | 37 | 37 | 36 | 36 | 35 | 35 | 34 | 34 | 33 | 32 | 31 | 30 | 29 | 28 | 26 | 24 | 21 | 19 |
| .66 | 39 | 39 | 39 | 38 | 37 | 37 | 36 | 36 | 35 | 35 | 34 | 33 | 32 | 30 | 29 | 27 | 25 | 22 | 20 |
| .68 | 41 | 41 | 40 | 40 | 39 | 39 | 38 | 38 | 37 | 36 | 35 | 34 | 33 | 32 | 30 | 28 | 26 | 24 | 21 |
| .70 | 43 | 43 | 42 | 42 | 41 | 41 | 40 | 40 | 39 | 38 | 37 | 36 | 35 | 33 | 32 | 30 | 28 | 25 | 22 |
| .72 | 45 | 45 | 44 | 44 | 43 | 43 | 42 | 42 | 41 | 40 | 39 | 37 | 36 | 35 | 33 | 31 | 29 | 26 | 23 |
| .74 | 47 | 47 | 46 | 46 | 45 | 45 | 44 | 43 | 42 | 42 | 40 | 39 | 38 | 36 | 35 | 32 | 30 | 27 | 24 |
| .76 | 49 | 49 | 48 | 48 | 47 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 38 | 36 | 34 | 31 | 28 | 25 |
| .78 | 52 | 51 | 50 | 50 | 49 | 49 | 48 | 47 | 46 | 45 | 44 | 42 | 41 | 39 | 38 | 35 | 32 | 29 | 26 |
| .80 | 54 | 53 | 53 | 52 | 51 | 51 | 50 | 49 | 48 | 47 | 46 | 44 | 43 | 41 | 39 | 37 | 34 | 31 | 27 |
| .82 | 56 | 55 | 55 | 54 | 53 | 53 | 52 | 51 | 50 | 49 | 48 | 46 | 45 | 43 | 41 | 38 | 35 | 32 | 29 |
| .84 | 58 | 58 | 57 | 56 | 55 | 55 | 54 | 53 | 52 | 50 | 49 | 48 | 46 | 44 | 42 | 40 | 37 | 33 | 30 |
| .86 | 60 | 60 | 59 | 58 | 58 | 57 | 56 | 55 | 54 | 52 | 51 | 50 | 48 | 46 | 44 | 41 | 38 | 34 | 31 |
| .88 | 62 | 62 | 62 | 61 | 60 | 59 | 58 | 57 | 56 | 54 | 53 | 51 | 49 | 47 | 45 | 42 | 39 | 35 | 32 |
| .90 | 65 | 64 | 64 | 63 | 62 | 61 | 60 | 59 | 58 | 56 | 55 | 53 | 51 | 49 | 47 | 44 | 41 | 37 | 33 |
| .92 | 67 | 66 | 66 | 65 | 64 | 63 | 62 | 61 | 60 | 58 | 57 | 55 | 53 | 51 | 49 | 46 | 42 | 38 | 34 |
| .94 | 70 | 69 | 69 | 68 | 67 | 66 | 64 | 63 | 62 | 60 | 59 | 57 | 55 | 53 | 50 | 47 | 43 | 39 | 35 |
| .96 | 72 | 71 | 71 | 70 | 69 | 68 | 67 | 66 | 64 | 62 | 61 | 59 | 57 | 54 | 52 | 49 | 45 | 41 | 37 |
| .98 | 74 | 73 | 73 | 72 | 71 | 70 | 69 | 68 | 66 | 64 | 63 | 61 | 59 | 56 | 53 | 50 | 46 | 42 | 38 |
| 1.00 | 77 | 76 | 76 | 75 | 74 | 73 | 71 | 70 | 69 | 67 | 65 | 63 | 61 | 58 | 55 | 52 | 48 | 44 | 39 |
| 1.02 | 79 | 78 | 78 | 77 | 76 | 75 | 73 | 72 | 71 | 69 | 67 | 65 | 63 | 60 | 57 | 54 | 50 | 45 | 40 |
| 1.04 | 82 | 81 | 80 | 79 | 78 | 77 | 75 | 74 | 73 | 71 | 69 | 67 | 64 | 61 | 58 | 55 | 51 | 46 | 41 |
| 1.06 | 84 | 83 | 83 | 82 | 81 | 80 | 78 | 77 | 75 | 73 | 71 | 69 | 66 | 63 | 60 | 57 | 53 | 48 | 43 |
| 1.08 | 86 | 85 | 85 | 84 | 83 | 82 | 80 | 79 | 77 | 75 | 73 | 71 | 68 | 65 | 62 | 58 | 54 | 49 | 44 |

(Continued)

TABLE 6.—SUBMERGED-FLOW DISCHARGE TABLE FOR 6-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 1.10 | 89 | 88 | 88 | 87 | 86 | 85 | 83 | 82 | 80 | 78 | 76 | 73 | 70 | 67 | 64 | 60 | 56 | 51 | 46 |
| 1.12 | 91 | 90 | 90 | 89 | 88 | 87 | 85 | 84 | 82 | 80 | 78 | 75 | 72 | 69 | 66 | 62 | 58 | 53 | 47 |
| 1.14 | 94 | 93 | 93 | 92 | 91 | 90 | 88 | 86 | 84 | 82 | 80 | 77 | 74 | 71 | 68 | 64 | 59 | 54 | 49 |
| 1.16 | 97 | 96 | 95 | 94 | 93 | 92 | 90 | 89 | 87 | 85 | 82 | 79 | 76 | 73 | 69 | 65 | 60 | 55 | 50 |
| 1.18 | 99 | 98 | 98 | 97 | 96 | 95 | 93 | 91 | 89 | 87 | 85 | 82 | 79 | 75 | 71 | 67 | 62 | 57 | 52 |
| 1.20 | 102 | 101 | 100 | 99 | 98 | 97 | 95 | 94 | 92 | 90 | 87 | 84 | 81 | 77 | 73 | 69 | 64 | 59 | 53 |
| 1.22 | 105 | 104 | 103 | 102 | 101 | 100 | 98 | 96 | 94 | 92 | 89 | 86 | 83 | 79 | 75 | 70 | 65 | 60 | 54 |
| 1.24 | 108 | 107 | 106 | 105 | 104 | 102 | 100 | 99 | 97 | 94 | 91 | 88 | 85 | 81 | 77 | 72 | 67 | 62 | 56 |
| 1.26 | 110 | 109 | 108 | 107 | 106 | 105 | 103 | 101 | 99 | 97 | 94 | 91 | 87 | 83 | 79 | 74 | 69 | 63 | 57 |
| 1.28 | 113 | 112 | 111 | 110 | 109 | 107 | 106 | 104 | 102 | 99 | 96 | 93 | 89 | 85 | 81 | 76 | 71 | 65 | 59 |
| 1.30 | 116 | 115 | 114 | 113 | 112 | 110 | 108 | 106 | 104 | 101 | 98 | 95 | 91 | 87 | 83 | 78 | 72 | 66 | 60 |
| 1.32 | 119 | 118 | 117 | 115 | 114 | 113 | 111 | 109 | 106 | 103 | 100 | 97 | 93 | 89 | 85 | 80 | 74 | 68 | 61 |
| 1.34 | 122 | 121 | 120 | 118 | 117 | 115 | 114 | 112 | 109 | 106 | 103 | 100 | 96 | 92 | 87 | 82 | 76 | 70 | 63 |
| 1.36 | 125 | 124 | 122 | 121 | 120 | 118 | 116 | 114 | 112 | 109 | 106 | 102 | 98 | 94 | 89 | 84 | 78 | 71 | 64 |
| 1.38 | 127 | 126 | 125 | 124 | 123 | 121 | 119 | 117 | 114 | 111 | 108 | 104 | 100 | 96 | 91 | 86 | 80 | 73 | 66 |
| 1.40 | 130 | 129 | 128 | 127 | 126 | 124 | 122 | 120 | 117 | 114 | 111 | 107 | 103 | 98 | 93 | 88 | 82 | 75 | 67 |
| 1.42 | 133 | 132 | 131 | 130 | 128 | 126 | 124 | 122 | 119 | 116 | 113 | 109 | 105 | 100 | 95 | 90 | 84 | 77 | 68 |
| 1.44 | 136 | 135 | 134 | 133 | 131 | 129 | 127 | 125 | 122 | 119 | 115 | 111 | 107 | 103 | 98 | 92 | 85 | 78 | 70 |
| 1.46 | 139 | 138 | 137 | 136 | 134 | 132 | 130 | 128 | 125 | 122 | 118 | 114 | 110 | 105 | 100 | 94 | 87 | 80 | 71 |
| 1.48 | 142 | 141 | 140 | 139 | 137 | 135 | 133 | 130 | 127 | 124 | 120 | 116 | 112 | 107 | 102 | 96 | 89 | 81 | 73 |
| 1.50 | 145 | 144 | 143 | 142 | 140 | 138 | 136 | 133 | 130 | 127 | 123 | 119 | 115 | 110 | 104 | 98 | 91 | 83 | 74 |

## TABLE 7.—SUBMERGED-FLOW DISCHARGE TABLE FOR 9-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 0.10 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| .12 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 2 | 2 |
| .14 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 2 |
| .16 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 4 | 3 |
| .18 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 6 | 6 | 5 | 4 |
| .20 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 7 | 7 | 6 | 5 |
| .22 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 9 | 9 | 9 | 8 | 8 | 7 | 6 |
| .24 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 12 | 12 | 12 | 12 | 11 | 10 | 10 | 9 | 9 | 8 | 7 |
| .26 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 14 | 14 | 14 | 13 | 13 | 12 | 11 | 11 | 10 | 10 | 9 | 8 |
| .28 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 15 | 15 | 15 | 14 | 14 | 13 | 13 | 12 | 11 | 10 | 9 |
| .30 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 17 | 17 | 17 | 16 | 16 | 15 | 14 | 14 | 13 | 12 | 11 | 10 |
| .32 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 19 | 19 | 19 | 18 | 17 | 17 | 16 | 15 | 14 | 13 | 12 | 11 |
| .34 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 21 | 21 | 20 | 19 | 19 | 18 | 17 | 16 | 15 | 13 | 12 |
| .36 | 24 | 24 | 24 | 23 | 23 | 23 | 23 | 23 | 23 | 22 | 22 | 21 | 21 | 20 | 19 | 18 | 17 | 15 | 13 |
| .38 | 26 | 26 | 26 | 25 | 25 | 25 | 25 | 24 | 24 | 24 | 23 | 23 | 22 | 21 | 20 | 19 | 18 | 16 | 14 |
| .40 | 28 | 28 | 28 | 27 | 27 | 27 | 27 | 26 | 26 | 26 | 25 | 25 | 24 | 23 | 22 | 21 | 19 | 17 | 15 |
| .42 | 30 | 30 | 30 | 29 | 29 | 29 | 29 | 28 | 28 | 28 | 27 | 27 | 26 | 25 | 24 | 23 | 21 | 19 | 17 |
| .44 | 33 | 33 | 33 | 32 | 32 | 32 | 31 | 31 | 30 | 30 | 29 | 29 | 28 | 27 | 26 | 24 | 23 | 20 | 18 |
| .46 | 35 | 35 | 35 | 35 | 34 | 34 | 34 | 33 | 33 | 32 | 32 | 31 | 30 | 29 | 28 | 26 | 24 | 22 | 19 |
| .48 | 38 | 38 | 37 | 37 | 37 | 36 | 36 | 35 | 35 | 34 | 34 | 33 | 32 | 31 | 30 | 28 | 26 | 23 | 20 |
| .50 | 40 | 40 | 40 | 40 | 39 | 39 | 39 | 38 | 37 | 37 | 36 | 35 | 34 | 33 | 32 | 30 | 28 | 25 | 22 |
| .52 | 42 | 42 | 42 | 42 | 41 | 41 | 41 | 40 | 39 | 39 | 38 | 37 | 36 | 35 | 34 | 32 | 30 | 27 | 23 |
| .54 | 45 | 45 | 44 | 44 | 43 | 43 | 43 | 42 | 42 | 42 | 41 | 40 | 39 | 38 | 36 | 34 | 31 | 28 | 25 |
| .56 | 48 | 48 | 47 | 47 | 46 | 46 | 45 | 45 | 45 | 44 | 43 | 42 | 41 | 40 | 38 | 36 | 33 | 30 | 26 |
| .58 | 50 | 50 | 49 | 49 | 48 | 48 | 47 | 47 | 47 | 46 | 45 | 44 | 43 | 42 | 40 | 38 | 35 | 32 | 28 |

(Continued)

TABLE 7.—SUBMERGED-FLOW DISCHARGE TABLE FOR 9-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| .60 | 53 | 53 | 52 | 52 | 51 | 51 | 50 | 50 | 50 | 49 | 48 | 47 | 46 | 44 | 42 | 40 | 37 | 33 | 29 |
| .62 | 56 | 56 | 55 | 55 | 54 | 54 | 53 | 53 | 52 | 51 | 50 | 49 | 48 | 46 | 45 | 42 | 39 | 35 | 31 |
| .64 | 59 | 59 | 58 | 58 | 57 | 57 | 56 | 56 | 55 | 54 | 53 | 52 | 51 | 49 | 47 | 44 | 41 | 37 | 32 |
| .66 | 62 | 62 | 61 | 61 | 60 | 60 | 59 | 59 | 58 | 57 | 56 | 55 | 53 | 51 | 49 | 46 | 43 | 38 | 34 |
| .68 | 65 | 65 | 64 | 63 | 63 | 62 | 61 | 61 | 60 | 59 | 58 | 57 | 55 | 53 | 51 | 48 | 45 | 40 | 35 |
| .70 | 68 | 68 | 67 | 66 | 66 | 65 | 64 | 64 | 63 | 62 | 61 | 60 | 58 | 56 | 54 | 51 | 47 | 42 | 37 |
| .72 | 71 | 70 | 70 | 69 | 69 | 68 | 67 | 66 | 65 | 64 | 63 | 62 | 60 | 58 | 56 | 53 | 49 | 44 | 39 |
| .74 | 74 | 73 | 73 | 72 | 71 | 70 | 70 | 69 | 68 | 67 | 66 | 65 | 63 | 61 | 58 | 55 | 51 | 46 | 40 |
| .76 | 77 | 76 | 76 | 75 | 74 | 73 | 73 | 72 | 71 | 70 | 69 | 67 | 66 | 63 | 60 | 57 | 53 | 48 | 42 |
| .78 | 80 | 79 | 79 | 78 | 77 | 76 | 76 | 75 | 74 | 73 | 72 | 70 | 68 | 66 | 63 | 59 | 55 | 50 | 44 |
| .80 | 83 | 82 | 82 | 81 | 80 | 79 | 79 | 78 | 77 | 76 | 74 | 72 | 70 | 68 | 66 | 62 | 58 | 52 | 46 |
| .82 | 86 | 85 | 85 | 84 | 84 | 83 | 82 | 81 | 80 | 79 | 77 | 75 | 73 | 71 | 68 | 64 | 60 | 54 | 47 |
| .84 | 89 | 88 | 88 | 87 | 87 | 86 | 85 | 84 | 83 | 82 | 80 | 78 | 76 | 74 | 71 | 67 | 62 | 56 | 49 |
| .86 | 93 | 92 | 92 | 91 | 90 | 89 | 88 | 87 | 86 | 85 | 83 | 81 | 79 | 76 | 73 | 69 | 64 | 58 | 51 |
| .88 | 96 | 95 | 95 | 94 | 93 | 92 | 91 | 90 | 89 | 88 | 86 | 84 | 82 | 79 | 76 | 72 | 67 | 60 | 52 |
| .90 | 99 | 98 | 98 | 97 | 96 | 95 | 94 | 93 | 92 | 91 | 89 | 87 | 85 | 82 | 78 | 74 | 69 | 62 | 54 |
| .92 | 103 | 102 | 101 | 100 | 100 | 99 | 97 | 96 | 95 | 94 | 92 | 90 | 88 | 85 | 81 | 77 | 72 | 64 | 56 |
| .94 | 106 | 105 | 105 | 104 | 103 | 102 | 101 | 100 | 98 | 97 | 95 | 93 | 90 | 88 | 84 | 79 | 74 | 66 | 58 |
| .96 | 109 | 108 | 108 | 107 | 106 | 105 | 104 | 103 | 102 | 100 | 98 | 96 | 93 | 90 | 87 | 82 | 76 | 68 | 60 |
| .98 | 113 | 112 | 111 | 110 | 109 | 108 | 107 | 106 | 105 | 103 | 102 | 99 | 96 | 93 | 89 | 84 | 78 | 70 | 62 |
| 1.00 | 116 | 115 | 114 | 114 | 113 | 112 | 111 | 110 | 109 | 107 | 105 | 103 | 100 | 96 | 92 | 87 | 81 | 73 | 64 |
| 1.02 | 120 | 119 | 118 | 117 | 116 | 115 | 114 | 113 | 112 | 110 | 108 | 106 | 103 | 99 | 95 | 90 | 83 | 75 | 65 |
| 1.04 | 124 | 123 | 122 | 121 | 120 | 119 | 117 | 116 | 115 | 113 | 111 | 109 | 105 | 102 | 98 | 92 | 85 | 77 | 67 |
| 1.06 | 127 | 126 | 125 | 124 | 123 | 122 | 121 | 119 | 118 | 116 | 114 | 112 | 108 | 105 | 101 | 95 | 88 | 79 | 69 |
| 1.08 | 131 | 130 | 129 | 128 | 127 | 126 | 125 | 123 | 122 | 120 | 118 | 115 | 112 | 108 | 104 | 98 | 91 | 81 | 71 |

(Continued)

TABLE 7.—SUBMERGED-FLOW DISCHARGE TABLE FOR 9-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 60 | 62 | 64 | 66 | 68 | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 1.10 | 135 | 134 | 133 | 132 | 131 | 130 | 129 | 127 | 125 | 123 | 121 | 118 | 115 | 111 | 106 | 100 | 93 | 83 | 73 |
| 1.12 | 139 | 138 | 137 | 136 | 134 | 133 | 132 | 130 | 128 | 126 | 124 | 121 | 118 | 114 | 109 | 103 | 95 | 85 | 74 |
| 1.14 | 143 | 142 | 140 | 139 | 138 | 137 | 135 | 134 | 132 | 130 | 128 | 125 | 121 | 117 | 112 | 106 | 98 | 88 | 76 |
| 1.16 | 147 | 146 | 144 | 143 | 142 | 140 | 139 | 137 | 135 | 133 | 131 | 128 | 125 | 121 | 116 | 109 | 101 | 90 | 78 |
| 1.18 | 151 | 150 | 148 | 147 | 146 | 144 | 143 | 141 | 139 | 137 | 135 | 132 | 128 | 124 | 119 | 112 | 104 | 93 | 80 |
| 1.20 | 155 | 154 | 152 | 151 | 150 | 148 | 146 | 145 | 143 | 140 | 138 | 135 | 131 | 127 | 122 | 115 | 107 | 96 | 82 |
| 1.22 | 159 | 158 | 156 | 155 | 154 | 152 | 150 | 148 | 146 | 144 | 142 | 138 | 134 | 130 | 125 | 118 | 109 | 98 | 84 |
| 1.24 | 163 | 161 | 160 | 158 | 157 | 155 | 153 | 152 | 150 | 148 | 145 | 142 | 138 | 133 | 128 | 120 | 111 | 100 | 86 |
| 1.26 | 167 | 165 | 164 | 162 | 160 | 159 | 157 | 155 | 153 | 151 | 149 | 145 | 141 | 136 | 131 | 123 | 114 | 102 | 88 |
| 1.28 | 171 | 169 | 168 | 166 | 165 | 163 | 161 | 159 | 157 | 155 | 152 | 148 | 144 | 140 | 134 | 126 | 117 | 105 | 90 |
| 1.30 | 175 | 173 | 172 | 170 | 169 | 167 | 165 | 163 | 161 | 159 | 156 | 152 | 148 | 143 | 137 | 129 | 119 | 107 | 92 |
| 1.32 | 179 | 178 | 176 | 174 | 173 | 171 | 169 | 167 | 165 | 163 | 160 | 156 | 152 | 146 | 140 | 132 | 122 | 109 | 94 |
| 1.34 | 184 | 182 | 180 | 178 | 177 | 175 | 173 | 171 | 169 | 166 | 163 | 159 | 155 | 150 | 143 | 135 | 125 | 112 | 96 |
| 1.36 | 188 | 186 | 184 | 182 | 181 | 179 | 177 | 175 | 172 | 170 | 167 | 163 | 158 | 153 | 146 | 138 | 128 | 115 | 98 |
| 1.38 | 192 | 190 | 189 | 187 | 185 | 183 | 181 | 179 | 177 | 174 | 171 | 167 | 162 | 156 | 149 | 141 | 131 | 117 | 100 |
| 1.40 | 196 | 194 | 193 | 191 | 189 | 188 | 185 | 183 | 181 | 178 | 175 | 171 | 166 | 160 | 153 | 144 | 134 | 120 | 102 |
| 1.42 | 201 | 199 | 198 | 196 | 194 | 192 | 190 | 187 | 185 | 182 | 179 | 175 | 170 | 164 | 157 | 148 | 137 | 122 | 104 |
| 1.44 | 205 | 203 | 202 | 200 | 198 | 196 | 194 | 191 | 189 | 186 | 183 | 178 | 173 | 167 | 160 | 151 | 140 | 125 | 106 |
| 1.46 | 209 | 207 | 206 | 204 | 202 | 200 | 198 | 195 | 193 | 190 | 186 | 181 | 176 | 170 | 163 | 154 | 143 | 128 | 108 |
| 1.48 | 213 | 211 | 210 | 208 | 206 | 204 | 202 | 200 | 197 | 194 | 190 | 185 | 180 | 174 | 166 | 157 | 145 | 130 | 110 |
| 1.50 | 217 | 215 | 214 | 212 | 211 | 209 | 207 | 204 | 202 | 198 | 194 | 189 | 184 | 177 | 169 | 160 | 148 | 132 | 112 |

## TABLE 8.—SUBMERGED-FLOW DISCHARGE TABLE FOR 12-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_a$ | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 0.10 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 |
| .12 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 2 |
| .14 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 4 | 3 | 3 | 3 |
| .16 | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 6 | 6 | 5 | 4 | 4 | 4 |
| .18 | 10 | 10 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 7 | 6 | 6 | 5 | 6 |
| .20 | 12 | 12 | 12 | 12 | 11 | 11 | 10 | 10 | 9 | 9 | 8 | 8 | 6 | 7 |
| .22 | 14 | 14 | 14 | 14 | 13 | 13 | 12 | 12 | 11 | 10 | 10 | 10 | 8 | 8 |
| .24 | 16 | 16 | 16 | 15 | 15 | 15 | 14 | 14 | 13 | 12 | 12 | 11 | 9 | 9 |
| .26 | 18 | 18 | 18 | 17 | 17 | 17 | 16 | 16 | 15 | 14 | 13 | 12 | 10 | 11 |
| .28 | 20 | 20 | 20 | 19 | 19 | 19 | 18 | 18 | 17 | 16 | 15 | 14 | 12 | 12 |
| .30 | 22 | 22 | 22 | 22 | 21 | 21 | 20 | 20 | 19 | 18 | 17 | 15 | 13 | 13 |
| .32 | 25 | 25 | 24 | 24 | 24 | 23 | 23 | 22 | 21 | 20 | 19 | 17 | 15 | 15 |
| .34 | 27 | 27 | 26 | 26 | 26 | 25 | 25 | 24 | 23 | 22 | 21 | 19 | 16 | 16 |
| .36 | 30 | 30 | 29 | 29 | 29 | 28 | 28 | 27 | 26 | 25 | 23 | 21 | 18 | 18 |
| .38 | 33 | 33 | 32 | 32 | 31 | 31 | 30 | 29 | 28 | 27 | 25 | 23 | 20 | 19 |
| .40 | 35 | 35 | 35 | 35 | 34 | 34 | 33 | 32 | 31 | 30 | 28 | 25 | 22 | 21 |
| .42 | 38 | 38 | 38 | 38 | 37 | 36 | 36 | 35 | 34 | 32 | 30 | 27 | 23 | 23 |
| .44 | 41 | 41 | 41 | 40 | 40 | 39 | 39 | 38 | 37 | 35 | 32 | 29 | 25 | 24 |
| .46 | 45 | 45 | 44 | 43 | 43 | 42 | 41 | 40 | 39 | 37 | 34 | 31 | 27 | 25 |
| .48 | 48 | 48 | 47 | 46 | 46 | 45 | 44 | 43 | 41 | 39 | 37 | 34 | 29 | 27 |
| .50 | 51 | 51 | 50 | 49 | 49 | 48 | 47 | 46 | 44 | 42 | 40 | 36 | 31 | 29 |
| .52 | 54 | 54 | 53 | 53 | 52 | 51 | 50 | 49 | 47 | 45 | 42 | 38 | 33 | 30 |
| .54 | 57 | 57 | 56 | 56 | 55 | 54 | 53 | 52 | 50 | 48 | 45 | 41 | 35 | 32 |
| .56 | 61 | 61 | 60 | 60 | 59 | 58 | 57 | 55 | 53 | 51 | 48 | 43 | 37 | 34 |
| .58 | 64 | 64 | 63 | 63 | 62 | 61 | 60 | 58 | 56 | 53 | 50 | 46 | 40 | 35 |

(Continued)

TABLE 8.—SUBMERGED-FLOW DISCHARGE TABLE FOR 12-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_a$ | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| .60 | 67 | 67 | 66 | 66 | 65 | 64 | 63 | 62 | 59 | 56 | 53 | 48 | 42 | 37 |
| .62 | 71 | 70 | 70 | 69 | 68 | 67 | 66 | 64 | 62 | 59 | 55 | 50 | 44 | 39 |
| .64 | 74 | 74 | 73 | 73 | 72 | 71 | 69 | 67 | 65 | 62 | 58 | 53 | 46 | 40 |
| .66 | 78 | 78 | 77 | 77 | 76 | 75 | 73 | 71 | 68 | 65 | 61 | 56 | 49 | 42 |
| .68 | 82 | 81 | 81 | 80 | 79 | 78 | 76 | 74 | 71 | 68 | 64 | 58 | 51 | 44 |
| .70 | 86 | 85 | 85 | 84 | 83 | 82 | 80 | 78 | 75 | 71 | 67 | 61 | 53 | 46 |
| .72 | 90 | 89 | 89 | 88 | 87 | 85 | 83 | 81 | 76 | 74 | 70 | 64 | 56 | 48 |
| .74 | 93 | 92 | 92 | 91 | 90 | 89 | 87 | 85 | 82 | 78 | 73 | 66 | 58 | 50 |
| .76 | 97 | 96 | 96 | 95 | 94 | 92 | 90 | 88 | 85 | 81 | 76 | 69 | 60 | 52 |
| .78 | 101 | 100 | 100 | 99 | 98 | 96 | 94 | 92 | 88 | 84 | 79 | 72 | 63 | 54 |
| .80 | 105 | 104 | 104 | 103 | 102 | 100 | 98 | 95 | 92 | 87 | 82 | 75 | 65 | 56 |
| .82 | 110 | 109 | 108 | 107 | 106 | 104 | 101 | 98 | 95 | 91 | 85 | 78 | 68 | 58 |
| .84 | 114 | 113 | 112 | 111 | 110 | 108 | 105 | 102 | 99 | 95 | 89 | 81 | 71 | 60 |
| .86 | 118 | 117 | 116 | 115 | 114 | 112 | 109 | 106 | 103 | 98 | 92 | 83 | 73 | 62 |
| .88 | 122 | 121 | 120 | 119 | 118 | 116 | 113 | 110 | 106 | 101 | 95 | 86 | 75 | 65 |
| .90 | 126 | 125 | 124 | 123 | 121 | 120 | 117 | 114 | 110 | 104 | 98 | 89 | 78 | 67 |
| .92 | 130 | 129 | 128 | 127 | 125 | 123 | 121 | 118 | 113 | 108 | 101 | 92 | 81 | 69 |
| .94 | 135 | 134 | 133 | 132 | 130 | 128 | 125 | 121 | 117 | 111 | 104 | 95 | 83 | 71 |
| .96 | 139 | 138 | 137 | 136 | 134 | 132 | 129 | 125 | 121 | 115 | 107 | 98 | 86 | 74 |
| .98 | 144 | 143 | 142 | 140 | 138 | 136 | 133 | 129 | 124 | 118 | 110 | 101 | 89 | 76 |
| 1.00 | 149 | 148 | 147 | 145 | 143 | 140 | 137 | 133 | 128 | 122 | 114 | 104 | 92 | 78 |
| 1.02 | 153 | 152 | 151 | 149 | 147 | 144 | 141 | 137 | 132 | 126 | 118 | 108 | 95 | 81 |
| 1.04 | 158 | 157 | 156 | 154 | 152 | 149 | 145 | 141 | 136 | 129 | 121 | 111 | 98 | 83 |
| 1.06 | 163 | 162 | 160 | 158 | 156 | 152 | 149 | 145 | 139 | 133 | 125 | 114 | 100 | 85 |
| 1.08 | 167 | 166 | 164 | 162 | 160 | 157 | 154 | 150 | 143 | 137 | 128 | 117 | 103 | 88 |

(Continued)

TABLE 8.—SUBMERGED-FLOW DISCHARGE TABLE FOR 12-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_a$ | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 1.10 | 172 | 170 | 169 | 167 | 165 | 161 | 158 | 154 | 147 | 140 | 131 | 120 | 106 | 90 |
| 1.12 | 176 | 175 | 174 | 172 | 170 | 166 | 162 | 158 | 151 | 144 | 135 | 124 | 109 | 93 |
| 1.14 | 180 | 179 | 178 | 176 | 174 | 171 | 167 | 162 | 156 | 148 | 138 | 127 | 112 | 95 |
| 1.16 | 185 | 184 | 182 | 180 | 178 | 175 | 171 | 166 | 160 | 152 | 142 | 130 | 115 | 98 |
| 1.18 | 190 | 189 | 187 | 185 | 183 | 180 | 176 | 171 | 164 | 156 | 146 | 134 | 118 | 100 |
| 1.20 | 196 | 194 | 192 | 190 | 187 | 184 | 180 | 175 | 168 | 160 | 150 | 137 | 121 | 103 |
| 1.22 | 201 | 199 | 197 | 195 | 192 | 189 | 184 | 179 | 172 | 164 | 153 | 140 | 124 | 106 |
| 1.24 | 206 | 204 | 202 | 200 | 197 | 193 | 189 | 183 | 176 | 168 | 157 | 144 | 127 | 108 |
| 1.26 | 211 | 209 | 207 | 205 | 202 | 198 | 193 | 187 | 180 | 172 | 161 | 148 | 130 | 111 |
| 1.28 | 216 | 214 | 212 | 210 | 207 | 203 | 198 | 192 | 185 | 176 | 165 | 151 | 133 | 114 |
| 1.30 | 221 | 219 | 217 | 215 | 212 | 208 | 203 | 196 | 190 | 180 | 168 | 154 | 136 | 117 |
| 1.32 | 226 | 224 | 222 | 220 | 217 | 213 | 207 | 200 | 194 | 184 | 172 | 157 | 139 | 119 |
| 1.34 | 232 | 230 | 228 | 225 | 222 | 218 | 212 | 205 | 198 | 188 | 176 | 161 | 143 | 122 |
| 1.36 | 237 | 235 | 233 | 230 | 227 | 223 | 217 | 211 | 203 | 192 | 180 | 165 | 146 | 125 |
| 1.38 | 242 | 240 | 238 | 235 | 232 | 227 | 222 | 216 | 207 | 197 | 184 | 168 | 149 | 128 |
| 1.40 | 248 | 246 | 243 | 240 | 237 | 232 | 226 | 220 | 211 | 201 | 188 | 171 | 152 | 130 |
| 1.42 | 253 | 251 | 248 | 245 | 242 | 237 | 231 | 224 | 215 | 205 | 192 | 175 | 155 | 133 |
| 1.44 | 259 | 257 | 254 | 251 | 247 | 242 | 236 | 229 | 220 | 209 | 196 | 179 | 159 | 136 |
| 1.46 | 264 | 262 | 259 | 256 | 252 | 247 | 241 | 234 | 225 | 213 | 200 | 183 | 162 | 139 |
| 1.48 | 269 | 267 | 264 | 261 | 257 | 252 | 246 | 239 | 229 | 218 | 204 | 187 | 165 | 142 |
| 1.50 | 275 | 272 | 269 | 266 | 262 | 257 | 251 | 243 | 234 | 222 | 208 | 191 | 168 | 145 |

## TABLE 9.—SUBMERGED-FLOW DISCHARGE TABLE FOR 18-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $H_a$ | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 0.10 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 2 |
| .12 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 5 | 4 | 4 |
| .14 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 7 | 7 | 6 | 5 |
| .16 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 9 | 8 | 7 | 6 |
| .18 | 14 | 14 | 14 | 14 | 14 | 14 | 13 | 13 | 13 | 12 | 11 | 10 | 9 | 8 |
| .20 | 17 | 17 | 17 | 17 | 17 | 16 | 16 | 16 | 16 | 15 | 14 | 13 | 11 | 10 |
| .22 | 19 | 19 | 19 | 19 | 19 | 19 | 18 | 18 | 18 | 17 | 16 | 15 | 14 | 12 |
| .24 | 22 | 22 | 22 | 22 | 22 | 22 | 21 | 21 | 21 | 20 | 19 | 17 | 15 | 13 |
| .26 | 25 | 25 | 25 | 25 | 25 | 25 | 24 | 24 | 23 | 22 | 21 | 19 | 17 | 15 |
| .28 | 29 | 29 | 29 | 28 | 28 | 28 | 27 | 27 | 26 | 25 | 24 | 22 | 20 | 17 |
| .30 | 32 | 32 | 32 | 32 | 32 | 31 | 30 | 30 | 29 | 28 | 26 | 24 | 22 | 19 |
| .32 | 36 | 36 | 36 | 36 | 36 | 35 | 34 | 34 | 33 | 31 | 29 | 27 | 24 | 21 |
| .34 | 40 | 40 | 40 | 40 | 39 | 39 | 38 | 37 | 36 | 33 | 31 | 29 | 26 | 23 |
| .36 | 44 | 44 | 43 | 43 | 43 | 42 | 42 | 41 | 39 | 37 | 35 | 32 | 29 | 25 |
| .38 | 48 | 48 | 47 | 47 | 47 | 46 | 45 | 44 | 43 | 41 | 38 | 35 | 31 | 27 |
| .40 | 53 | 53 | 52 | 51 | 51 | 50 | 49 | 48 | 47 | 45 | 42 | 39 | 34 | 29 |
| .42 | 57 | 57 | 56 | 56 | 55 | 54 | 53 | 52 | 50 | 48 | 45 | 42 | 36 | 31 |
| .44 | 61 | 61 | 60 | 60 | 60 | 59 | 58 | 56 | 54 | 52 | 49 | 45 | 39 | 33 |
| .46 | 66 | 66 | 65 | 65 | 64 | 63 | 62 | 60 | 58 | 56 | 53 | 48 | 42 | 35 |
| .48 | 71 | 70 | 70 | 69 | 68 | 67 | 66 | 65 | 63 | 60 | 56 | 51 | 45 | 38 |
| .50 | 75 | 74 | 74 | 73 | 72 | 71 | 70 | 68 | 66 | 64 | 60 | 55 | 48 | 40 |
| .52 | 80 | 79 | 79 | 78 | 77 | 76 | 75 | 73 | 71 | 68 | 64 | 58 | 51 | 42 |
| .54 | 85 | 84 | 84 | 83 | 82 | 81 | 80 | 78 | 75 | 72 | 68 | 62 | 54 | 44 |
| .56 | 90 | 89 | 89 | 88 | 87 | 86 | 84 | 82 | 79 | 76 | 72 | 66 | 58 | 47 |
| .58 | 95 | 94 | 94 | 93 | 92 | 91 | 89 | 87 | 84 | 80 | 76 | 69 | 61 | 49 |

(Continued)

TABLE 9.—SUBMERGED-FLOW DISCHARGE TABLE FOR 18-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| .60 | 100 | 100 | 99 | 98 | 97 | 96 | 94 | 92 | 89 | 85 | 80 | 73 | 64 | 52 |
| .62 | 105 | 105 | 104 | 103 | 102 | 101 | 99 | 96 | 93 | 89 | 84 | 77 | 68 | 54 |
| .64 | 111 | 110 | 110 | 109 | 108 | 106 | 104 | 102 | 98 | 94 | 88 | 81 | 71 | 57 |
| .66 | 117 | 116 | 115 | 114 | 113 | 111 | 109 | 106 | 103 | 99 | 93 | 85 | 75 | 59 |
| .68 | 122 | 121 | 120 | 119 | 118 | 116 | 114 | 111 | 108 | 103 | 97 | 89 | 79 | 62 |
| .70 | 128 | 127 | 126 | 124 | 123 | 121 | 119 | 116 | 113 | 108 | 102 | 93 | 82 | 64 |
| .72 | 134 | 133 | 132 | 130 | 129 | 127 | 125 | 122 | 118 | 113 | 106 | 97 | 86 | 67 |
| .74 | 139 | 139 | 137 | 136 | 135 | 133 | 130 | 127 | 123 | 118 | 111 | 101 | 89 | 70 |
| .76 | 146 | 145 | 144 | 142 | 141 | 139 | 136 | 133 | 128 | 123 | 116 | 106 | 93 | 72 |
| .78 | 152 | 151 | 150 | 148 | 146 | 144 | 141 | 138 | 133 | 128 | 121 | 111 | 98 | 75 |
| .80 | 158 | 157 | 156 | 154 | 152 | 150 | 147 | 143 | 138 | 132 | 125 | 115 | 102 | 78 |
| .82 | 164 | 163 | 162 | 160 | 158 | 155 | 152 | 148 | 143 | 137 | 130 | 119 | 106 | 81 |
| .84 | 170 | 169 | 168 | 166 | 164 | 162 | 159 | 154 | 149 | 143 | 135 | 124 | 110 | 83 |
| .86 | 177 | 175 | 174 | 172 | 170 | 168 | 164 | 160 | 155 | 148 | 140 | 129 | 114 | 87 |
| .88 | 183 | 182 | 181 | 179 | 177 | 174 | 170 | 166 | 160 | 153 | 144 | 133 | 118 | 90 |
| .90 | 189 | 188 | 187 | 185 | 183 | 180 | 176 | 171 | 166 | 158 | 149 | 138 | 122 | 93 |
| .92 | 196 | 195 | 194 | 192 | 189 | 186 | 182 | 177 | 171 | 164 | 155 | 143 | 126 | 96 |
| .94 | 203 | 202 | 200 | 198 | 196 | 193 | 189 | 184 | 177 | 169 | 160 | 147 | 131 | 99 |
| .96 | 210 | 209 | 207 | 205 | 203 | 199 | 195 | 190 | 183 | 175 | 165 | 152 | 136 | 103 |
| .98 | 217 | 215 | 213 | 211 | 209 | 205 | 201 | 196 | 189 | 180 | 170 | 157 | 140 | 106 |
| 1.00 | 223 | 222 | 220 | 218 | 215 | 212 | 207 | 201 | 195 | 186 | 176 | 162 | 144 | 109 |
| 1.02 | 230 | 229 | 227 | 225 | 222 | 218 | 213 | 207 | 201 | 192 | 181 | 167 | 149 | 112 |
| 1.04 | 237 | 235 | 233 | 231 | 228 | 225 | 220 | 214 | 206 | 197 | 185 | 171 | 153 | 116 |
| 1.06 | 244 | 242 | 240 | 238 | 235 | 231 | 226 | 220 | 212 | 203 | 191 | 176 | 157 | 119 |
| 1.08 | 251 | 249 | 247 | 245 | 242 | 238 | 233 | 227 | 219 | 209 | 197 | 182 | 162 | 122 |

(Continued)

TABLE 9.—SUBMERGED-FLOW DISCHARGE TABLE FOR 18-INCH PARSHALL MEASURING FLUME. DISCHARGE UNIT, COLORADO STATUTORY INCH.

| Upper head | Gage ratio, $H_b/H_a$, or degree of submergence | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ha | 70 | 72 | 74 | 76 | 78 | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 |
| *Feet* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* | *Colo. Inch* |
| 1.10 | 259 | 257 | 255 | 252 | 249 | 245 | 240 | 233 | 225 | 215 | 202 | 187 | 166 | 126 |
| 1.12 | 266 | 264 | 262 | 259 | 256 | 251 | 246 | 239 | 231 | 221 | 208 | 192 | 171 | 129 |
| 1.14 | 273 | 271 | 269 | 266 | 263 | 258 | 253 | 246 | 238 | 227 | 214 | 197 | 176 | 133 |
| 1.16 | 280 | 278 | 276 | 273 | 270 | 265 | 260 | 253 | 244 | 233 | 220 | 202 | 180 | 136 |
| 1.18 | 288 | 286 | 284 | 281 | 277 | 272 | 266 | 259 | 250 | 239 | 225 | 207 | 185 | 140 |
| 1.20 | 296 | 294 | 291 | 288 | 284 | 279 | 273 | 265 | 256 | 245 | 231 | 213 | 190 | 144 |
| 1.22 | 303 | 301 | 298 | 295 | 291 | 286 | 280 | 272 | 263 | 251 | 237 | 218 | 195 | 147 |
| 1.24 | 311 | 309 | 306 | 303 | 299 | 293 | 287 | 279 | 270 | 258 | 243 | 224 | 200 | 151 |
| 1.26 | 318 | 316 | 313 | 310 | 306 | 300 | 294 | 286 | 276 | 264 | 249 | 229 | 205 | 155 |
| 1.28 | 326 | 324 | 321 | 318 | 314 | 308 | 301 | 293 | 283 | 270 | 255 | 235 | 210 | 158 |
| 1.30 | 335 | 332 | 329 | 326 | 322 | 316 | 309 | 300 | 290 | 276 | 261 | 241 | 215 | 162 |
| 1.32 | 343 | 340 | 337 | 333 | 329 | 323 | 316 | 307 | 297 | 283 | 267 | 246 | 220 | 166 |
| 1.34 | 351 | 348 | 344 | 341 | 336 | 331 | 323 | 314 | 303 | 289 | 272 | 251 | 225 | 170 |
| 1.36 | 359 | 356 | 353 | 349 | 344 | 338 | 330 | 321 | 310 | 296 | 279 | 257 | 230 | 174 |
| 1.38 | 367 | 364 | 360 | 356 | 351 | 345 | 337 | 328 | 317 | 303 | 286 | 263 | 236 | 178 |
| 1.40 | 375 | 372 | 368 | 364 | 359 | 353 | 345 | 335 | 324 | 309 | 292 | 269 | 241 | 182 |
| 1.42 | 383 | 380 | 376 | 372 | 367 | 360 | 352 | 342 | 331 | 315 | 297 | 274 | 246 | 186 |
| 1.44 | 392 | 388 | 384 | 380 | 375 | 368 | 360 | 350 | 338 | 322 | 303 | 280 | 251 | 190 |
| 1.46 | 400 | 397 | 393 | 388 | 383 | 376 | 367 | 357 | 345 | 329 | 310 | 286 | 256 | 194 |
| 1.48 | 408 | 405 | 401 | 396 | 391 | 384 | 375 | 364 | 352 | 336 | 316 | 292 | 262 | 198 |
| 1.50 | 417 | 414 | 410 | 405 | 399 | 392 | 383 | 372 | 360 | 343 | 323 | 298 | 267 | 202 |

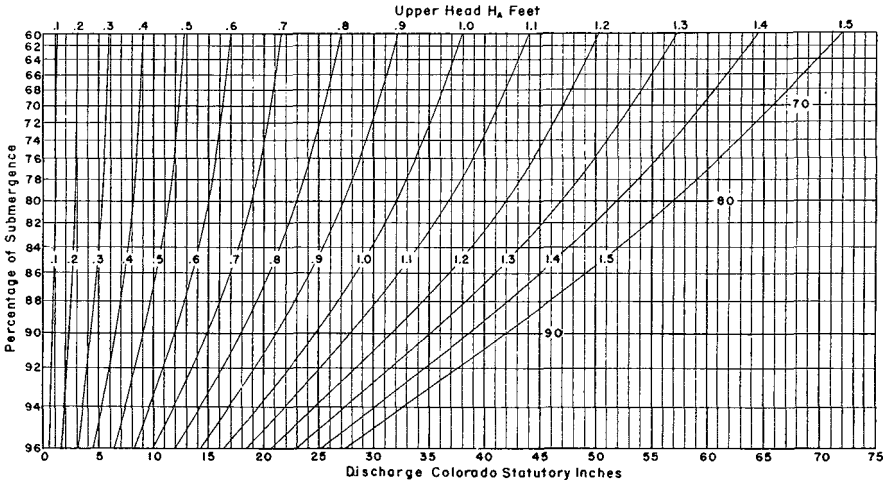


**FIGURE 2.—Diagram for computing submerged flow through a 3-inch Parshall measuring flume.**

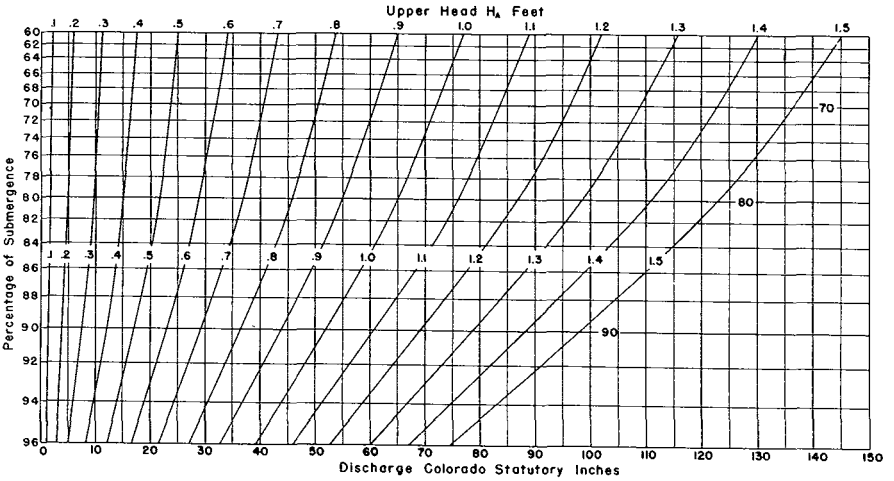


**FIGURE 3.—Diagram for computing submerged flow through a 6-inch Parshall measuring flume.**

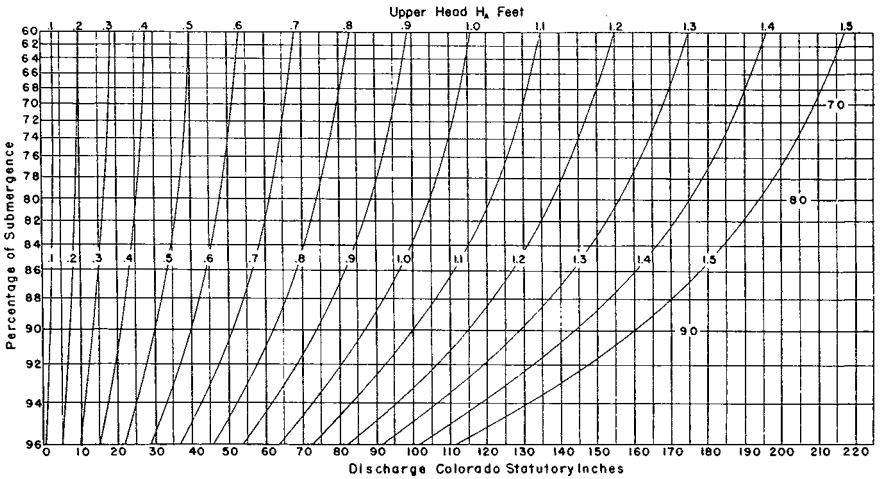


**FIGURE 4.—Diagram for computing submerged flow through a 9-inch Parshall measuring flume.**

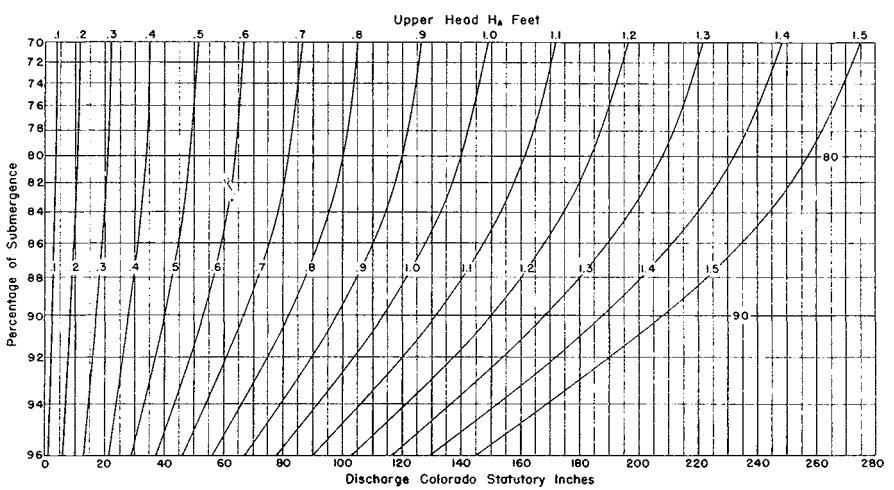


**FIGURE 5.—Diagram for computing submerged flow through a 12-inch Parshall measuring flume.**

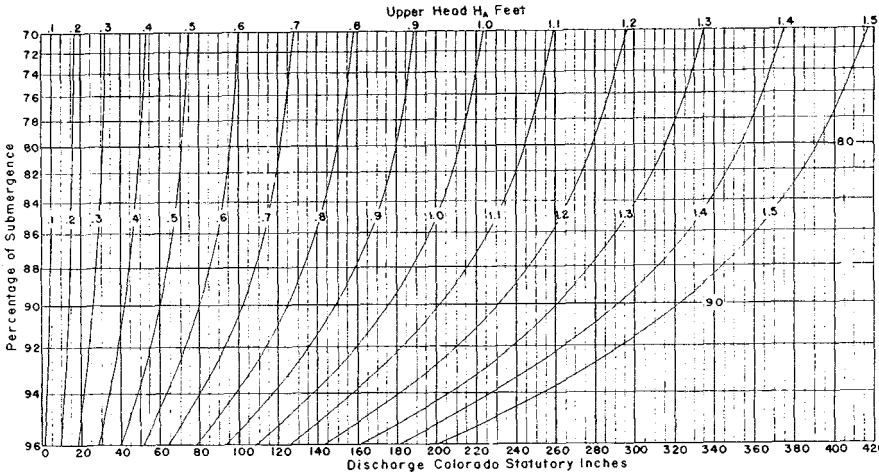


**FIGURE 6.—Diagram for computing submerged flow through an 18-inch Parshall measuring flume.**

## Parshall Measuring Flumes of Small Size

Experience shows that the Parshall measuring flume is especially well suited for use in measuring irrigation deliveries ranging in flow from a minimum of 0.03 second-foot, approximately 1 Colorado statutory inch, to more than 10 second-feet. Ordinarily, the size of small flumes for the farmer's lateral will be confined to throat widths ranging from 3 to 18 inches. Table 2 gives the discharge in second-feet and Colorado statutory inches for these small flumes for heads up to 1.5 feet. These small structures may be built of wood, sheet metal, or concrete. Timber flumes, unless made of treated material, will have a limited period of usefulness of only 5 to 7 years; galvanized iron flumes are durable and under ordinary conditions should give satisfactory service for 15 to 20 years. A number of small reinforced concrete flumes were built on the Lake Canal near Fort Collins, Colorado, in May 1926, and at the present time are all in perfect condition. The 1-foot reinforced concrete flume, complete with enamel staff gage constructed by means of a semi-portable form, was built in 1926 at a cost of about $20.

Equipping an entire irrigation system with some type of measuring device involves the building of many structures. A special method, as described later, has been developed to construct the small Parshall measuring flumes of reinforced concrete at a cost of about $12 apiece. This is a distinct advantage in standardizing this device for general use as applied to measuring farm deliveries.

## Size and Setting of Flume

Successful operation of the Parshall flume depends upon setting the crest at the correct elevation with reference to the bed of the channel. Where the grade or slope of the channel permits of sufficient fall, the setting may be determined with little difficulty, but if the grade is slight, care must be taken in so fixing the height of the crest that, if possible, the degree of submergence will not exceed the limits of free-flow operation as previously explained. The elevation of the crest depends upon the quantity of water to be measured and the size of the flume to be used. For general conditions under any particular irrigation system, about three-fourths of all the farm laterals will be of sufficient grade to permit the flume to operate as a free-flow device. However, in some cases the flow will be at moderate degree of submergence, the remainder approaching the extreme practical limit of submergence of 95 to 96 percent. For the condition of slight grade of channel, the setting of the flume should be determined by use of an engineer's level or the ordinary carpenter's level and straight edge.

As an example, suppose the farmer's share of water to be delivered is 2.25 second-feet. It is assumed that at the site of installation of the measuring flume, the grade of the lateral is relatively flat, and when carrying this amount of flow the depth of water is 0.9 foot. Referring to table 3, it is found that this quantity of water can be measured through the 6-, 9-, 12-, or 18-inch flume. The selection of the most practical size will be determined largely by the loss of head permissible with the crest elevation low enough as not to materially affect the delivery of water from the canal.

The flow of 2.25 second-feet is found to be 86 statutory inches (see table 3). As a preliminary investigation into the problem of size of flume, first consider the 6-inch flume. In table 6, submerged flow for the 6-inch flume, it is observed that for a flow of 86 inches, the upper head $H_a$ will be 1.38 feet at a submergence of 90 percent. Since the ratio of the $H_b$ to the $H_a$ heads will be 0.9, it is therefore evident that the $H_b$ head will be 1.24 feet, and the loss of head, or difference, between the water surfaces upstream and downstream from the flume, will be 0.14 foot. The water depth in the lateral is 0.9 foot, and since the $H_b$ head will be about 1.2 feet, this trial assumption shows the crest to be set 0.3 foot below the bed of the channel. For a submergence of 80 percent, the $H_a$ head would be 1.19 feet, $H_b$ about 0.95 foot, and the loss of head 0.24 foot. This assumption would place the crest of the 6-inch flume 0.05 foot below the bed of the channel. If the crest is set to agree with the bed of the channel, the degree of submergence will be 78 percent and the loss of head 0.27 foot. It should now be determined definitely whether this 3-inch rise in the upstream water surface will interfere seriously with the delivery of water from the canal with the 6-inch flume set at the grade of the lateral. If this increased depth of water upstream

from the new structure will not interfere with the draft from the canal, then the size and setting so determined would be a fairly good selection in meeting the requirements.

Considering the 9-inch flume to operate at a minimum loss of head or a submergence of 95 percent for a flow of 2.25 second-feet at a water depth of 0.9 foot in the lateral, the following is determined from table 7. It is found that with $H_a$ 1.18 feet, $H_b$ 1.12 feet, the loss of head will be 0.06 foot. For this setting the crest should be placed at 0.22 foot below the bed of the channel. It is not generally good practice to place the crest or floor of the converging section of the flume below grade. If set to grade, the submergence will be 90 percent and the loss of head 0.10 foot. For the 12-inch flume, with crest set at grade (table 8), the $H_a$ head will be 0.96 foot, $H_b$ 0.90 foot, submergence 94 percent, and the loss of head only 0.06 foot. The 18-inch flume with crest at grade will result in submergence much beyond the recommended limit. With a flow of 86 Colorado inches through this size of flume, submerged 95 percent, the $H_a$ head would be about 0.78 foot, $H_b$ 0.74 foot, loss of head 0.04 foot, with the crest set just 0.16 foot above grade or bed of channel. The investigation of these sizes of flume shows that as the width of throat increases, the higher in elevation the crest must be placed for equal submergence, and the loss of head correspondingly decreased. Actual experience in the field in the determination of the correct elevation of the crest of flume indicates first, that the actual water line or depth in the channel for a definite flow is doubtful, and second, that even though this flow depth is fairly accurate, there remains an uncertainty as to the true discharge for that particular depth. For these reasons, it is better not to attempt to set the crest at a point to give the maximum allowable submergence and the minimum loss of head as this might be based on doubtful depth and flow in the channel. If conditions will permit, then a lesser degree of submergence should be taken in determining the crest elevation as a precaution against uncertainty of depth and flow, and against the possibilities of the channel filling with sand and silt, growth of moss in the flowing water, growth of grass and weeds along the banks, or temporary checks placed in the channel downstream. These possibilities all tend to raise the water surface and thus increase the degree of submergence. To measure the 2.25 second-feet with a water depth of 0.9 foot, it is believed that the 6-inch flume would be reasonably adaptable but will require the greatest loss in head. The 9-inch flume with crest at 0.2 foot above the bed of the channel will give 0.70 foot for the $H_b$ head, and from table 7 it is found that the $H_a$ head will be 0.88 foot, submergence approximately 80 percent, and the loss of head only 0.18 foot. The 9-inch flume at this setting is believed best suited in meeting the necessary conditions of operation.

It is suggested that a reference stake be driven into the bank of the channel, just downstream from the site of the new structure, to mark the elevation of the water surface for a flow of 2.25

second-feet, and that with a carpenter's level and straight edge a grade stake be set solidly at the center of the channel just upstream from the work (figure 7) with its top exactly 0.70 foot lower in elevation than the reference point for the 9-inch flume setting. The downstream stake will later indicate the deviation in setting.

## Constructing Small Concrete Flumes By Means of Portable Form

The most practical method of building small concrete flumes is by use of a portable knock-down form, easily assembled and placed in position ready for casting the structure.

A portable form was designed and constructed of common 1-inch lumber as a main framing and ⅜-inch special waterproof plywood as the casting surfaces. The principal joints in the frame and the plywood panels were made up with a good grade of waterproof glue and the plywood fixed in place with 1¼-inch No. 9 common wood screws. Two sizes of forms were made, one for the 6- and the other for the 9-inch flume. When completed and ready for use, each weighed about 150 pounds. The estimated cost of materials and labor for building such a form was $75 (see figures 8 and 9). These two forms were used for

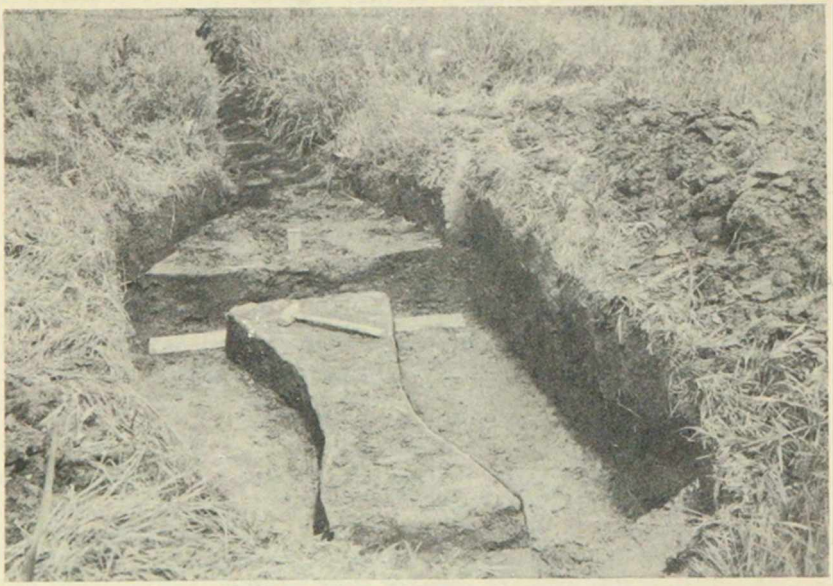

FIGURE 7.—Showing center stake in bottom of channel, upstream from excavation, with top at elevation of the crest of the flume. Note the raised central portion of the excavation which serves as the base for casting the floors of the flume structure.

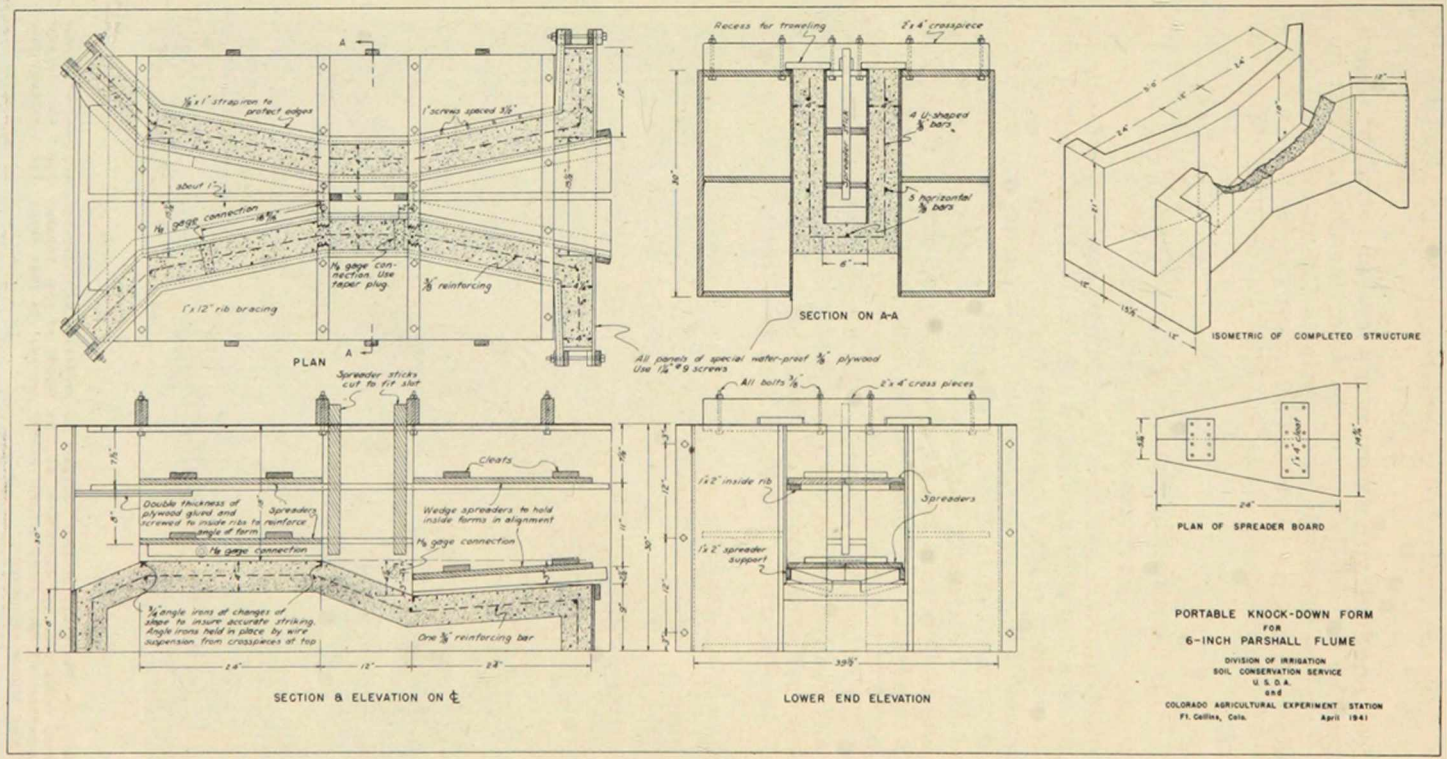


**FIGURE 8.—Design of portable knock-down wood form for ea sting the 6-inch reinforced concrete Parshall measuring flume. This form, materials and labor, costs $75.00.**

casting approximately 130 structures in April 1941. At the conclusion of the work both were found to be in good condition except for minor repairing and the replacement of the 2- by 4-inch transverse pieces across the top of the form. The 6- and 9-inch flumes built with these forms contained less than one-half cubic yard of concrete and were constructed at a cost of about $12 each including the tile stilling wells. Figures 7, 10, 11, 12, and 13 show the excavated base for the structure, leveling the endboard supports, form assembled and placed in the lateral ready for casting, the structure being cast, and the finished flume in operation. Although this wooden form was experimental, the design proved to be practical. However, its use suggested certain changes which would increase the efficiency of assembly by the elimination of several bolts, together with other minor alterations. The experience thus gained in casting these several small flumes, using the wooden forms, led to the design and construction of a metal form (figure 14), which incorporates the good features of the wooden form with added improvements and conveniences.

After the site has been located, the size of flume determined, and the grade stake set, the excavation is made of the required dimensions and depth for the setting of the form. An elevated portion is left in the central part of the excavation to serve as a base for casting the bottom surface of the floor of the structure (figure 7). Short pieces of common 1-inch board are placed at each end of the pit and carefully leveled to insure correctness of

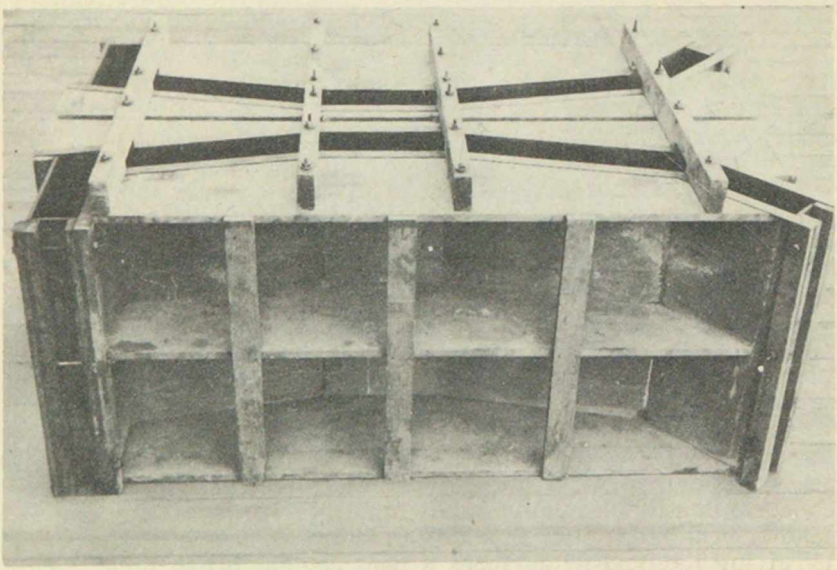

FIGURE 9.—Portable knock-down wood form, for 6-inch flume, assembled ready for placing in the excavated section of the lateral. This form ready for use weighs 150 pounds.

FIGURE 10.—Fixing the two end cross boards in the excavation as proper bases upon which the portable form is positioned.

elevation and alignment of the form (figure 10). Before pouring the concrete a final check is made of the setting (figure 11). The form is filled with a relatively dry mixed concrete to a depth of the thickness of the floor. The angle iron pieces, fixed at the upper end of the converging section and at the crest and lower end of the throat, serve as guides for striking the floor surfaces of the converging and diverging sections of the flume. The concrete fill in the floor of the throat is left below grade and finished after the form is removed from the structure. After the floor surfaces have been finished, the walls are brought up to the full depth and troweled to a smooth surface agreeing with the top edges of the form.

At the time of setting the form, the horizontal and "U" reinforcing steel bars are placed in position, and the tapered wooden plugs are fixed in place for casting the holes for the $H_a$ and $H_b$ inlet tubes for the stilling wells. After the concrete has set, the form is dismantled and removed from the structure, the two tapered wooden plugs are withdrawn, and the floor of the throat section is finished to a smooth surface. While the newly poured concrete is still damp, any slight imperfection in casting can be readily repaired. Much is added to the appearance of the work by giving all exposed surfaces a neat cement brush finish. The form should be thoroughly cleaned and the casting surfaces well coated with waste motor oil, which is inexpensive and satisfactory for the purpose.

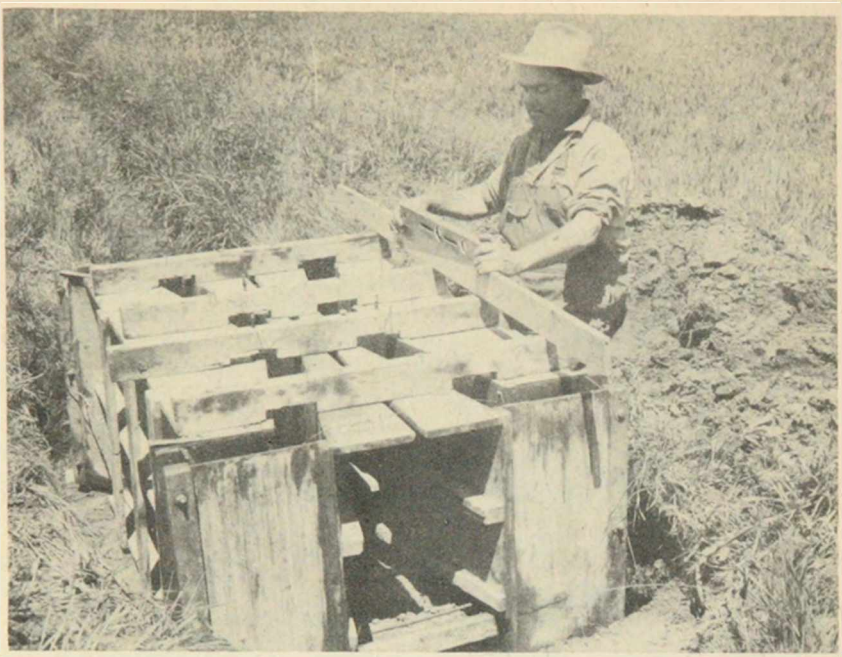

FIGURE 11.—The 6-inch portable form is checked for position and alignment after being set on the foundation boards at the ends of the excavation.

FIGURE 12.—Filling the portable form with concrete to cast a monolithic 6-inch Parshall measuring flume permanently in place.

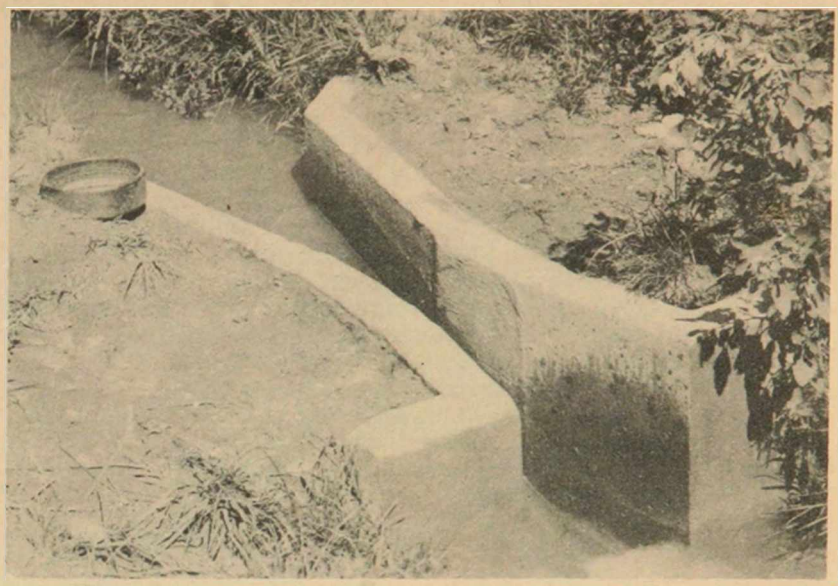

**FIGURE 13.—The 6-inch Parshall measuring flume operating under free flow.**

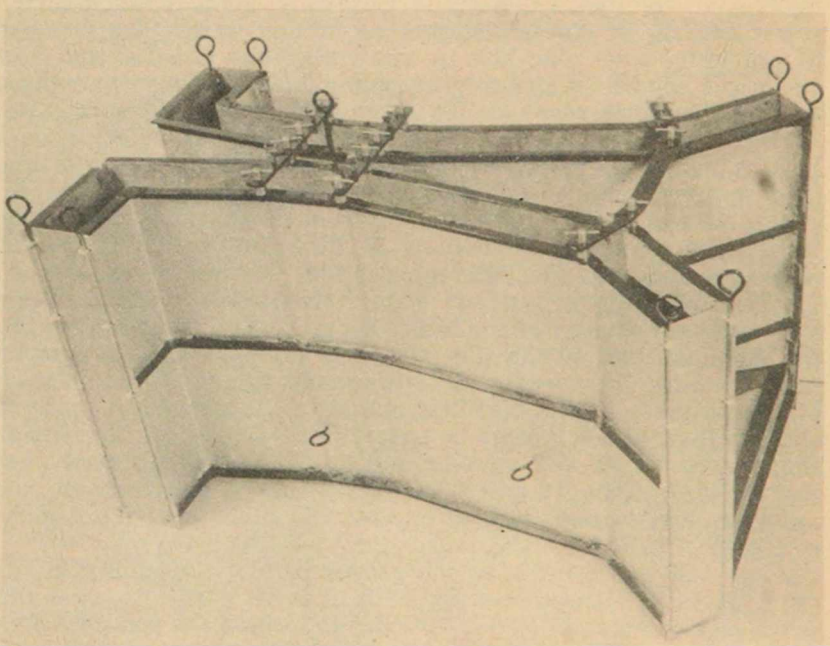

**FIGURE 14.—Improved sheet metal knock-down portable form for casting a 3-inch Parshall measuring flume. The eye-pins through side wall of form hold the tapered wooden plugs in position for casting the holes for the $H_a$ and $H_b$ inlet tubes to the stilling wells.**

## The Stilling Wells

Generally, for the measurement of free-flow discharge through the Parshall measuring flume, the $H_a$ head is determined by a simple staff gage placed vertically at the correct position on the face of the wall of the converging section of the flume. Ordinarily, an enameled metal gage in feet, tenths and hundredths, is used, recessed flush with the surface of the wall to provide for a smooth flow of water passing the gage. Quite accurate readings of the $H_a$ head can be obtained from the staff gage when properly set. For submerged-flow measurements, a staff gage in the throat section has been found wholly unsuited because of the roughness of the water surface at this place. It is not unusual in measuring farm deliveries to find a few of the farmers' laterals laid out on a flat grade to permit the irrigation of fields at the higher elevations. For such conditions the setting of the flume must provide for a minimum loss of head and thus necessitate submerged-flow measurements. For dependable observations of the $H_a$ and $H_b$ heads the measurements should be taken in stilling wells placed along the outside of the flume structure. The use of the portable form for casting small concrete flumes is not readily adaptable to the construction of stilling wells as an integral part of the structure, and in lieu thereof a successful and inexpensive method has been developed by using common 6-inch sewer tile, 24- or 30-inch lengths, as stilling wells. The problem of providing a suitable hole in the wall of the tile, for the inlet tube, was solved by shooting-in such a hole at the proper place with a 45-caliber revolver. To accomplish this the tile was set vertically in position behind a metal shield provided with a hole to permit the bullet to be fired at close range. The gun was held securely by fixed supports, as shown in figure 15. The 45-caliber size of bullet made a perforation of almost a true circle, ¾ inch in diameter, with little spalling on the inside and no radial cracking for the light-colored tile. The dark hard-burned tile cracked slightly but not enough to justify culling. Tests show that the energy of the bullet is practically spent in piercing the 5/8-inch wall of the tile, and thus there is little danger of double holing. However, to guard against the possible variation of the softness of the tile, it is suggested that a short piece of steel plate or 4-inch I-beam be placed in a vertical position inside the tile to arrest the piercing bullet. These caliber cartridges cost 5 cents each. It was later found that a satisfactory hole could be put through with a special 22-caliber cartridge bullet at a cost of about 1 cent each.

After the tile is holed at the proper height, depending on its use as an $H_a$ or $H_b$ well (see table 10), it is set upright, spigot end down, on a common 1- by 8-inch board to receive the concrete plug at the bottom. Where several tiles are being prepared, this base board, about 16 feet long, is provided with 7/16-inch holes, along the center line, spaced at 11-inch intervals with guide blocks as shown in figure 16. From the back of this board a blank 45-

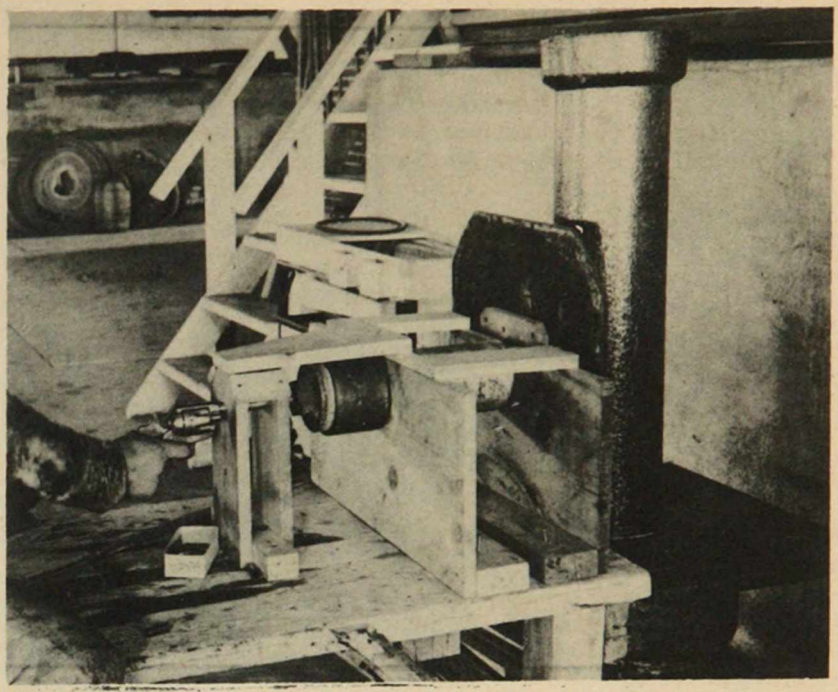

FIGURE 15.—Arrangement for shooting hole through side wall of tile with a 45-caliber revolver. The distance from base of tile to hole is regulated by blocking up the support to give the correct elevation. The tile as shown is too low for either the $H_6$ or $H_8$ holes.

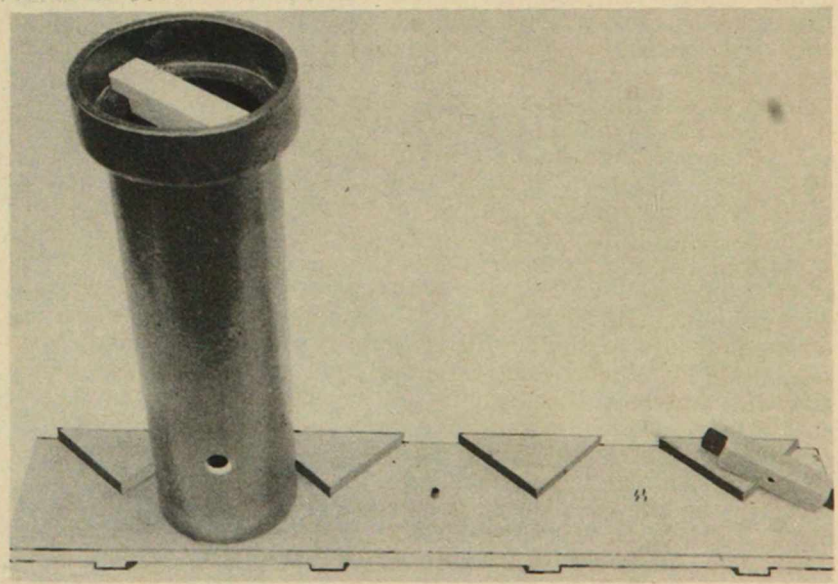

FIGURE 16.—Tile on section of template board ready for pouring concrete plug in bottom. Hole in tile for $H_6$ inlet tube. The tip of 45-caliber cartridge shell shows at the right of the upright tile. The four nails, in adjacent space, may also serve as a means of holding the lower end of the guide rod at the center of the plug. The top cross block, 1½ inches wide, supports the top end of the guide rod. The details of this block may be noted at the right end of the template board.

caliber cartridge shell is driven through each hole. When driven in to its full length the shell extends about ½-inch above the top surface of the board. The purpose of the cartridge shell is to hold the bottom end of the 3/8-inch iron rod at the center of the tile. The empty shell should be filled by a wooden plug or cement mortar to the elevation of the top surface of the board. Anchorage for the bottom end of the rod may also be provided by driving four finishing nails into the top side of this base board, equally spaced in a ½-inch circle, with heads protruding 3/16 inch. Both these arrangements will cast the rod flush with the bottom side of the concrete plug. When the tile is properly set in position, a piece of 3/8-inch common round iron rod is set into the anchor hole in the base board and held at the top end with a block which spans the bell opening and centers the rod in the axis of the tile. The length of rod should be the length of the tile used, that is, 24 or 30 inches. The supporting block at the top is narrow in width, thus leaving ample space for pouring in a thin mix of concrete to serve as the bottom of the well and at the same time to cast the upright 3/8-inch rod securely in place. To insure rigidity of the rod in the concrete, that portion within the thickness of the plug should be scored with a heavy hammer or slightly bent. Before casting the iron rod in place, it should be given a double coating of red lead. Galvanized rods are objectionable if copper inlet tubes are used. Brass rods and tubes may be used where the condition of water is suitable, but these will be more expensive than the iron-copper combination.

After the form has been removed from the flume structure, the tile stilling well is placed vertically on a firm footing at an elevation so that the hole through the wall of the tile and the hole through the wall of the flume coincide. For a 4-inch thickness of flume wall and inside wall height of 18 inches, a 6-inch length of inlet tube will be found suitable. The end of the tube into the flume should be grouted flush with the face of the wall; the end extending into the tile can be easily grouted by a stiff mixture of mortar placed on the outside of the tile. After the grouting has been completed, backfilling is brought up to an elevation of about 2 inches below the top of the flume wall.

TABLE 10.—DIMENSIONS FOR PIERCING THE $H_a$ AND $H_b$ TILE STILLING WELLS. THESE DIMENSIONS ARE FOR AN 18-INCH SIDE WALL, AT THE $H_a$ GAGE. (*Overall length of a 24-inch tile is 26¼ inches; 30-inch tile, 32¼ inches.*)

| W | Bottom of tile to center of hole | | | | Depth from top of bell to top of plug. | |
|---|---|---|---|---|---|---|
| | $H_a$ | Tile Length | $H_b$ | Tile Length | $H_a$ | $H_b$ |
| Inches | Inches | Inches | Inches | Inches | Inches | Inches |
| 3 | 5¼ | 24 | 3½ | 24 | 23 | 23½ |
| 6 | 5¼ | 24 | 2¾ | 24 | 23 | 24¼ |
| 9 | 5¼ | 24 | 2¾ | 24 | 23 | 24¼ |
| 12 | 5¼ | 24 | 4¼ | 30 | 23 | 28¾ |
| 18 | 5¼ | 24 | 4¼ | 30 | 23 | 28¾ |

For water which carries considerable silt in suspension, it is suggested that the wells be flushed out occasionally by filling the tile with water to full capacity and then stirring the bottom deposit vigorously with a stick. The agitated mud will be washed out through the inlet tube.

### Setting the Datum Point in the Stilling Well

The depth of the concrete plug in the well should be according to the dimensions given in table 10. The base or datum point for gaging the discharge by use of the measuring stick, to be described later, should agree in elevation with the crest. To fix this base or datum point in the well, a simple "L"-shaped frame is used (figure 17). The short leg is exactly 24 inches long, and the other leg is sufficient in length to reach horizontally from the midpoint of the crest to beyond the center of the stilling wells. A piece of ½-inch pipe, also exactly 24 inches in length, is dropped over the ⅜-inch vertical rod in the well. With the short leg of the "L" frame held vertically at the midpoint of the crest and a carpenter's level resting on the straight-top side of the long leg, the adjusting to a level position shows immediately the distance that the top side of the concrete plug is below the

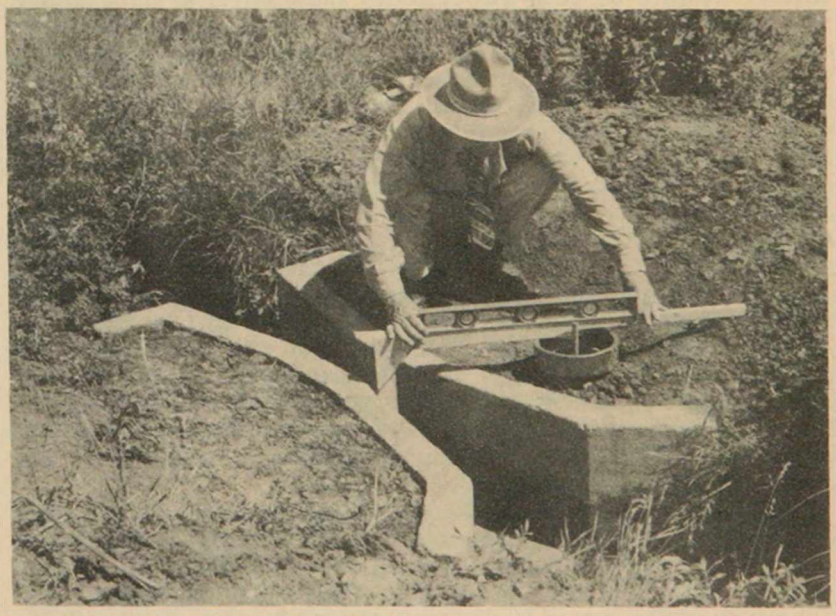

FIGURE 17.—Checking the elevation of the datum point in the stilling well by means of the "L" frame and the carpenter's level.

crest elevation. This distance varies slightly among the several wells because of the approximate setting of each one. Because of these variations, the distance from the top side of the concrete plug to the point of elevation of the crest is likewise variable.

Short pieces of ½-inch pipe, ranging from ½ to 1 inch long, are prepared, preferably cut in a lathe to insure true end surfaces, to be used in fixing the datum point. When the "L" frame is in the proper position, the top of the 24-inch length of pipe setting in the well over the vertical rod will be lower than the top edge of the horizontal leg of the frame and will show the exact length of short piece of pipe necessary to establish the true reference datum. Remove the 24-inch piece of pipe and drop over the vertical guide rod one of these short nipples and test again for setting. If found slightly below grade, ½-inch common washers are then to be added to bring the datum point to exactness. It is suggested that at the beginning of the irrigation season the datum point be checked by means of the "L" frame and carpenter's level.

## The Measuring Stick

The measuring stick is of special design and is intended for use in connection with this new type of stilling well to gage accurately the rate of flow through the Parshall measuring flume. For farm deliveries, flumes ranging in size from 3 to 18 inches are most applicable, and the measuring stick is designed to accommodate this group of small flumes. The stick is triangular in cross section with 1½-inch faces and is 23¼ inches long with a 1/2-inch hole throughout the entire axial length. The stick is shod with brass plates at both ends, the bottom plate having a 1/2-inch hole. The discharge scales for the 3-inch and 6-inch flumes are mounted on one of the faces. The scales are parallel to the axis of the stick and set ⅜ inch apart, as shown in figure 18. This space is occupied by a strip of black rubber 1/16 inch thick and inset so that the top surface is flush with the face of the stick. On another face are mounted the scales for the 9- and 12-inch flumes, and on the third side is the scale for the 18-inch flume and one graduated in feet, tenths and hundredths, which is for the purpose of determining the $H_a$ and $H_b$ heads in feet as required for submerged flow measurements. Each face of the measuring stick is provided with the center strip of black rubber.

Since the datum point in the well has been carefully set, it is necessary only to drop the measuring stick downward into the stilling well over the guide rod until the base of the stick rests upon the datum point (figure 19). Because of the slight displacement of the water in the well caused by the added volume

of the stick, it is best to lower it slowly the last 1/2 inch of travel. The water surface in the stilling well is marked clearly on the rubber strip and when the stick is withdrawn the water depth thus shown indicates the rate of free-flow discharge in statutory inches for that particular size of flume (figure 20). If the flow is submerged, the $H_b$ depth in feet is first observed and recorded, and then the $H_a$ depth is taken. The purpose of observing in this order is that the $H_b$ reading will be the lesser and will wet the rubber strip to a point beneath that reached when the stick is placed in the $H_a$ stilling well. The rubber strip dries readily, making the stick ready for further immediate observations. The discharge scales are prepared on paper, securely cemented to the wood surface of the stick, and then thoroughly waterproofed.

These measuring sticks, as herein described, may be obtained through Irrigation Investigations, Colorado Agricultural Experiment station, Fort Collins, Colorado.

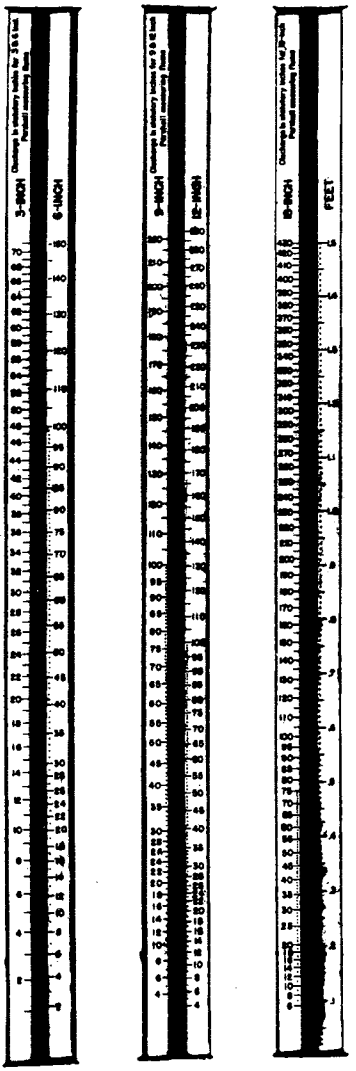


FIGURE 18.—The three faces of the measuring stick showing the free-flow discharge graduations in Colorado statutory inches for the 3-, 6-, 9-, 12-, and 18-inch flumes, also the scale in tenths and hundredths feet for calculating submerged-flow discharge.

FIGURE 19.—Lowering the measuring stick in the $H_b$ stilling well as the first of the two heads to be taken for calculating the submerged-flow discharge. Actual flow of 33 statutory inches at 85 percent submergence through 6-inch flume.

FIGURE 20.—Reading the measuring stick after withdrawal from the $H_a$ stilling well. Free flow through 6-inch flume.

## SUMMARY

Measuring the water supply with a fair degree of accuracy tends to increase the availability of water to the extent of having more head gates in operation. Where deliveries are poorly measured or merely estimated, the inclination is to over-serve in order to avoid dispute in the amount of water turned out.

•

Various types of measuring devices have been used in gaging the rate of delivery of water, but because of the many advantages in the use of the Parshall measuring flume this device is growing in popularity.

•

Many irrigation systems are mutually owned by the water users, whose interest in the water supply is represented by their share holdings. The amount of delivery each day is based upon the shares or rights owned in the company.

•

The Parshall measuring flume is accurate enough to meet all irrigation requirements. It can be constructed of concrete, timber, or sheet metal for the smaller sizes. It is immune to alteration in the willful unfair advantage of measurement. Measuring the discharge can be successfully accomplished over a wide range of downstream backwater conditions.

•

Ordinarily the grade of the farmer's lateral is sufficient to permit of free-flow measurements. For such laterals having a flat grade, submerged flows can be reliably measured up to about 95 percent submergence, a condition of small loss of head through the structure.

•

Attention must be given to the selection of the proper size of flume best suited to meet the requirements of operation. The setting of the structure in the lateral should be high enough in elevation to insure the least degree of submergence and at the same time permit of drawing the full rightful share of water from the canal.

•

The use of the improved knock-down portable form for casting monolithic reinforced concrete flumes of small sizes shows construction costs to be low where a number of structures of the same size are to be built.

•

Stilling wells of ordinary 6-inch common sewer tile, hard-burned with glazed finish, are found to be admirably suited for the observation of the $H_a$ and $H_b$ heads required in calculating the rate of discharge.

•

The piercing of the side wall of the tile with a bullet from a gun gives a clean round hole of the right diameter for the 3/4-inch inlet tube from the flume.

•

The datum point in the stilling well can be set accurately with the "L" frame and carpenter's level to within a limit of 1/32 inch.

•

The determination of the rate of flow by use of the measuring stick has proved highly satisfactory. This scheme eliminates the need of staff gages for observing the heads. The indicated discharge on the stick is accurate and reliable. The measuring stick can be so graduated as to show the discharge in cubic feet per second or any other practical unit desired.

•

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