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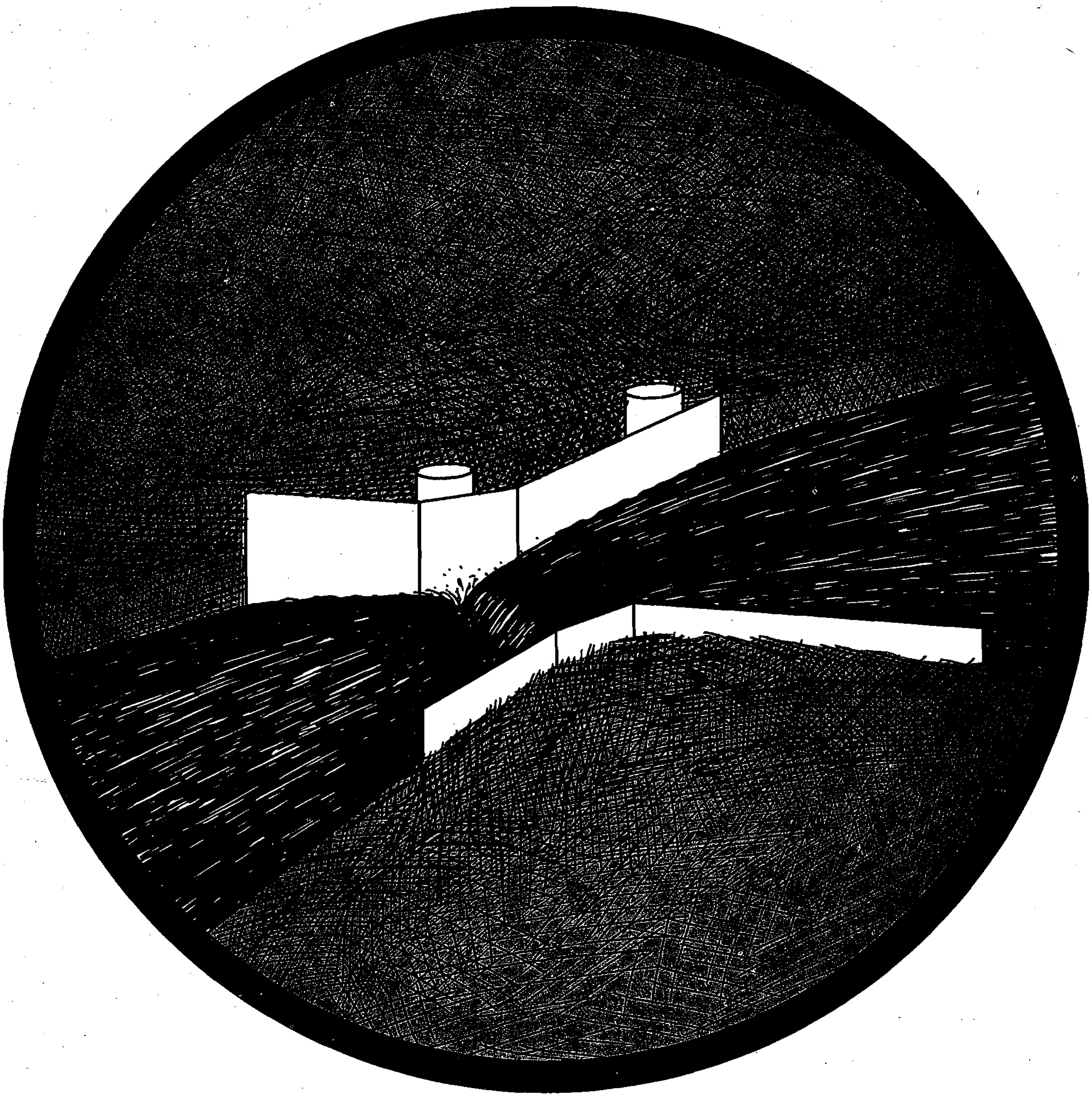

MEASURING WATER WITH PARSHALL FLUMES

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PREFACE

As the value of water increases, the extent to which measurement is employed in an irrigation system also increases. Additional flow measurements provide information for improved management of the water supply. Good water management requires accurate measurement. Many devices have been developed for this purpose and are in use. Included among them are weirs, orifices, calibrated gates, Parshall flumes, and current meters. Of these, the Parshall flume is one of the most widely accepted and used.

Presented in this publication is a discussion concerning the use of Parshall flumes for measuring water, including the utilization of a new approach for treating submerged flow that was developed at Utah State University.

The information presented on free flow has been taken from the original publications of Ralph L. Parshall, and the bulletin, "Measurement of Irrigation Water," prepared by Eldon M. Stock. Utilizing data developed by Ralph L. Parshall, A. R. Robinson, and the authors.

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DEFINITIONS

The two forms under which irrigation water is normally measured are volume and rate of flow. Some of the common volumetric and flow rate terms are listed below.

Acre-foot. An acre-foot is a volume of water sufficient to cover one acre of ground with a one-foot depth of water.

Acre-inch. An acre-inch is a volume of water sufficient to cover one acre of ground with water one inch deep.

Cubic feet per second. Also referred to as second-feet or cfs. The term is a measure of the rate at which water flows (discharge) past a point. The flow rate of a stream of water is the cross-sectional area of flow in square feet ($ft.^2$) multiplied by the average velocity of the flow in feet per second (ft/sec).

Gallons per minute. Also referred to as gpm. The term is also a measure of the rate at which water flows past a point.

The following relationships exist for the volume and flow rate units.

1 acre-foot = 43,560 cubic feet
1 acre-inch = 3,630 cubic feet
1 cfs = 450 gpm (appxoimately)
1 cfs = 2 acre-feet in 24 hours (approximately)
1 cfs = 1 acre-inch per hour (approximately)

The nomenclature for a Parshall flume is illustrated in Figure 2 and is defined below.

Converging inlet section. The entrance section of the Parshall flume consists of a level floor with walls which come together in the direction of flow (converge).

Throat section. The throat section constitutes the middle portion of the Parshall flume. The floor of the throat section dips downward in the direction of flow. The walls are parellel.

Diverging outlet section. The exit section of the Parshall flume has a floor which rises in the direction of flow. The walls become further separated in the direction of flow (diverge).

Flume crest. The flume crest is the edge of the floor at the junction of the converging inlet section and the throat section.

Two types of flow conditions can exist in a Parshall flume, free flow and submerged flow. A definition of the types of flow along with the measurements required for evaluating flow rates are defined below.

Free flow. Free flow exists in a Parshall flume when a change in the water surface elevation downstream from the flume does not cause a change in water surface elevation upstream from the flume. When free flow exists, only the depth of flow at H_a need be measured to determine the flow rate or discharge.

Submerged flow. Submerged flow exists in a Parshall flume when a change in the water surface elevation downstream from the flume causes a change in water surface elevation upstream from the flume. When submerged flow exists, the depths of flow at both H_a and H_b must be measured to determine the flow rate or discharge.

H_a. The depth of flow measured in the converging inlet section at a point two-thirds the length of the entrance section upstream from the flume crest.

H_b. The depth of flow measured at a specified point in the throat. The value of H_b is the depth of flow above the elevation of the flume crest.

Head loss. Head loss is the loss of energy of the flow between two points. For the purpose of this publication, the head loss has been taken as the difference between H_a and H_b (head loss = $H_a - H_b$). Technically speaking, this is not true, but such an assumption is usually made for Parshall flumes.

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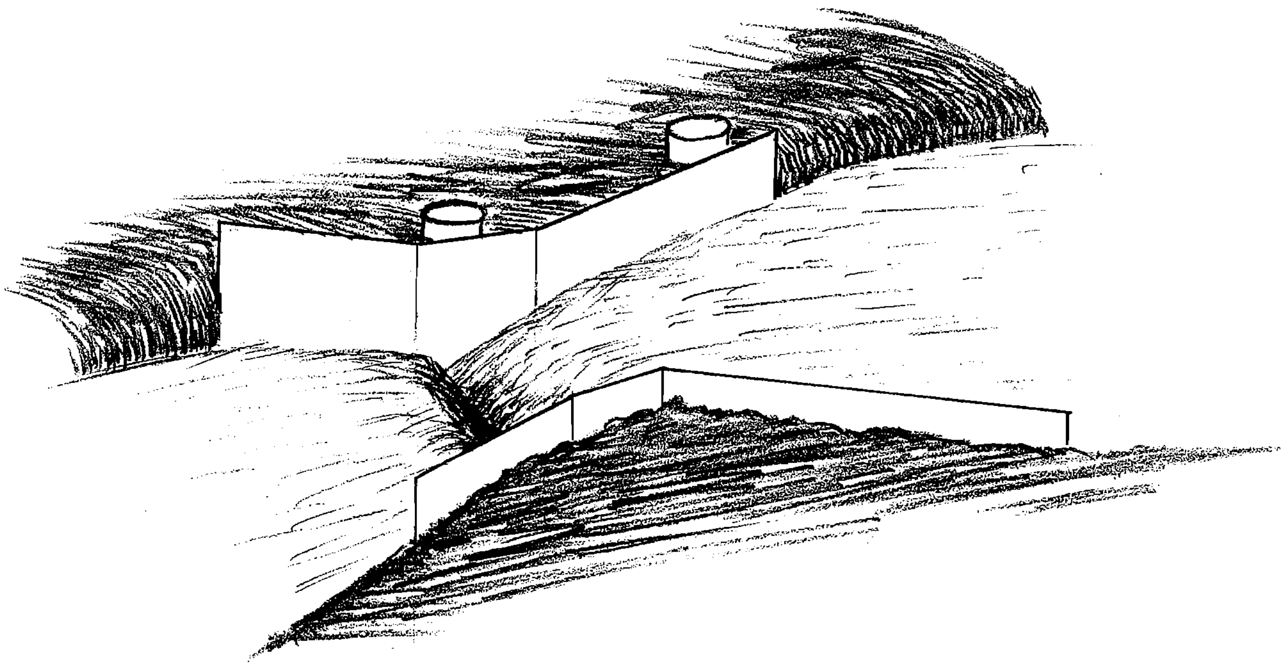
The Parshall measuring flume is a water measuring device that can be used to measure water flowing in an open channel. It is intended primarily for use in irrigation, and consists of a converging inlet section, a throat section with straight parallel sides, and a diverging outlet section (Figure 1). The two most desirable features of the flume are that it operates very satisfactorily with a loss of head much less than required for a weir, and under normal operating conditions, the discharge can be determined with an accuracy of 2 to 5 percent.

Discharge through the flume is called "free flow" when the water elevation downstream is not high enough to affect flow conditions upstream. However, when the water elevation downstream is not high enough to affect flow conditions upstream. However, when the water elevation downstream is high enough to affect conditions upstream, submerged flow occurs. A further clarification between free flow and submerged flow is illustrated in Figure 3.

Figure 1. Three dimensional drawing of Parshall flume.



DIMENSIONS OF PARSHALL FLUMES

The Parshall measuring flume consists of: a converging inlet section, a throat, and a diverging outlet section each with vertical side walls. Figure 2 is a plan and sectional view of a Parshall flume, along with a letter for each dimension line. Listed in Table 1 are the values of each dimension for various sizes of flumes which have a discharge capacity varying from 0.03 cfs to 140 cfs. The size of a Parshall flume is denoted by its throat-width. This dimension is indicated as W in Table 1. The converging floor section must be level in all directions. The floor of the throat is inclined downward with a slope of 9 inches vertically, to 24 inches horizontally. The floor of the outlet or diverging section has a slope upward of 6 inches vertically to 36 inches horizontally, with the downstream end of the flume 3 inches lower than the crest. These dimensions are for flumes having a throat width of 1 foot or more. Parshall flumes having 50-foot throat widths are in use that are capable of measuring flow rates as high as 3,000 cfs.

The flume may be constructed of wood, concrete, metal, or any other material depending on existing conditions, and desired use and durability.

DEFINITION OF FREE FLOW AND SUBMERGED FLOW

Free flow is the condition under which the rate of discharge depends only upon the depth of flow, H_a, (Fig. 2) in the converging section. For a Parshall flume, the free-flow discharge relationship remains valid for a relatively high degree of submergence, thus allowing a wide range of downstream flow conditions. For free flow conditions, the submergence should not exceed the limits as given in Table 2. The submergence, which is often expressed as a percentage, is the ratio of the downstream head, H_b, to the upstream head, H_a, (H_b/H_a) (Fig. 2). The point at which the transition from free flow to submerged flow occurs can be observed in a Parshall flume. When downstream flow conditions cause the water surface in the flume to be raised until a ripple or wave is formed at or near the downstream end of the throat (Fig. 3, water surface profile line b), the flow is near the transition submergence.

Figure 2. Plan and sectional view of Parshall measuring flumes.

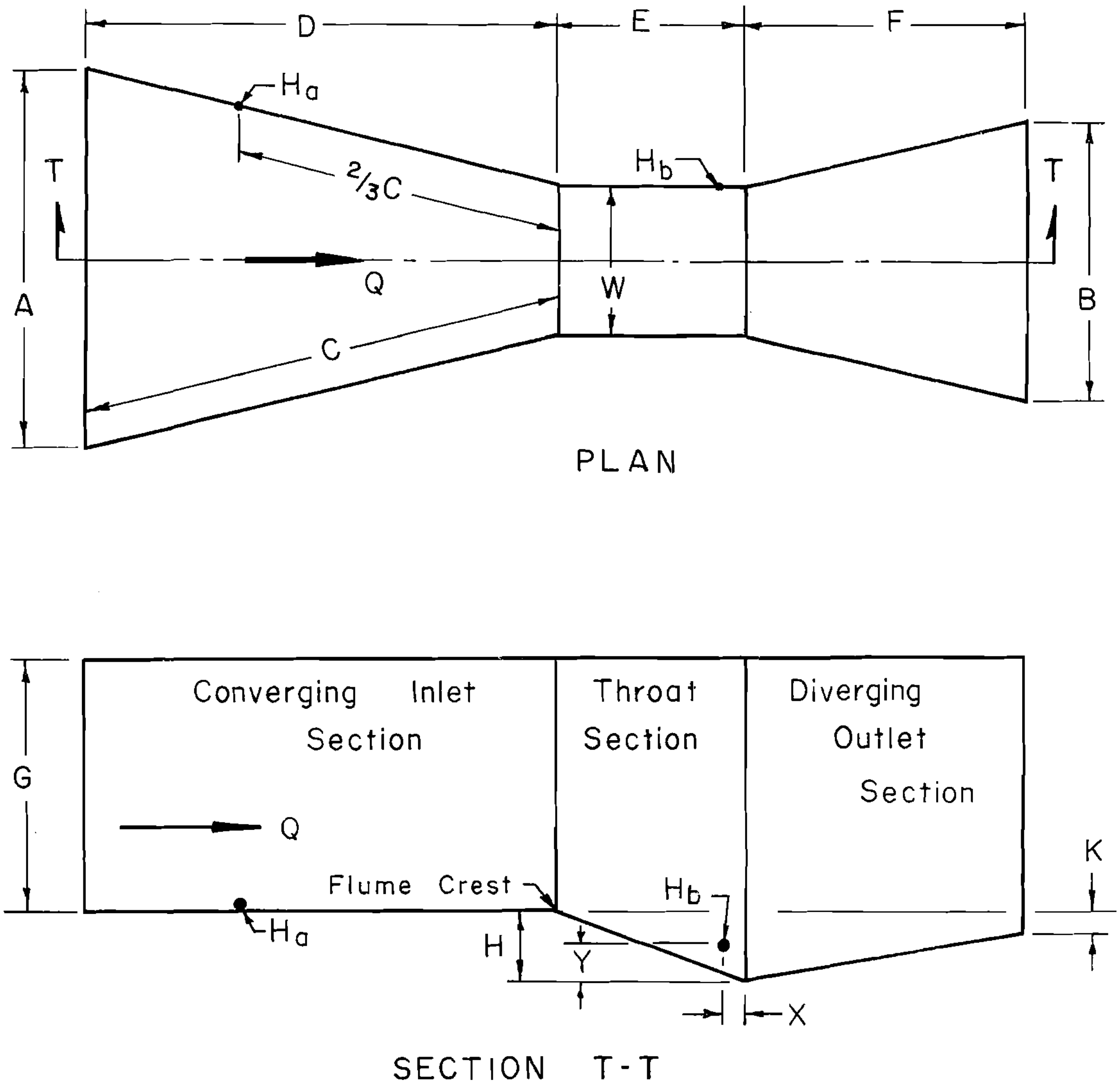


Table 1. Dimensions and Capacities for Parshall Flumes.

Throat Width W	Dimensions in Feet and Inches													Free Flow Capacities	
ft. in.	A	B	C	2/3 C	D	E	F	G	H	K	X	Y	Min. cfs	Max. cfs
0' 3"	0' 10 3/16"	0' 7"	1' 6 3/8"	1' 0 1/4"	1' 6"	0' 6"	1' 0"	1' 3"	0' 2 1/4"	0' 1"	1"	1 1/2"	0.03	.6
0' 6"	1' 3 1/2"	1' 3 1/2"	2' 0 7/16"	1' 4 5/16"	2' 0"	1' 0"	2' 0"	1' 6"	0' 4 1/2"	0' 3"	2"	3"	0.05	2.9
0' 9"	1' 10 5/8"	1' 3"	2' 10 5/8"	1' 11 1/8"	2' 10"	1' 0"	1' 6"	2' 0"	0' 4 1/2"	0' 3"	2"	3"	0.1	5.1
12"	2' 9 1/4"	2' 0"	4' 6"	3' 0"	4' 4 7/8"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	0.4	16.0
18"	3' 4 3/8"	2' 6"	4' 9"	3' 2"	4' 7 7/8"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	0.5	24.0
24"	3' 11 1/2"	3' 0"	5' 0"	3' 4"	4' 10 7/8"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	0.7	33.0
30"	4' 6 3/4"	3' 6"	5' 4 1/4"	3' 6 3/4"	5' 3"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	0.8	41.0
3' 0"	5' 1 7/8"	4' 0"	5' 6"	3' 8"	5' 4 3/4"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	1.0	50.0
4' 0"	6' 4 1/4"	5' 0"	6' 0"	4' 0"	5' 10 5/8"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	1.3	68.0
5' 0"	7' 6 5/8"	6' 0"	6' 6"	4' 4"	6' 4 1/2"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	2.2	86.0
6' 0"	8' 9"	7' 0"	7' 0"	4' 8"	6' 10 3/8"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	2.6	104.0
7' 0"	9' 11 3/8"	8' 0"	7' 6"	5' 0"	7' 4 1/4"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	4.1	121.0
8' 0"	11' 1 3/4"	9' 0"	8' 0"	5' 4"	7' 10 1/8"	2' 0"	3' 0"	3' 0"	0' 9"	0' 3"	2"	3"	4.6	140.0

With this condition, there is a marked reduction in the velocity of the water as it leaves the lower end of the flume.

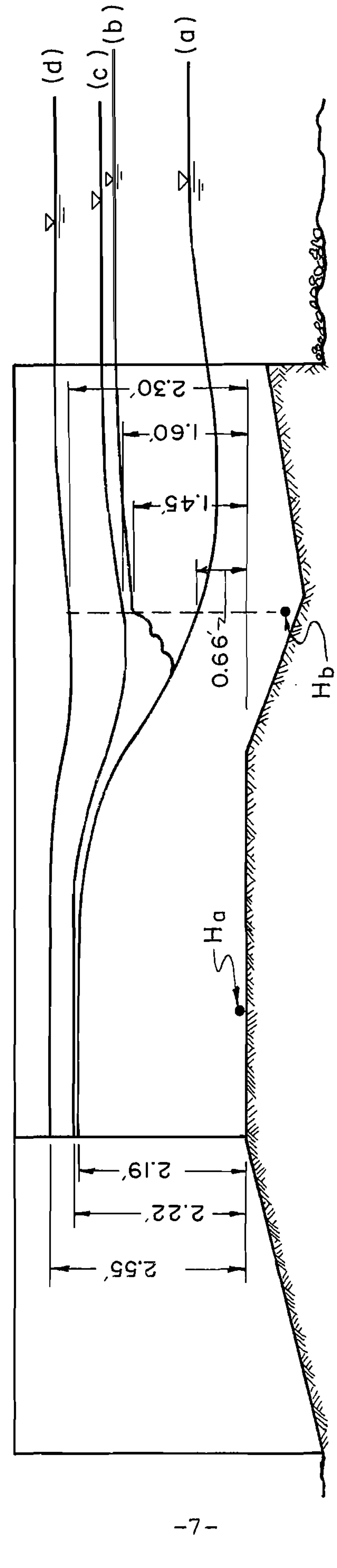
Shown in Figure 3 is a two-foot Parshall flume with a discharge of 27.0 cfs. The water surface profiles (lines a, b, c, and d) represent both free flow and submerged flow, with lines a and b being free flow and lines c and d being submerged flow. Water surface profile lines a and b both have an upstream depth equal to 2.19 feet. Line a is for a very low submergence of 30 percent. This results in a jetting action at the exit. Line b has a submergence of 66 percent which is the transition submergence. This **is** the maximum value of submergence that can occur for free flow conditions in the flume. Lines a and b show the wide range of possible downstream conditions for free flow. Water surface profile lines c and d are for submerged flow conditions with line c having a submergence of 72 percent, which is slightly greater than the transition submergence, and line d having a submergence of 90 percent. Of particular importance is the change in upstream water depth, H_a, under submerged flow conditions (water surface profile lines c and d).

In Table 2 are the transition submergence values for Parshall flumes ranging in size from 3 inches to 8 feet. When the submergence, H_b/H_a, for any given flume size exceeds the transition submergence value given in Table 2, the flow is submerged. For this condition, the submerged flow calibration curves must be used to determine the discharge.

Table 2. Transition submergences in Parshall flumes.

Flume Size	Transition Submergence	Flume Size	Transition Submergence	Flume Size	Transition Submergence
3"	56%	18"	64%	4'	70%
6"	56%	24"	66%	5'	72%
9"	60%	30"	67%	6'	74%
12"	62%	3'	68%	7'	76%
				8'	78%

Figure 3. Illustration of free flow and submerged flow in a two-foot Parshall flume.



FREE FLOW CALIBRATIONS

Under free flow conditions, the discharge depends only upon the upstream depth of flow, H_a. Utilizing this relationship, Table 3 has been prepared to give the free flow discharge in second-feet (cfs) for most possible H_a values, and for Parshall flumes ranging in size from 3 inches to 8 feet.

<u>Example 1</u>. To illustrate the use of Table 3, take a two-foot Parshall flume with an upstream depth of flow, H_a, equal to 2.19 feet. Enter Table 3 at the left side with a value of H_a equal to 2.19 feet, then under the column headed by a throat width of two feet, observe that the rate of flow is 27.0 cfs.

SUBMERGED FLOW CALIBRATIONS

When the ratio of H_b to H_a (H_b/H_a) exceeds the limits given in Table 2, which is the transition submergence value, the flow is said to be submerged. Here, the rate of discharge depends on both the upstream and downstream depths of flow, H_a and H_b. To obtain the discharge under submerged flow conditions, the downstream and upstream depths are measured. Using the values of H_a and H_b, the nomographs in Figures 4 and 5 are used to obtain values of the change in water surface elevation ($H_a - H_b$) and submergence (H_b/H_a). To accomplish this, a straightedge is aligned on the values of H_a and H_b, and the values of $H_a - H_b$ and H_b/H_a are read along the straightedge alignment.

<u>Example 2</u>. For H_a equal to 2.19 feet and H_b equal to 1.97 feet, Figure 4 is used with a straightedge aligned on $H_a = 2.19$ and $H_b = 1.97$ and the difference ($H_a - H_b$) taken from the alignment is 0.22 feet. From Figure 5, with a straightedge aligned on $H_a = 2.19$ and $H_b = 1.97$, the value of submergence taken from the alignment is 90 percent.

With the values of $H_a - H_b$ and H_b/H_a, it is now possible to enter the submerged calibration curves and obtain the value of submerged flow discharge. To illustrate the use of the submergence flow calibration curves, the two-foot Parshall flume is selected.

Example 3. Using the values of $H_a - H_b$ and H_b/H_a as obtained in the above example, the submerged flow calibration curves for the 2-foot Parshall flume (Fig. 11) is entered from below with the value of $H_a - H_b$ = 0.22 feet. Then, move vertically upward to the 90 percent submergence line. At this point of intersection, move horizontally to the left to the discharge value located on the vertical scale which is 21.3 cfs.

Table 3. **Free flow calibration tables for Parshall flumes.**

Upper head Ha	Throat Width												
	3 inches	6 inches	9 inches	12 inches	18 inches	24 inches	30 inches	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
Feet	Flow in cubic feet per second												
0.10	0.028	0.05	0.09	----	----	----	----	----	----	----	----	----	----
0.11	0.033	0.06	0.10	----	----	----	----	----	----	----	----	----	----
0.12	0.037	0.07	0.12	----	----	----	----	----	----	----	----	----	----
0.13	0.042	0.08	0.14	----	----	----	----	----	----	----	----	----	----
0.14	0.047	0.09	0.15	----	----	----	----	----	----	----	----	----	----
0.15	0.053	0.10	0.17	----	----	----	----	----	----	----	----	----	----
0.16	0.058	0.11	0.19	----	----	----	----	----	----	----	----	----	----
0.17	0.064	0.12	0.20	----	----	----	----	----	----	----	----	----	----
0.18	0.070	0.14	0.22	----	----	----	----	----	----	----	----	----	----
0.19	0.076	0.15	0.24	----	----	----	----	----	----	----	----	----	----
0.20	0.082	0.16	0.26	0.35	0.51	0.66	0.81	0.97	1.26	----	----	----	----
0.21	0.089	0.18	0.28	0.37	0.55	0.71	0.88	1.04	1.36	----	----	----	----
0.22	0.095	0.19	0.30	0.40	0.59	0.77	0.95	1.12	1.47	----	----	----	----
0.23	0.102	0.20	0.32	0.43	0.63	0.82	1.01	1.20	1.58	----	----	----	----
0.24	0.109	0.22	0.35	0.46	0.67	0.88	1.08	1.28	1.69	----	----	----	----
0.25	0.117	0.23	0.37	0.49	0.71	0.93	1.15	1.37	1.80	2.22	2.63	----	----
0.26	0.124	0.25	0.39	0.51	0.76	0.99	1.23	1.46	1.91	2.36	2.80	----	----
0.27	0.131	0.26	0.41	0.54	0.80	1.05	1.30	1.55	2.03	2.50	2.97	----	----
0.28	0.138	0.28	0.44	0.58	0.85	1.11	1.38	1.64	2.15	2.65	3.15	----	----
0.29	0.146	0.29	0.46	0.61	0.90	1.18	1.45	1.73	2.27	2.80	3.33	----	----
0.30	0.154	0.31	0.49	0.64	0.94	1.24	1.53	1.82	2.39	2.96	3.52	4.08	4.62
0.31	0.162	0.32	0.51	0.68	0.99	1.30	1.61	1.92	2.52	3.12	3.71	4.30	4.88
0.32	0.170	0.34	0.54	0.71	1.04	1.37	1.70	2.02	2.65	3.28	3.90	4.52	5.13
0.33	0.179	0.36	0.56	0.74	1.09	1.44	1.78	2.12	2.78	3.44	4.10	4.75	5.39
0.34	0.187	0.38	0.59	0.77	1.14	1.50	1.87	2.22	2.92	3.61	4.30	4.98	5.66
0.35	0.196	0.39	0.62	0.80	1.19	1.57	1.95	2.32	3.06	3.78	4.50	5.22	5.93
0.36	0.205	0.41	0.64	0.84	1.25	1.64	2.04	2.42	3.19	3.95	4.71	5.46	6.20
0.37	0.213	0.43	0.67	0.88	1.30	1.72	2.11	2.53	3.34	4.13	4.92	5.70	6.48
0.38	0.222	0.45	0.70	0.92	1.36	1.79	2.22	2.64	3.48	4.31	5.13	5.95	6.76
0.39	0.231	0.47	0.73	0.95	1.41	1.86	2.31	2.75	3.62	4.49	5.35	6.20	7.05
0.40	0.241	0.48	0.76	0.99	1.47	1.93	2.40	2.86	3.77	4.68	5.57	6.46	7.34
0.41	0.250	0.50	0.78	1.03	1.53	2.01	2.49	2.97	3.92	4.86	5.80	6.72	7.64
0.42	0.260	0.52	0.81	1.07	1.58	2.09	2.59	3.08	4.07	5.05	6.02	6.98	7.94
0.43	0.269	0.54	0.84	1.11	1.64	2.16	2.68	3.20	4.22	5.24	6.25	7.25	8.24
0.44	0.279	0.56	0.87	1.15	1.70	2.24	2.78	3.32	4.38	5.43	6.48	7.52	8.55
0.45	0.289	0.58	0.90	1.19	1.76	2.32	2.88	3.44	4.54	5.63	6.72	7.80	8.87
0.46	0.299	0.61	0.94	1.23	1.82	2.40	2.98	3.56	4.70	5.83	6.96	8.08	9.19
0.47	0.309	0.63	0.97	1.27	1.88	2.48	3.08	3.68	4.86	6.03	7.20	8.36	9.51
0.48	0.319	0.65	1.00	1.31	1.94	2.57	3.19	3.80	5.03	6.24	7.44	8.65	9.8
0.49	0.329	0.67	1.03	1.35	2.00	2.65	3.29	3.92	5.20	6.45	7.69	8.94	10.2

Table 3. (Continued)

Upper head Ha	Throat Width												
	3 inches	6 inches	9 inches	12 inches	18 inches	24 inches	30 inches	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
Feet	Flow in cubic feet per second												
0.50	0.339	0.69	1.06	1.39	2.06	2.73	3.39	4.05	5.36	6.66	7.94	9.23	10.5
0.51	0.350	0.71	1.10	1.44	2.13	2.82	3.50	4.18	5.53	6.87	8.20	9.53	10.9
0.52	0.361	0.73	1.13	1.48	2.19	2.90	3.61	4.31	5.70	7.09	8.46	9.83	11.2
0.53	0.371	0.76	1.16	1.52	2.25	2.99	3.72	4.44	5.88	7.30	8.72	10.1	11.5
0.54	0.382	0.78	1.20	1.57	2.32	3.08	3.83	4.57	6.05	7.52	8.98	10.5	11.9
0.55	0.393	0.80	1.23	1.62	2.39	3.17	3.94	4.70	6.23	7.74	9.25	10.8	12.2
0.56	0.404	0.82	1.26	1.66	2.45	3.26	4.05	4.84	6.41	7.97	9.52	11.1	12.6
0.57	0.415	0.85	1.30	1.70	2.52	3.35	4.16	4.98	6.59	8.20	9.79	11.4	13.0
0.58	0.427	0.87	1.33	1.75	2.59	3.44	4.28	5.11	6.77	8.43	10.1	11.7	13.3
0.59	0.438	0.89	1.37	1.80	2.66	3.53	4.39	5.25	6.96	8.66	10.4	12.0	13.7
0.60	0.450	0.92	1.40	1.84	2.73	3.62	4.51	5.39	7.15	8.89	10.6	12.4	14.1
0.61	0.462	0.94	1.44	1.88	2.80	3.72	4.63	5.53	7.34	9.13	10.9	12.7	14.5
0.62	0.474	0.97	1.48	1.93	2.87	3.81	4.75	5.68	7.53	9.37	11.2	13.0	14.8
0.63	0.485	0.99	1.51	1.98	2.95	3.91	4.87	5.82	7.72	9.61	11.5	13.4	15.2
0.64	0.497	1.02	1.55	2.03	3.02	4.01	4.99	5.97	7.91	9.85	11.8	13.7	15.6
0.65	0.509	1.04	1.59	2.08	3.09	4.11	5.11	6.12	8.11	10.1	12.1	14.1	16.0
0.66	0.522	1.07	1.63	2.13	3.17	4.20	5.24	6.26	8.31	10.3	12.4	14.4	16.4
0.67	0.534	1.10	1.66	2.18	3.24	4.30	5.36	6.41	8.51	10.6	12.7	14.8	16.8
0.68	0.546	1.12	1.70	2.23	3.31	4.40	5.49	6.56	8.71	10.9	13.0	15.1	17.2
0.69	0.558	1.15	1.74	2.28	3.39	4.50	5.61	6.71	8.91	11.1	13.3	15.5	17.6
0.70	0.571	1.17	1.78	2.33	3.46	4.60	5.74	6.86	9.11	11.4	13.6	15.8	18.0
0.71	0.584	1.20	1.82	2.38	3.54	4.70	5.87	7.02	9.32	11.6	13.9	16.2	18.5
0.72	0.597	1.23	1.86	2.43	3.62	4.81	6.00	7.17	9.53	11.9	14.2	16.6	18.9
0.73	0.610	1.26	1.90	2.48	3.69	4.91	6.12	7.33	0.74	12.1	14.5	16.9	19.3
0.74	0.623	1.28	1.94	2.53	3.77	5.02	6.25	7.49	9.95	12.4	14.9	17.3	19.7
0.75	-----	1.31	1.98	2.58	3.85	5.12	6.38	7.65	10.2	12.7	15.2	17.7	20.1
0.76	-----	1.34	2.02	2.63	3.93	5.23	6.52	7.81	10.4	12.9	15.5	18.0	20.6
0.77	-----	1.36	2.06	2.68	4.01	5.34	6.65	7.97	10.6	13.2	15.8	18.4	21.0
0.78	-----	1.39	2.10	2.74	4.09	5.44	6.79	8.13	10.8	13.5	16.2	18.8	21.5
0.79	-----	1.42	2.14	2.80	4.17	5.55	6.92	8.30	11.0	13.8	16.5	19.2	21.9
0.80	-----	1.45	2.18	2.85	4.26	5.66	7.06	8.46	11.3	14.0	16.8	19.6	22.4
0.81	-----	1.48	2.22	2.90	4.34	5.77	7.20	8.63	11.5	14.3	17.2	20.0	22.8
0.82	-----	1.50	2.27	2.96	4.42	5.88	7.34	8.79	11.7	14.6	17.5	20.4	23.3
0.83	-----	1.53	2.31	3.02	4.50	6.00	7.48	8.96	11.9	14.9	17.8	20.8	23.7
0.84	-----	1.56	2.35	3.07	4.59	6.11	7.62	9.13	12.2	15.2	18.2	21.2	24.2
0.85	-----	1.59	2.39	3.12	4.67	6.22	7.76	9.30	12.4	15.5	18.5	21.6	24.6
0.86	-----	1.62	2.44	3.18	4.76	6.33	7.91	9.48	12.6	15.8	18.9	22.0	25.1
0.87	-----	1.65	2.48	3.24	4.84	6.44	8.05	9.65	12.8	16.0	19.2	22.4	25.6
0.88	-----	1.68	2.52	3.29	4.93	6.56	8.20	9.82	13.1	16.3	19.6	22.8	26.1
0.89	-----	1.71	2.57	3.35	5.01	6.68	8.34	10.0	13.3	16.6	19.9	23.2	26.5

Table 3. (Continued)

Upper head Ha	Throat Width												
	3 inches	6 inches	9 inches	12 inches	18 inches	24 inches	30 inches	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
Feet	Flow in cubic feet per second												
0.90	----	1.74	2.61	3.41	5.10	6.80	8.49	10.2	13.6	16.9	20.3	23.7	27.0
0.91	----	1.77	2.66	3.46	5.19	6.92	8.64	10.4	13.8	17.2	20.7	24.1	27.5
0.92	----	1.81	2.70	3.52	5.28	7.03	8.79	10.5	14.0	17.5	21.0	24.5	28.0
0.93	----	1.84	2.75	3.58	5.37	7.15	8.93	10.7	14.3	17.8	21.4	24.9	28.5
0.94	----	1.87	2.79	3.64	5.46	7.27	9.08	10.9	14.5	18.1	21.8	25.4	29.0
0.95	----	1.90	2.84	3.70	5.55	7.39	9.23	11.1	14.8	18.4	22.1	25.8	29.5
0.96	----	1.93	2.88	3.76	5.64	7.51	9.38	11.3	15.0	18.8	22.5	26.2	30.0
0.97	----	1.97	2.93	3.82	5.73	7.63	9.53	11.4	15.3	19.1	22.9	26.7	30.5
0.98	----	2.00	2.98	3.88	5.82	7.75	9.69	11.6	15.5	19.4	23.2	27.1	31.0
0.99	----	2.03	3.02	3.94	5.91	7.88	9.84	11.8	15.8	19.7	23.6	27.6	31.5
1.00	----	2.06	3.07	4.00	6.00	8.00	10.00	12.0	16.0	20.0	24.0	28.0	32.0
1.01	----	2.09	3.12	4.06	6.09	8.12	10.16	12.2	16.3	20.3	24.4	28,4	32.5
1.02	----	2.12	3.17	4.12	6.19	8.25	10.32	12.4	16.5	20.6	24.8	28.9	33.0
1.03	----	2.16	3.21	4.18	6.28	8.38	10.47	12.6	16.8	21.0	25.2	29.4	33.6
1.04	----	2.19	3.26	4.25	6.37	8.50	10.63	12.8	17.0	21.3	25.6	29.8	34.1
1.05	----	2.22	3.31	4.31	6.47	8.63	10.79	13.0	17.3	21.6	25.9	30.3	34.6
1.06	----	2.26	3.36	4.37	6.56	8.76	10.95	13.2	17.5	21.9	26.3	30.7	35.1
1.07	----	2.29	3.40	4.43	6.66	8.88	11.11	13.3	17.8	22.3	26.7	31.2	35.7
1.08	----	2.32	3.45	4.50	6.75	9.01	11.28	13.5	18.1	22.6	27.1	31.7	36.2
1.09	----	2.36	3.50	4.56	6.85	9.14	11.44	13.7	18.3	22.9	27.5	32.1	36.8
1.10	----	2.40	3.55	4.62	6.95	9.27	11.60	13.9	18.6	23.3	27.9	32.6	37.3
1.11	----	2.43	3.60	4.68	7.04	9.40	11.76	14.1	18.9	23.6	28.4	33.1	37.8
1.12	----	2.46	3.65	4.75	7.14	9.54	11.93	14.3	19.1	23.9	28.8	33.6	38.4
1.13	----	2.50	3.70	4.82	7.24	9.67	12.09	14.5	19.4	24.3	29.2	34.1	38.9
1.14	----	2.53	3.75	4.88	7.34	9.80	12.26	14.7	19.7	24.6	29.6	34.5	39.5
1.15	----	2.57	3.80	4.94	7.44	9.94	12.43	14.9	19.9	25.0	30.0	35.0	40.1
1.16	----	2.60	3.85	5.01	7.54	10.1	12.60	15.1	20.2	25.3	30.4	35.5	40.6
1.17	----	2.64	3.90	5.08	7.64	10.2	12.77	15.3	20.5	25.7	30.8	36.0	41.2
1.18	----	2.68	3.95	5.15	7.74	10.3	12.94	15.6	20.8	26.0	31.3	36.5	41.8
1.19	----	2.71	4.01	5.21	7.84	10.5	13.11	15.8	21.1	26.4	31.7	37.0	42.3
1.20	----	2.75	4.06	5.28	7.94	10.6	13.28	16.0	21.3	26.7	32.1	37.5	42.9
1.21	----	2.78	4.11	5.34	8.05	10.8	13.45	16.2	21.6	27.1	32.5	38.0	43.5
1.22	----	2.82	4.16	5.41	8.15	10.9	13.63	16.4	21.9	27.4	33.0	38.5	44.1
1.23	----	2.86	4.22	5.48	8.25	11.0	13.80	16.6	22.2	27.8	33.4	39.0	44.6
1.24	----	2.89	4.27	5.55	8.36	11.2	13.98	16.8	22.5	28.1	33.8	39.5	45.2
1.25	----	----	4.32	5.62	8.46	11.3	14.15	17.0	22.8	28.5	34.3	40.0	45.8
1.26	----	----	4.37	5.69	8.56	11.5	14.33	17.2	23.0	28.9	34.7	40.5	46.4
1.27	----	----	4.43	5.76	8.67	11.6	14.51	17.4	23.3	29.2	35.1	41.1	47.0
1.28	----	----	4.48	5.82	8.77	11.7	14.69	17.7	23.6	29.6	35.6	41.6	47.6
1.29	----	----	4.53	5.89	8.88	11.9	14.87	17.9	23.9	30.0	36.0	42.1	48.2

Table 3. (Continued)

Upper head Ha	Throat Width												
	3 inches	6 inches	9 inches	12 inches	18 inches	24 inches	30 inches	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
Feet	Flow in cubic feet per second												
1.30	----	----	4.50	5.96	8.99	12.0	15.05	18.1	24.2	30.3	36.5	42.6	48.8
1.31	----	----	4.64	6.03	9.09	12.2	15.23	18.3	24.5	30.7	36.9	43.1	49.4
1.32	----	----	4.69	6.10	9.20	12.3	15.42	18.5	24.8	31.1	37.4	43.7	50.0
1.33	----	----	4.75	6.18	9.30	12.4	15.60	18.8	25.1	31.4	37.8	44.2	50.6
1.34	----	----	4.80	6.25	9.41	12.6	15.79	19.0	25.4	31.8	38.3	44.7	51.2
1.35	----	----	4.86	6.32	9.52	12.7	15.97	19.2	25.7	32.2	38.7	45.3	51.8
1.36	----	----	4.92	6.39	9.63	12.9	16.16	19.4	26.0	32.6	39.2	45.8	52.5
1.37	----	----	4.97	6.46	9.74	13.0	16.34	19.6	26.3	33.0	39.7	46.4	53.1
1.38	----	----	5.03	6.53	9.85	13.2	16.53	19.9	26.6	33.3	40.1	46.9	53.7
1.39	----	----	5.08	6.60	9.96	13.3	16.71	20.1	26.9	33.7	40.6	47.4	54.3
1.40	----	----	----	6.68	10.1	13.5	16.90	20.3	27.2	34.1	41.1	48.0	55.0
1.41	----	----	----	6.75	10.2	13.6	17.09	20.6	27.5	34.5	41.5	48.5	55.6
1.42	----	----	----	6.82	10.3	13.8	17.28	20.8	27.8	34.9	42.0	49.1	56.2
1.43	----	----	----	6.89	10.4	13.9	17.47	21.0	28.1	35.3	42.5	49.6	56.9
1.44	----	----	----	6.97	10.5	14.1	17.66	21.2	28.5	35.7	42.9	50.2	57.5
1.45	----	----	----	7.04	10.6	14.2	17.85	21.3	28.8	36.1	43.4	50.8	58.1
1.46	----	----	----	7.12	10.7	14.4	18.04	21.7	29.1	36.5	43.9	51.3	58.8
1.47	----	----	----	7.19	10.8	14.5	18.23	21.9	29.4	36.9	44.4	51.9	59.4
1.48	----	----	----	7.26	11.0	14.7	18.43	22.2	29.7	37.3	44.9	52.4	60.1
1.49	----	----	----	7.34	11.1	14.9	18.62	22.4	30.0	37.7	45.3	53.0	60.7
1.50	----	----	----	7.41	11.2	15.0	18.82	22.6	30.3	38.1	45.8	53.6	61.4
1.51	----	----	----	7.49	11.3	15.2	19.02	22.9	30.7	38.5	46.3	54.2	62.1
1.52	----	----	----	7.57	11.4	15.3	19.22	23.1	31.0	38.9	46.8	54.7	62.7
1.53	----	----	----	7.64	11.5	15.5	19.41	23.4	31.3	39.3	47.3	55.3	63.4
1.54	----	----	----	7.72	11.7	15.6	19.61	23.6	31.6	39.7	47.8	55.9	64.0
1.55	----	----	----	7.80	11.8	15.8	19.81	23.8	32.0	40.1	48.3	56.5	64.7
1.56	----	----	----	7.87	11.9	15.9	20.01	24.1	32.3	40.5	48.8	57.1	65.4
1.57	----	----	----	7.95	12.0	16.1	20.21	24.3	32.6	40.9	49.3	57.7	66.1
1.58	----	----	----	8.02	12.1	16.3	20.41	24.6	32.9	41.4	49.8	58.2	66.7
1.59	----	----	----	8.10	12.2	16.4	20.61	24.8	33.3	41.8	50.3	58.8	67.4
1.60	----	----	----	8.18	12.4	16.6	20.81	25.1	33.6	42.2	50.8	59.4	68.1
1.61	----	----	----	8.26	12.5	16.7	21.01	25.3	33.9	42.6	51.3	60.0	68.8
1.62	----	----	----	8.34	12.6	16.9	21.22	25.5	34.3	43.0	51.8	60.6	69.5
1.63	----	----	----	8.42	12.7	17.1	21.42	25.8	34.6	43.4	52.3	61.2	70.2
1.64	----	----	----	8.49	12.8	17.2	21.63	26.0	34.9	43.9	52.8	61.8	70.9
1.65	----	----	----	8.57	13.0	17.4	21.83	26.3	35.3	44.3	53.3	62.4	71.6
1.66	----	----	----	8.65	13.1	17.6	22.04	26.5	35.6	44.7	53.9	63.0	72.3
1.67	----	----	----	8.73	13.2	17.7	22.24	26.8	35.9	45.1	54.4	63.6	73.0
1.68	----	----	----	8.81	13.3	17.9	22.45	27.0	36.3	45.6	54.9	64.3	73.7
1.69	----	----	----	8.89	13.5	18.0	22.66	27.3	36.6	46.0	55.4	64.9	74.4

Table 3. (Continued)

Upper head Ha	Throat Width												
	3 inches	6 inches	9 inches	12 inches	18 inches	24 inches	30 inches	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
Feet	Flow in cubic feet per second												
1.70	----	----	----	8.97	13.6	18.2	22.87	27.6	37.0	46.4	56.0	65.5	75.1
1.71	----	----	----	9.05	13.7	18.4	23.08	27.8	37.3	46.9	56.5	66.1	75.8
1.72	----	----	----	9.13	13.8	18.5	23.29	28.1	37.7	47.3	57.0	66.7	76.5
1.73	----	----	----	9.21	13.9	18.7	23.50	28.3	38.0	47.7	57.5	67.3	77.2
1.74	----	----	----	9.29	14.1	18.9	23.72	28.6	38.3	48.2	58.1	68.0	77.9
1.75	----	----	----	9.38	14.2	19.0	23.93	28.8	38.7	48.6	58.6	68.6	78.7
1.76	----	----	----	9.46	14.3	19.2	24.15	29.1	39.0	49.1	59.1	69.2	79.4
1.77	----	----	----	9.54	14.4	19.4	24.36	29.3	39.4	49.5	59.7	69.9	80.1
1.78	----	----	----	9.62	14.6	19.6	24.58	29.6	39.7	49.9	60.2	70.5	80.8
1.79	----	----	----	9.70	14.7	19.7	24.79	29.9	40.1	50.4	60.7	71.1	81.6
1.80	----	----	----	9.79	14.8	19.9	25.01	30.1	40.5	50.8	61.3	71.8	82.3
1.81	----	----	----	9.87	15.0	20.1	25.23	30.4	40.8	51.3	61.8	72.4	83.0
1.82	----	----	----	9.95	15.1	20.2	25.45	30.7	41.2	51.7	62.4	73.0	83.8
1.83	----	----	----	10.0	15.2	20.4	25.66	30.9	41.5	52.2	62.9	73.7	84.5
1.84	----	----	----	10.1	15.3	20.6	25.88	31.2	41.9	52.6	63.5	74.3	85.3
1.85	----	----	----	10.2	15.5	20.8	26.10	31.5	42.2	53.1	64.0	75.0	86.0
1.86	----	----	----	10.3	15.6	20.9	26.32	31.7	42.6	53.6	64.6	75.6	86.8
1.87	----	----	----	10.4	15.7	21.1	26.54	32.0	43.0	54.0	65.1	76.3	87.5
1.88	----	----	----	10.5	15.8	21.3	26.76	32.3	43.3	54.5	65.7	76.9	88.3
1.89	----	----	----	10.5	16.0	21.5	26.98	32.5	43.7	54.9	66.3	77.6	89.0
1.90	----	----	----	10.6	16.1	21.6	27.20	32.8	44.1	55.4	66.8	78.2	89.8
1.91	----	----	----	10.7	16.2	21.8	27.44	33.1	44.4	55.9	67.4	78.9	90.5
1.92	----	----	----	10.8	16.4	22.0	27.65	33.3	44.8	56.3	67.9	79.6	91.3
1.93	----	----	----	10.9	16.5	22.2	27.87	33.6	45.2	56.8	68.5	80.2	92.1
1.94	----	----	----	11.0	16.6	22.4	28.10	33.9	45.5	57.3	69.1	80.9	92.8
1.95	----	----	----	11.1	16.7	22.5	28.32	34.1	45.9	57.7	69.6	81.6	93.6
1.96	----	----	----	11.1	16.9	22.7	28.55	34.4	46.3	58.2	70.2	82.2	94.4
1.97	----	----	----	11.2	17.0	22.9	28.77	34.7	46.6	58.7	70.8	82.9	95.1
1.98	----	----	----	11.3	17.2	23.1	29.00	35.0	47.0	59.1	71.4	83.6	95.9
1.99	----	----	----	11.4	17.3	23.2	29.23	35.3	47.4	59.6	71.9	84.3	96.7
2.00	----	----	----	11.5	17.4	23.4	29.46	35.5	47.8	60.1	72.5	84.9	97.5
2.01	----	----	----	11.6	17.6	23.6	29.69	35.8	48.1	60.6	73.1	85.6	98.3
2.02	----	----	----	11.7	17.7	23.8	29.92	36.1	48.5	61.0	73.7	86.3	99.1
2.03	----	----	----	11.8	17.8	24.0	30.15	36.4	48.9	61.5	74.2	87.0	99.8
2.04	----	----	----	11.8	18.0	24.2	30.39	36.7	49.3	62.0	74.8	87.7	100.6
2.05	----	----	----	11.9	18.1	24.3	30.62	36.9	49.7	62.5	75.4	88.4	101.4
2.06	----	----	----	12.0	18.2	24.5	30.85	37.2	50.1	63.0	76.0	89.1	102.2
2.07	----	----	----	12.1	18.4	24.7	31.08	37.5	50.4	63.5	76.6	89.8	103.0
2.08	----	----	----	12.2	18.5	24.9	31.32	37.8	50.8	63.9	77.2	90.4	103.8
2.09	----	----	----	12.3	18.7	25.1	31.55	38.1	51.2	64.4	77.8	91.1	104.6

Table 3. (Continued)

Upper head Ha	Throat Width												
	3 inches	6 inches	9 inches	12 inches	18 inches	24 inches	30 inches	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
Feet	Flow in cubic feet per second												
2.10	----	----	----	12.4	18.8	25.3	31.79	38.4	51.6	64.9	78.4	91.8	105.4
2.11	----	----	----	12.5	18.9	25.5	32.03	38.6	52.0	65.4	79.0	92.5	106.2
2.12	----	----	----	12.6	19.0	25.6	32.27	38.9	52.4	65.9	79.6	93.3	107.0
2.13	----	----	----	12.6	19.2	25.8	32.50	39.2	52.8	66.4	80.2	94.0	107.9
2.14	----	----	----	12.7	19.3	26.0	32.74	39.5	53.2	66.9	80.8	94.7	108.7
2.15	----	----	----	12.8	19.5	26.2	32.98	39.8	53.5	67.4	81.4	95.4	109.5
2.16	----	----	----	12.9	19.6	26.4	33.22	40.1	53.9	67.9	82.0	96.1	110.3
2.17	----	----	----	13.0	19.7	26.6	33.46	40.4	54.3	68.4	82.6	96.8	111.1
2.18	----	----	----	13.1	19.9	26.8	33.71	40.7	54.7	68.9	83.2	97.5	111.9
2.19	----	----	----	13.2	20.0	27.0	33.95	41.0	55.1	69.4	83.8	98.2	112.8
2.20	----	----	----	13.3	20.2	27.2	34.19	41.3	55.5	69.9	84.4	98.9	113.6
2.21	----	----	----	13.4	20.3	27.3	34.43	41.5	55.9	70.4	85.0	99.7	114.4
2.22	----	----	----	13.5	20.5	27.5	34.68	41.8	56.3	70.9	85.6	100.0	115.3
2.23	----	----	----	13.6	20.6	27.7	34.92	42.1	56.7	71.4	86.3	101.1	116.1
2.24	----	----	----	13.7	20.7	27.9	35.17	42.4	57.1	71.9	86.9	101.8	116.9
2.25	----	----	----	13.7	20.9	28.1	35.41	42.7	57.5	72.4	87.5	102.6	117.8
2.26	----	----	----	13.8	21.0	28.3	35.66	43.0	57.9	72.9	88.1	103.3	118.6
2.27	----	----	----	13.9	21.2	28.5	35.90	43.3	58.3	73.5	88.7	104.0	119.5
2.28	----	----	----	14.0	21.3	28.7	36.15	43.6	58.7	74.0	89.4	104.8	120.3
2.29	----	----	----	14.1	21.4	28.9	36.39	43.9	59.2	74.5	90.0	105.5	121.2
2.30	----	----	----	14.2	21.6	29.1	36.64	44.2	59.6	75.0	90.6	106.2	122.0
2.31	----	----	----	14.3	21.7	29.3	36.89	44.5	60.0	75.5	91.2	107.0	122.9
2.32	----	----	----	14.4	21.9	29.5	37.14	44.8	60.4	76.0	91.9	107.7	123.7
2.33	----	----	----	14.5	22.0	29.7	37.39	45.1	60.8	76.6	92.5	108.5	124.6
2.34	----	----	----	14.6	22.2	29.9	37.64	45.4	61.2	77.1	93.1	109.2	125.4
2.35	----	----	----	14.7	22.4	30.1	37.89	45.7	61.6	77.6	93.8	110.0	126.3
2.36	----	----	----	14.8	22.5	30.3	38.14	46.0	62.0	78.1	94.4	110.7	127.2
2.37	----	----	----	14.9	22.6	30.5	38.39	46.4	62.4	78.7	95.1	111.5	128.0
2.38	----	----	----	15.0	22.8	30.7	38.65	46.7	62.9	79.2	95.7	112.2	128.9
2.39	----	----	----	15.1	22.9	30.9	38.90	47.0	63.3	79.7	96.3	113.0	129.8
2.40	----	----	----	15.2	23.0	31.1	39.15	47.3	63.7	80.3	97.0	113.7	130.7
2.41	----	----	----	15.3	23.2	31.3	39.40	47.6	64.1	80.8	97.6	114.5	131.5
2.42	----	----	----	15.4	23.3	31.5	39.66	47.9	64.5	81.3	98.3	115.3	132.4
2.43	----	----	----	15.5	23.5	31.7	39.91	48.2	65.0	81.8	98.9	116.0	133.3
2.44	----	----	----	15.6	23.7	31.9	40.17	48.5	65.4	82.4	99.6	116.8	134.2
2.45	----	----	----	15.6	23.8	32.1	40.43	48.8	65.8	82.9	100.2	117.6	135.1
2.46	----	----	----	15.7	23.9	32.3	40.69	49.1	66.2	83.5	100.9	118.3	135.9
2.47	----	----	----	15.9	24.1	32.5	40.94	49.5	66.7	84.0	101.5	119.1	136.8
2.48	----	----	----	15.9	24.2	32.7	41.20	49.8	67.1	84.5	102.2	119.9	137.7
2.49	----	----	----	16.0	24.4	32.9	41.46	50.1	67.5	85.1	102.8	120.6	138.6
2.50	----	----	----	16.1	24.6	33.1	41.72	50.4	67.9	85.6	103.5	121.4	139.5

Figure 4. Nomograph for obtaining the change in water surface elevation, $H_a - H_b$.

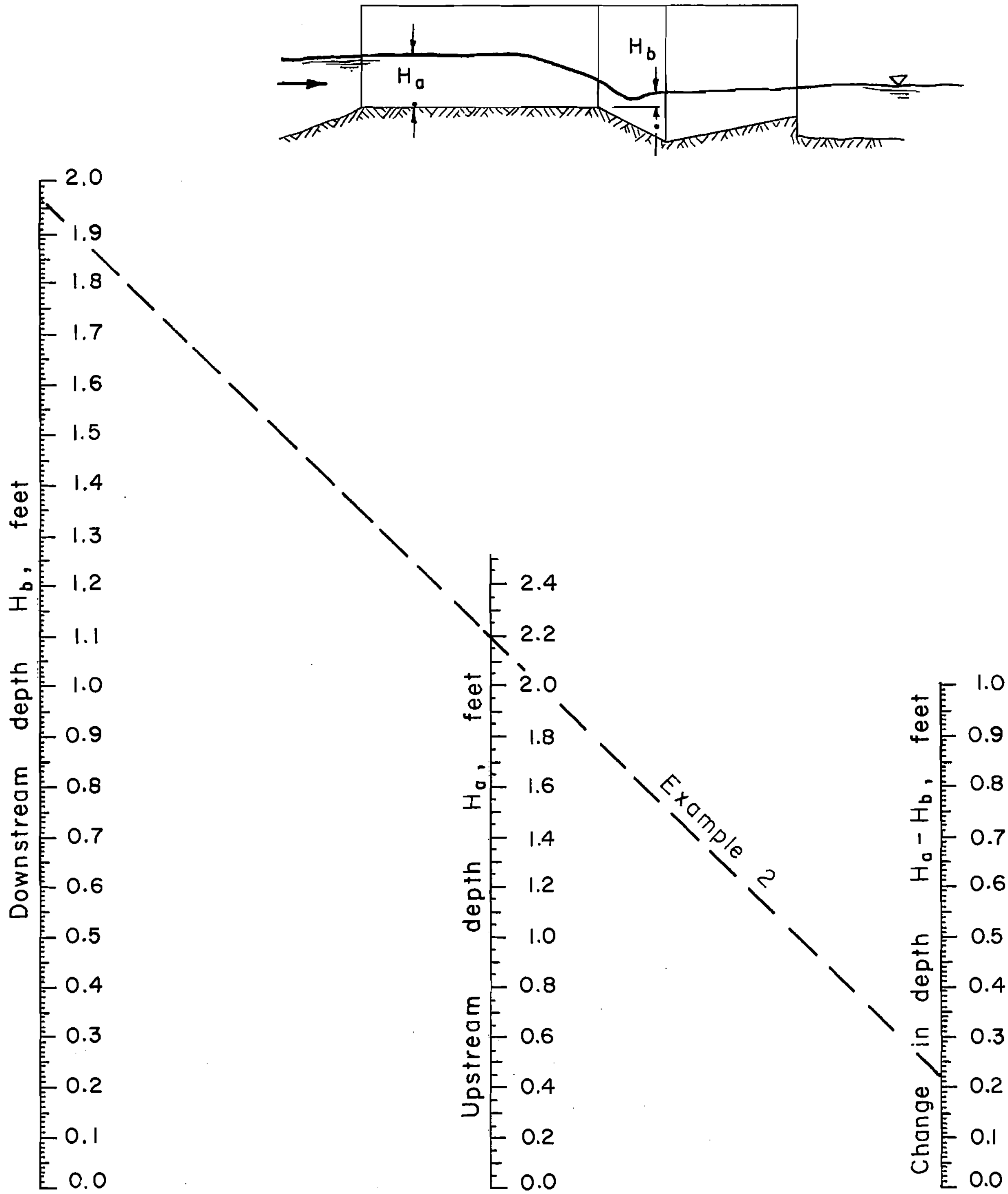


Figure 5. Nomograph for obtaining submergence, H_b/H_a.

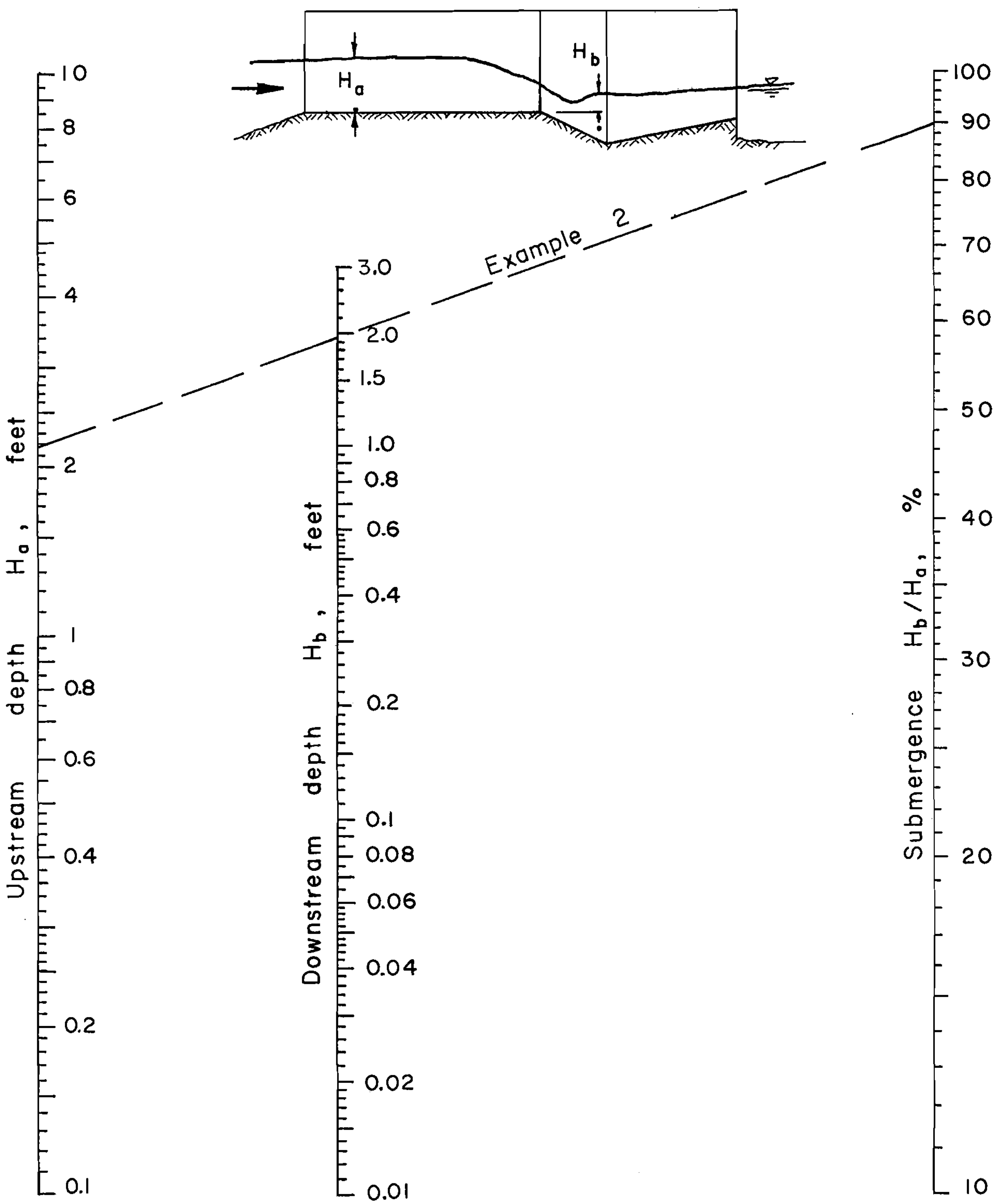


Figure 6. Submerged flow calibration curves for 3-inch Parshall flume.

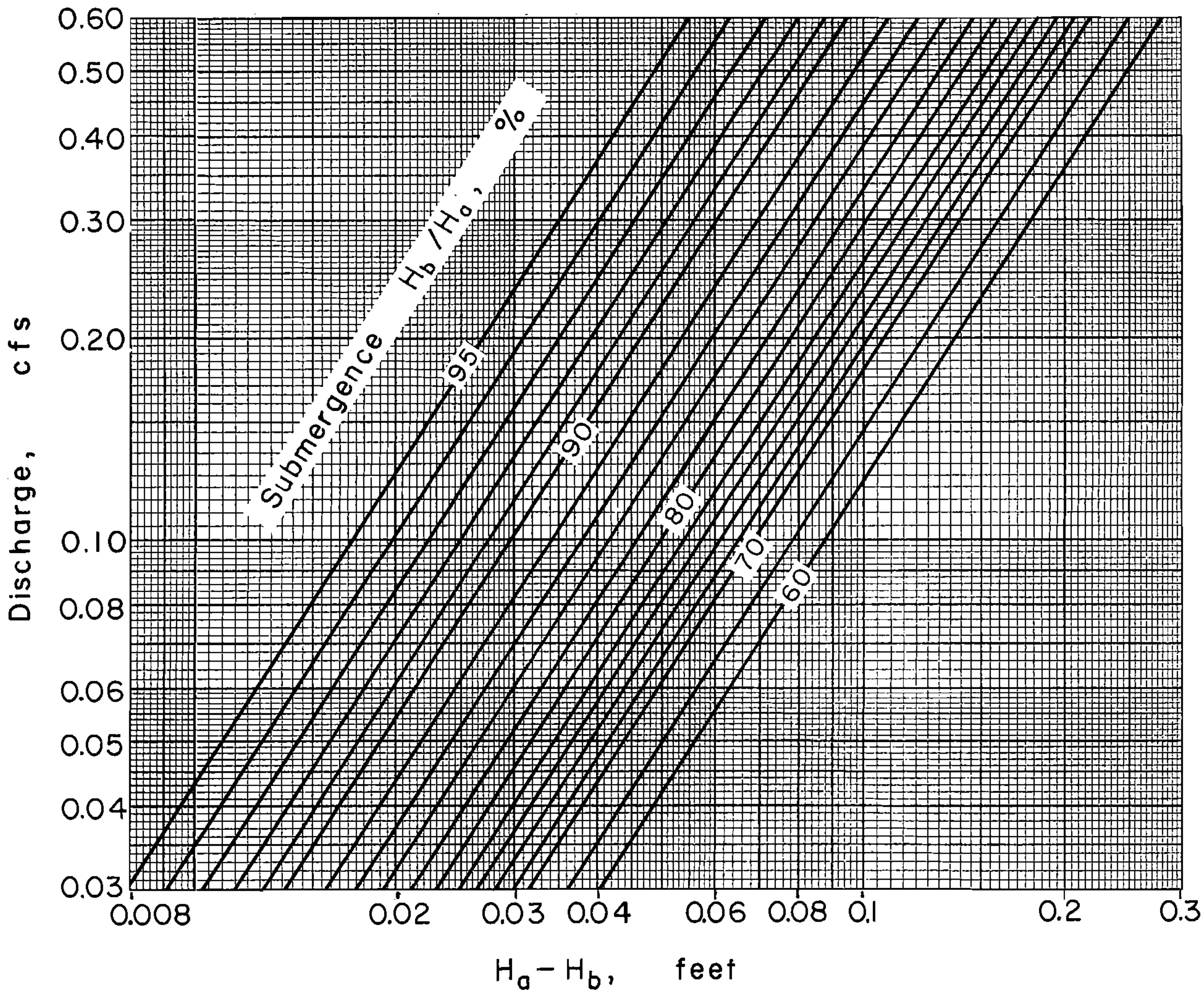


Figure 7. Submerged flow calibration curves for 6-inch Parshall flume.

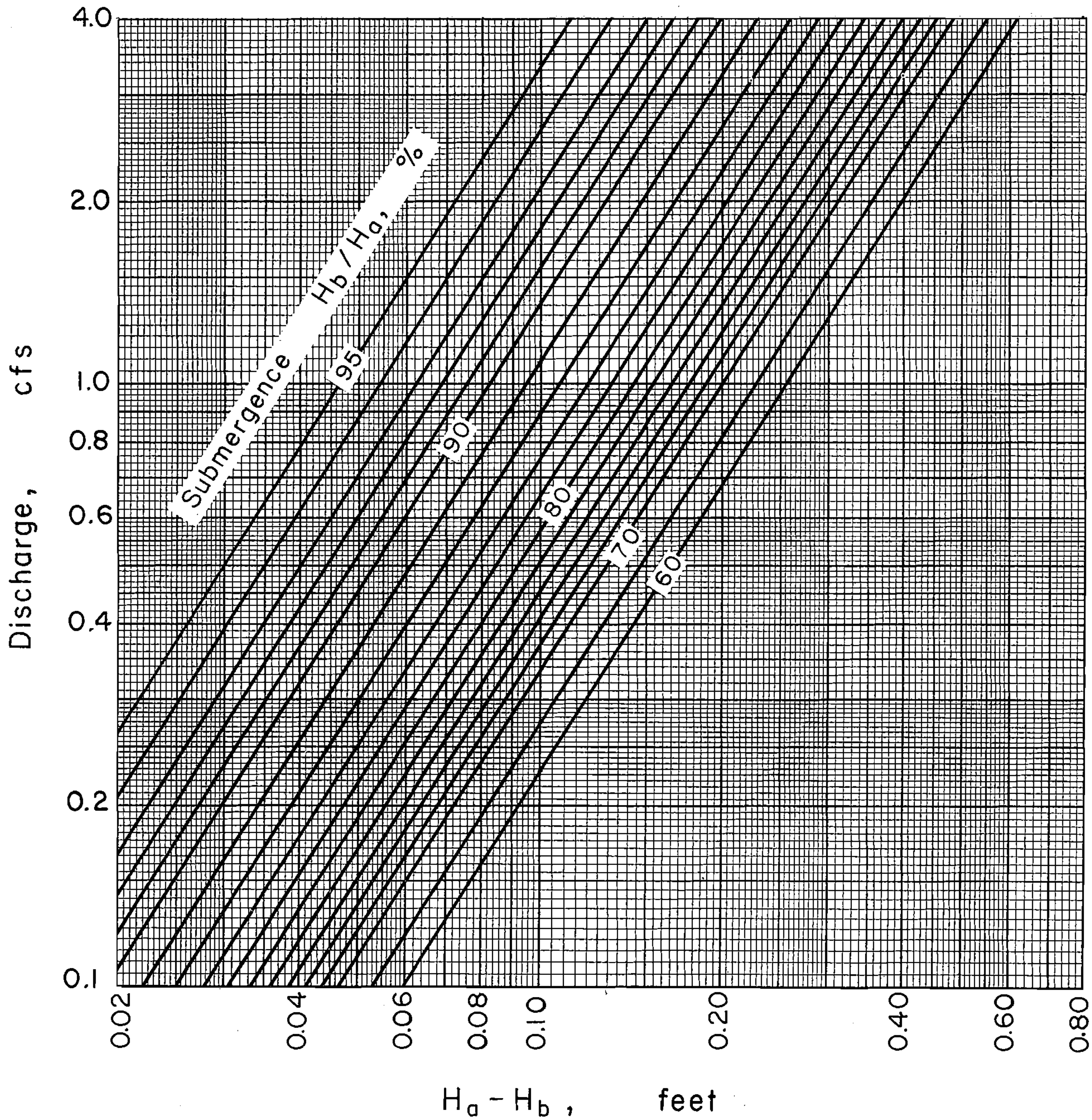


Figure 8. Submerged flow calibration curves for 9-inch Parshall flume.

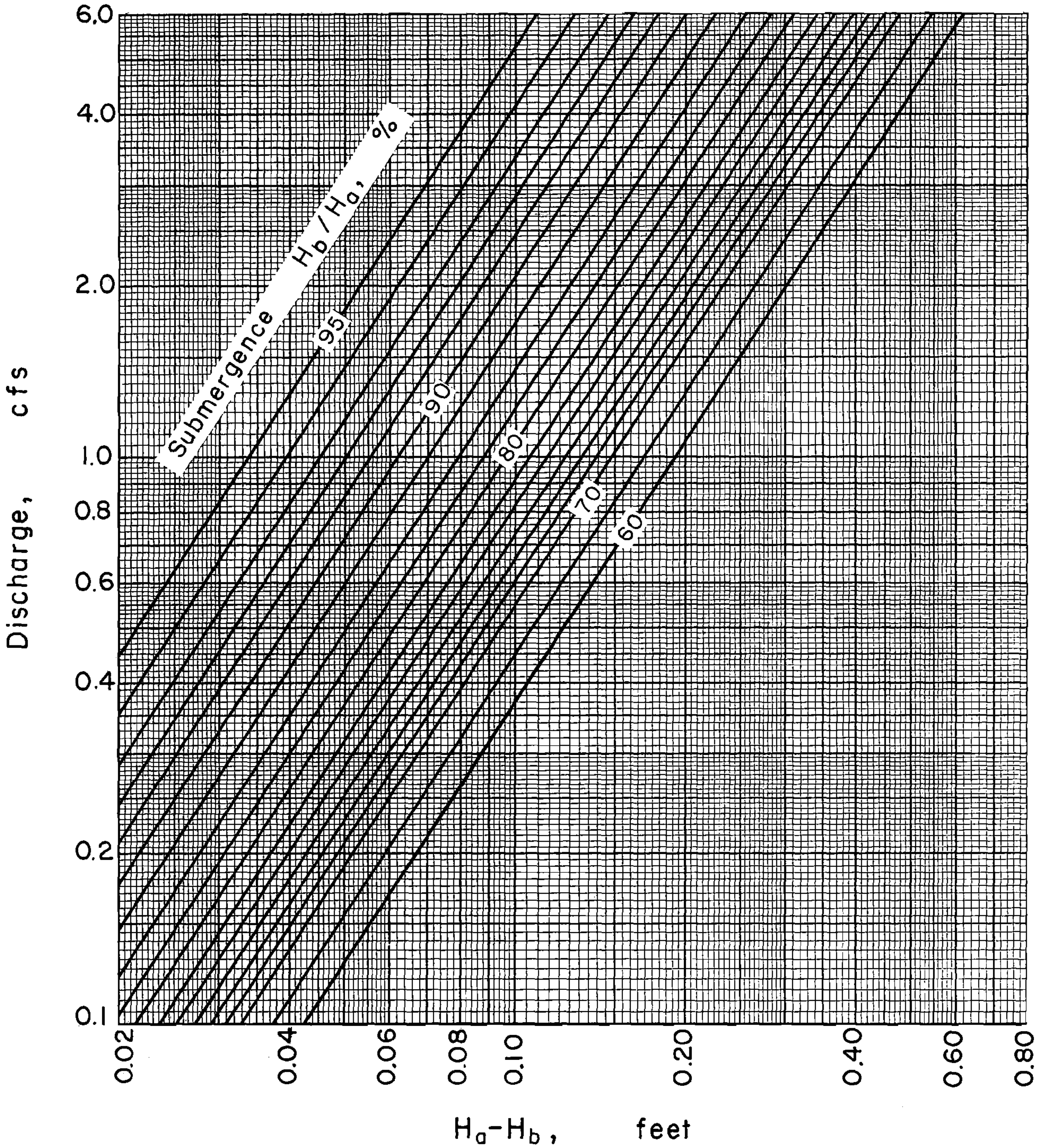


Figure 9. Submerged flow calibration curves for 12-inch Parshall flume.

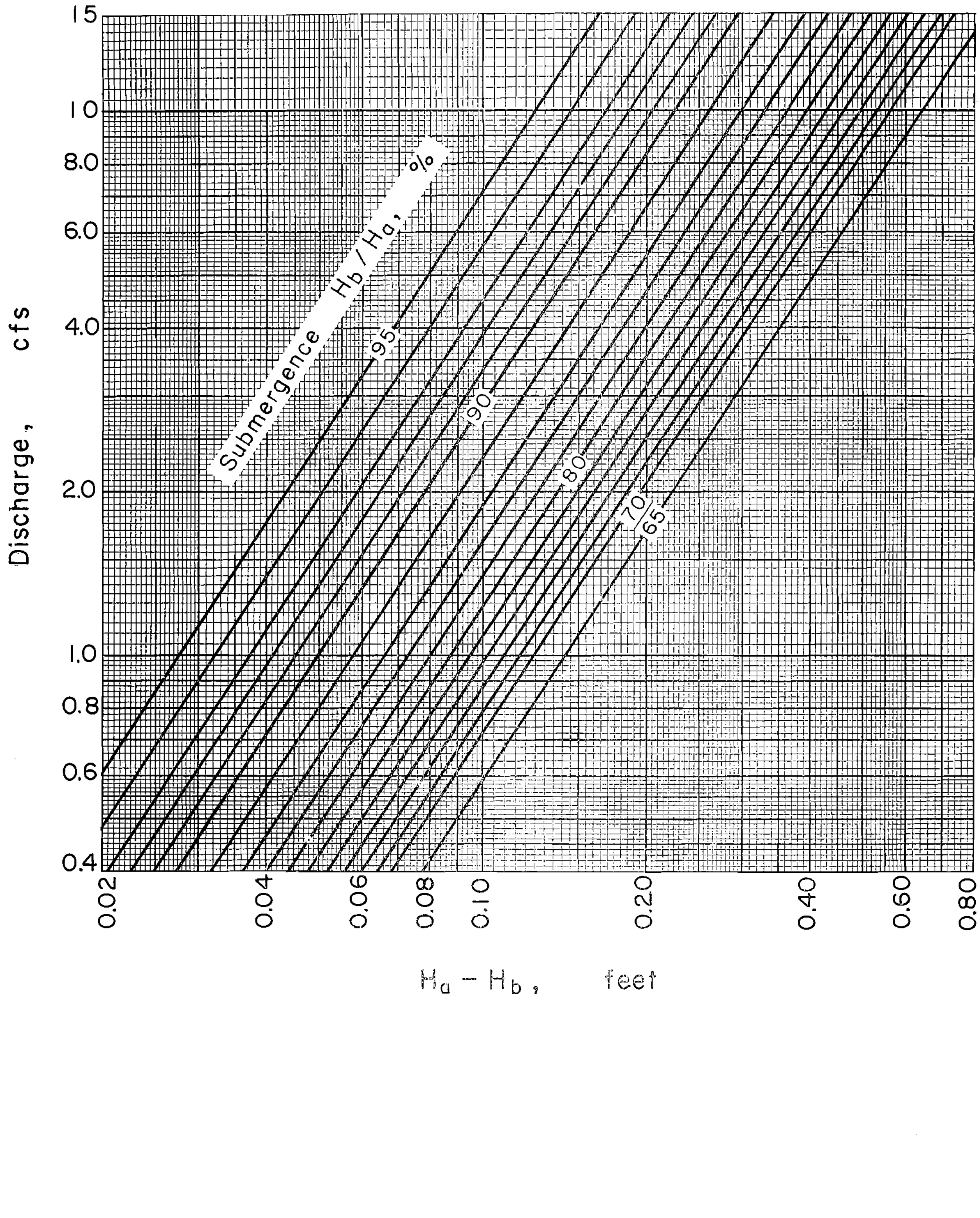


Figure 10. Submerged flow calibration curves for 18-inch Parshall flume.

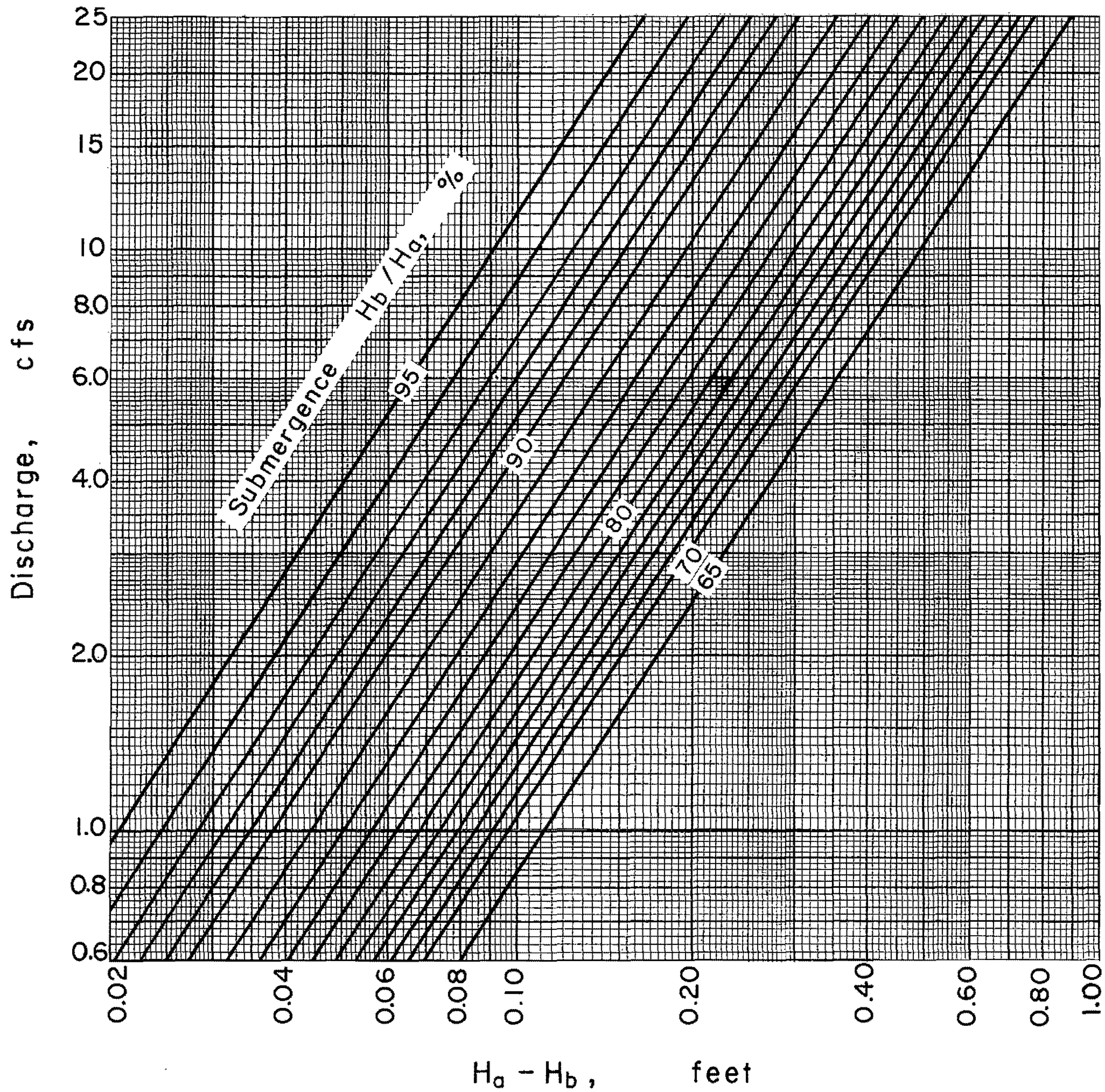


Figure 11. Submerged flow calibration curves for 24-inch Parshall flume.

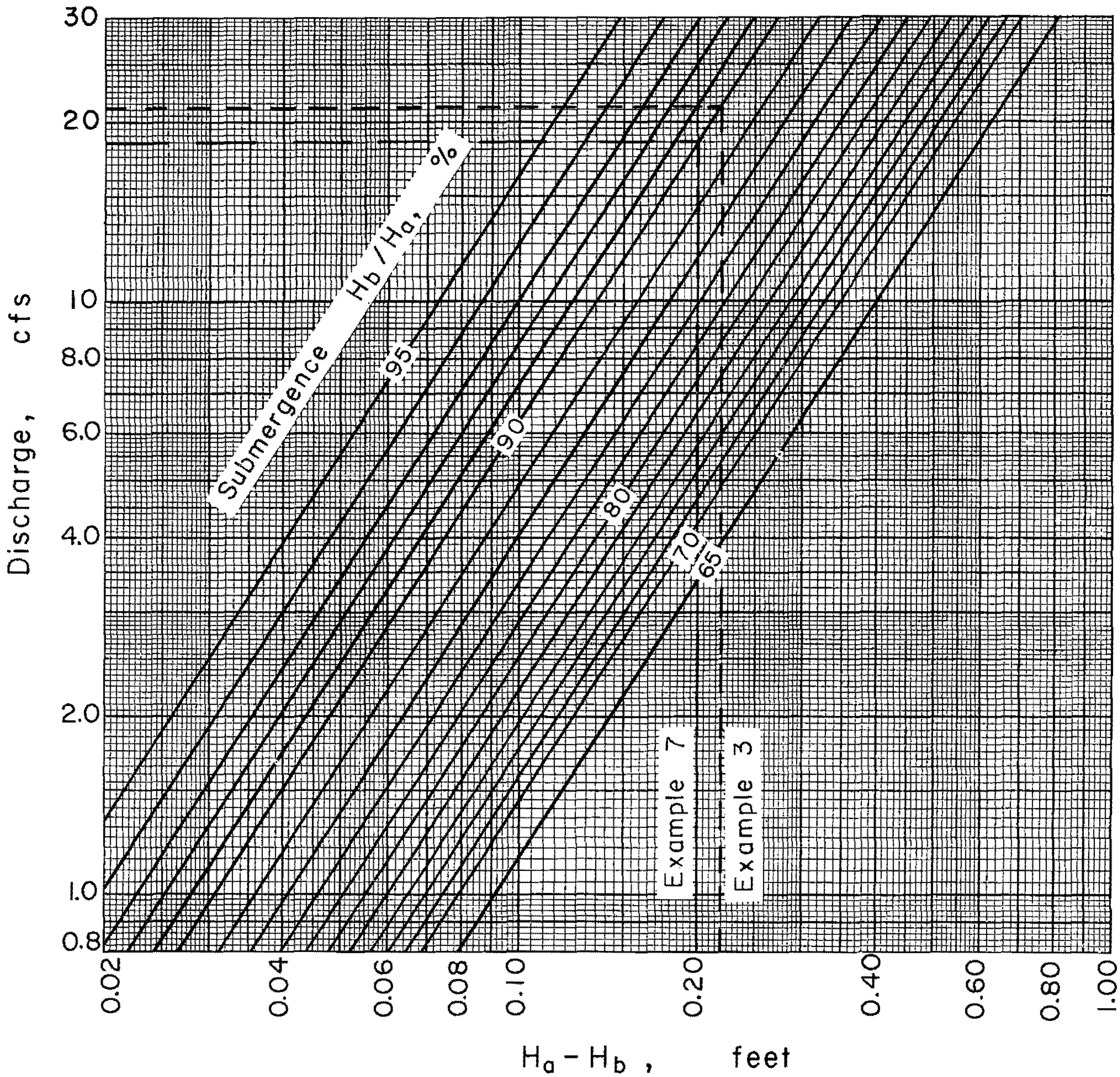


Figure 12. Submerged flow calibration curves for 30-inch Parshall flume.

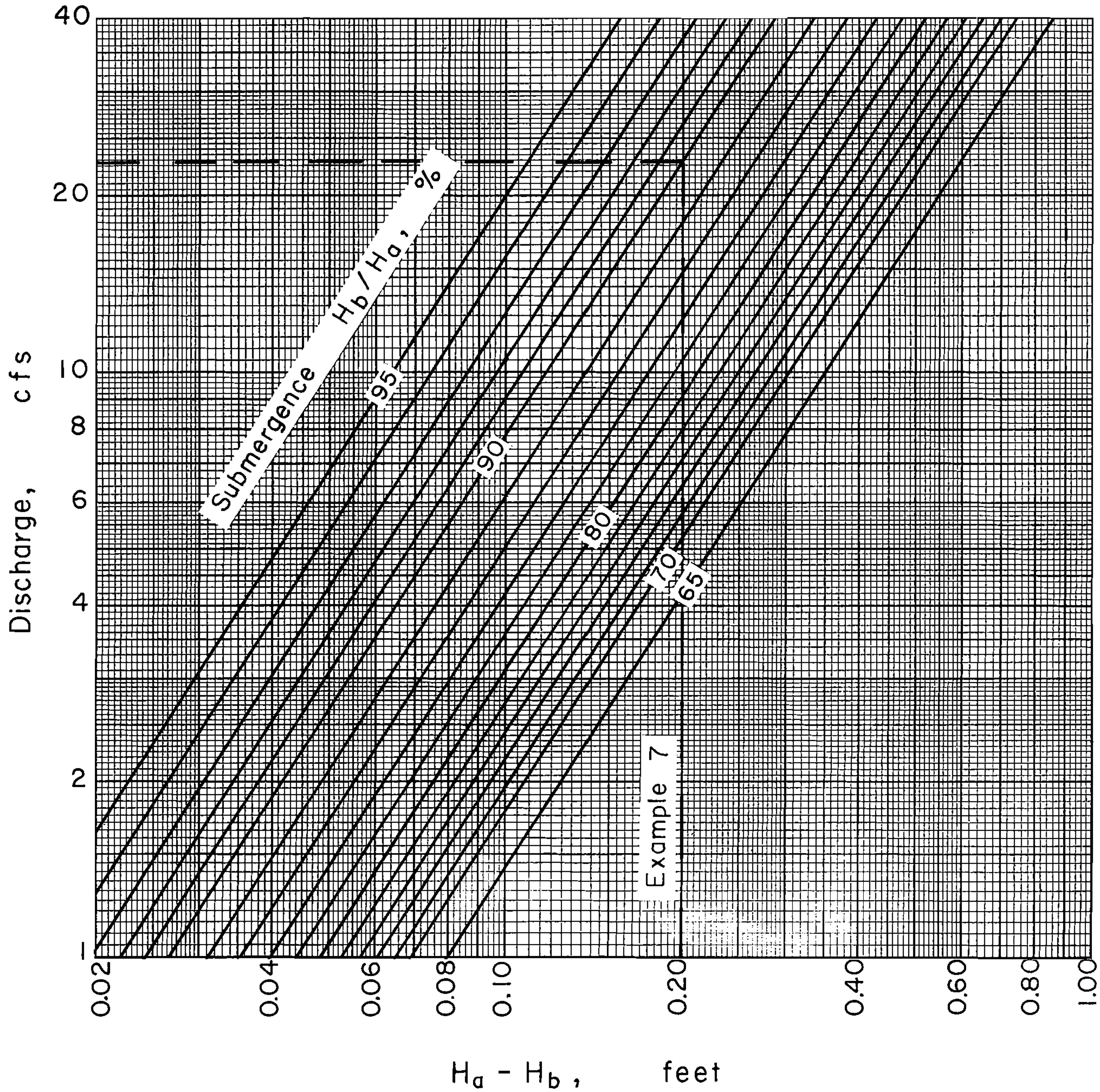


Figure 13. Submerged flow calibration curves for 3-foot Parshall flume.

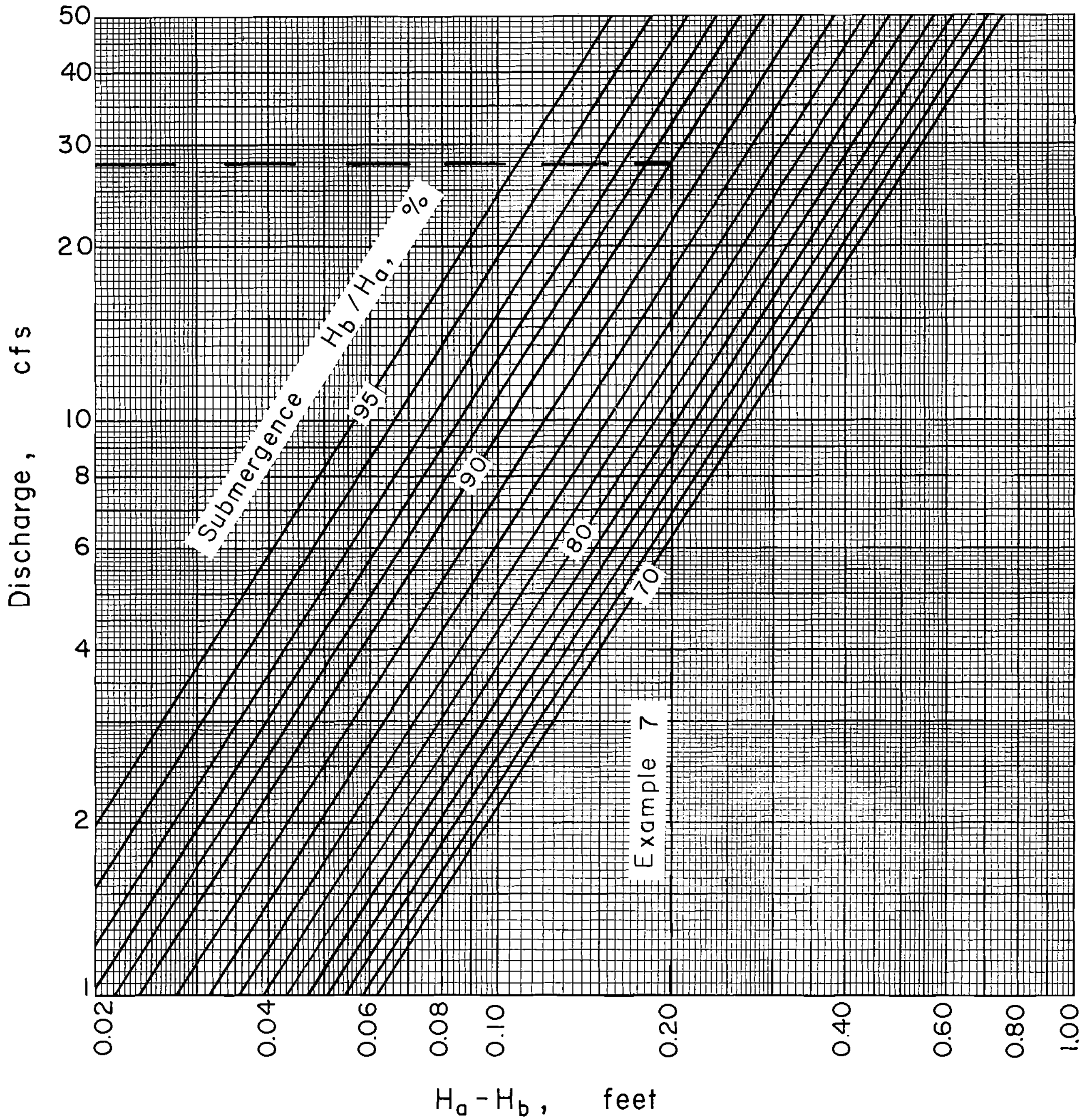


Figure 14. Submerged flow calibration curves for 4-foot Parshall flume.

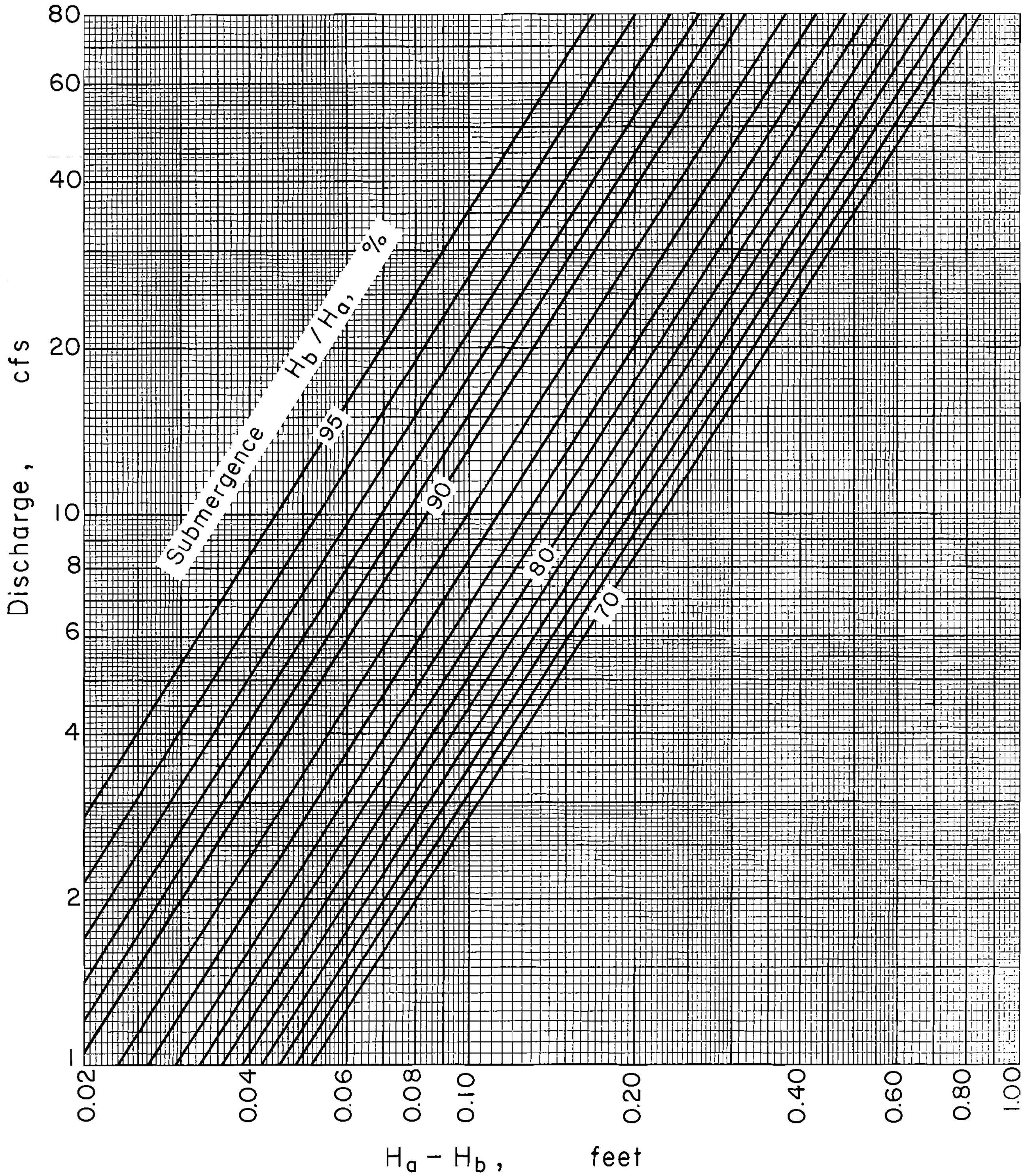


Figure 15. Submerged flow calibration curves for 5-foot Parshall flume.

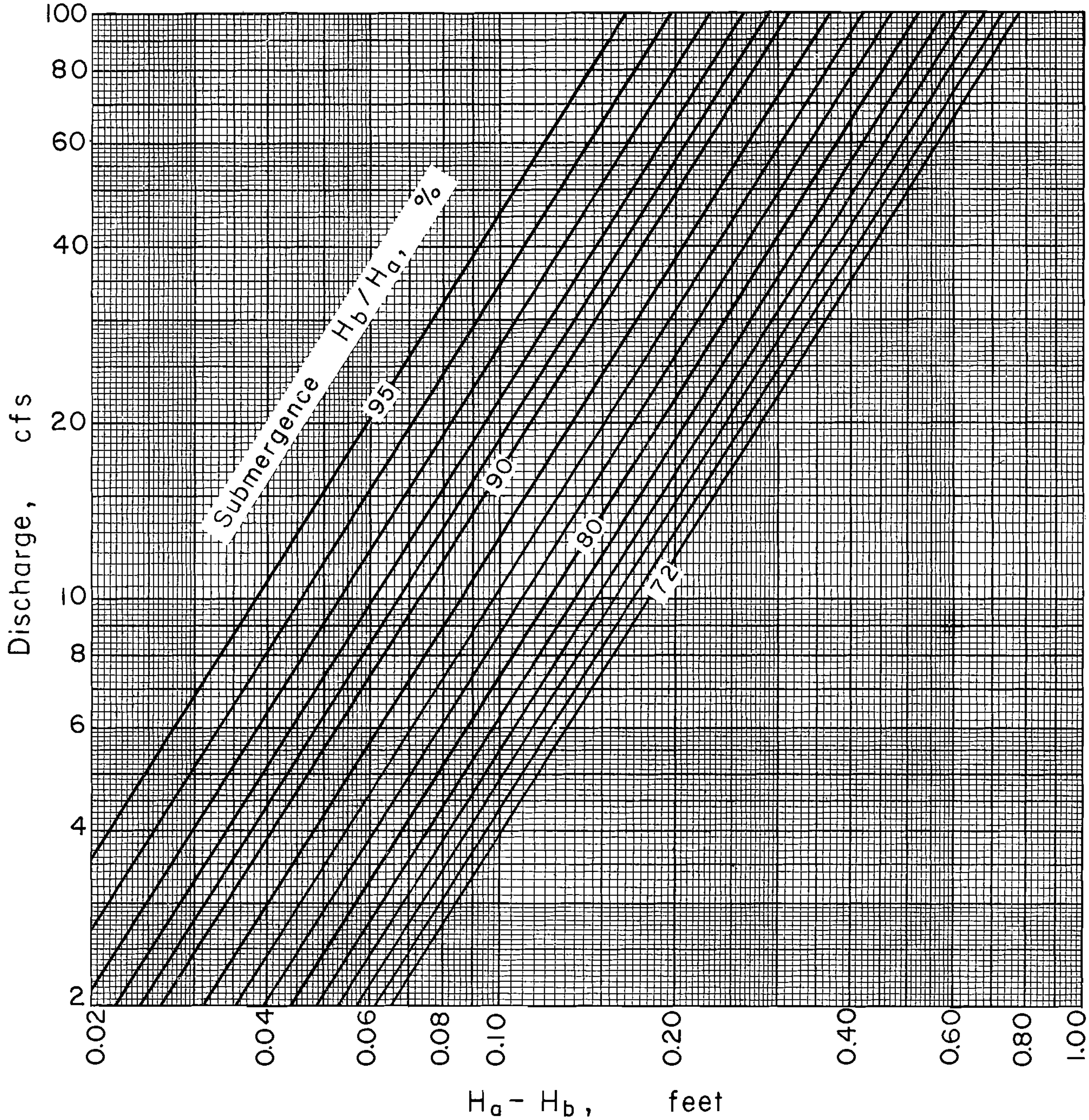


Figure 16. Submerged flow calibration curves for 6-foot Parshall flume.

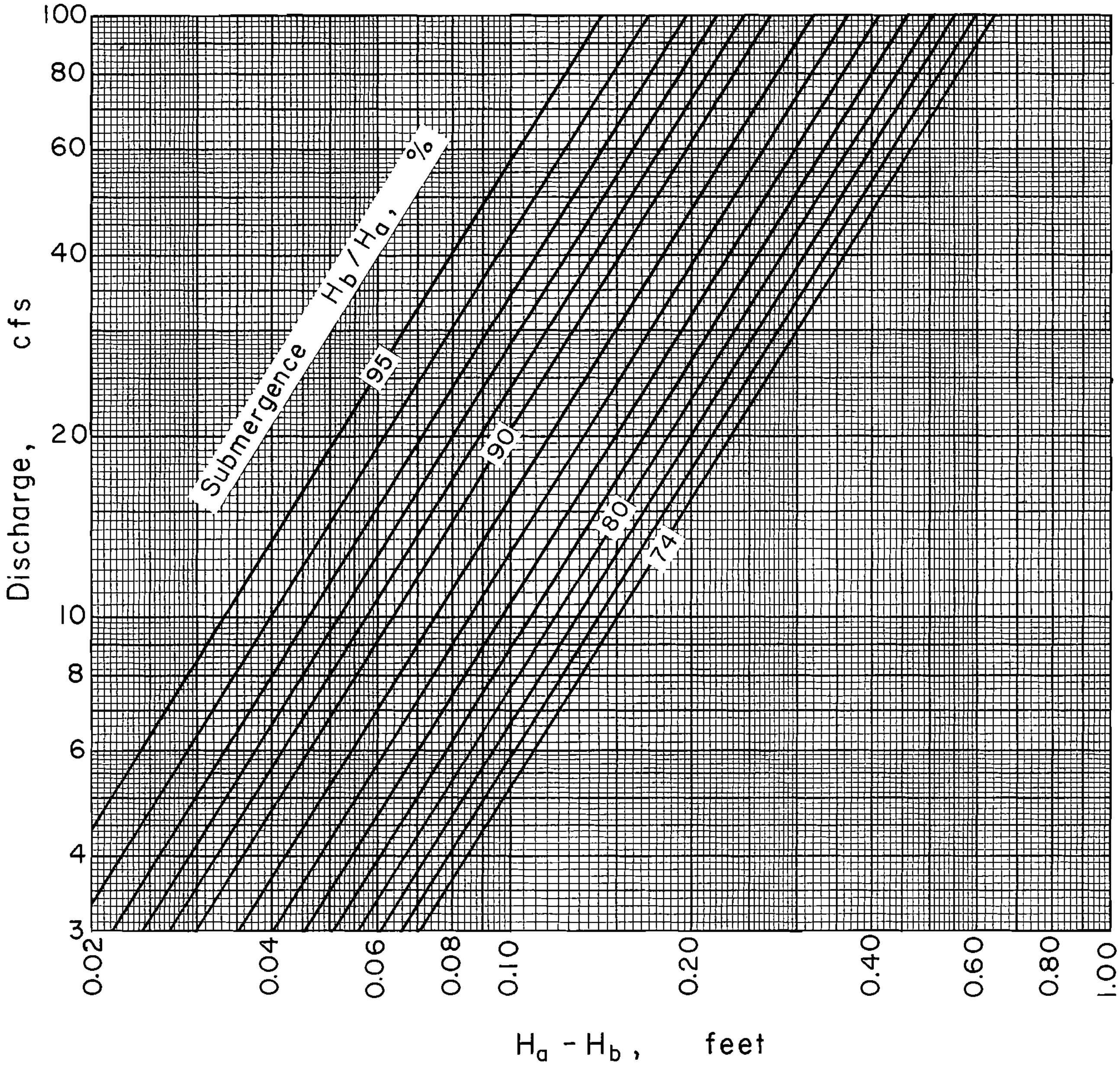


Figure 17. Submerged flow calibration curves for 7-foot Parshall flume.

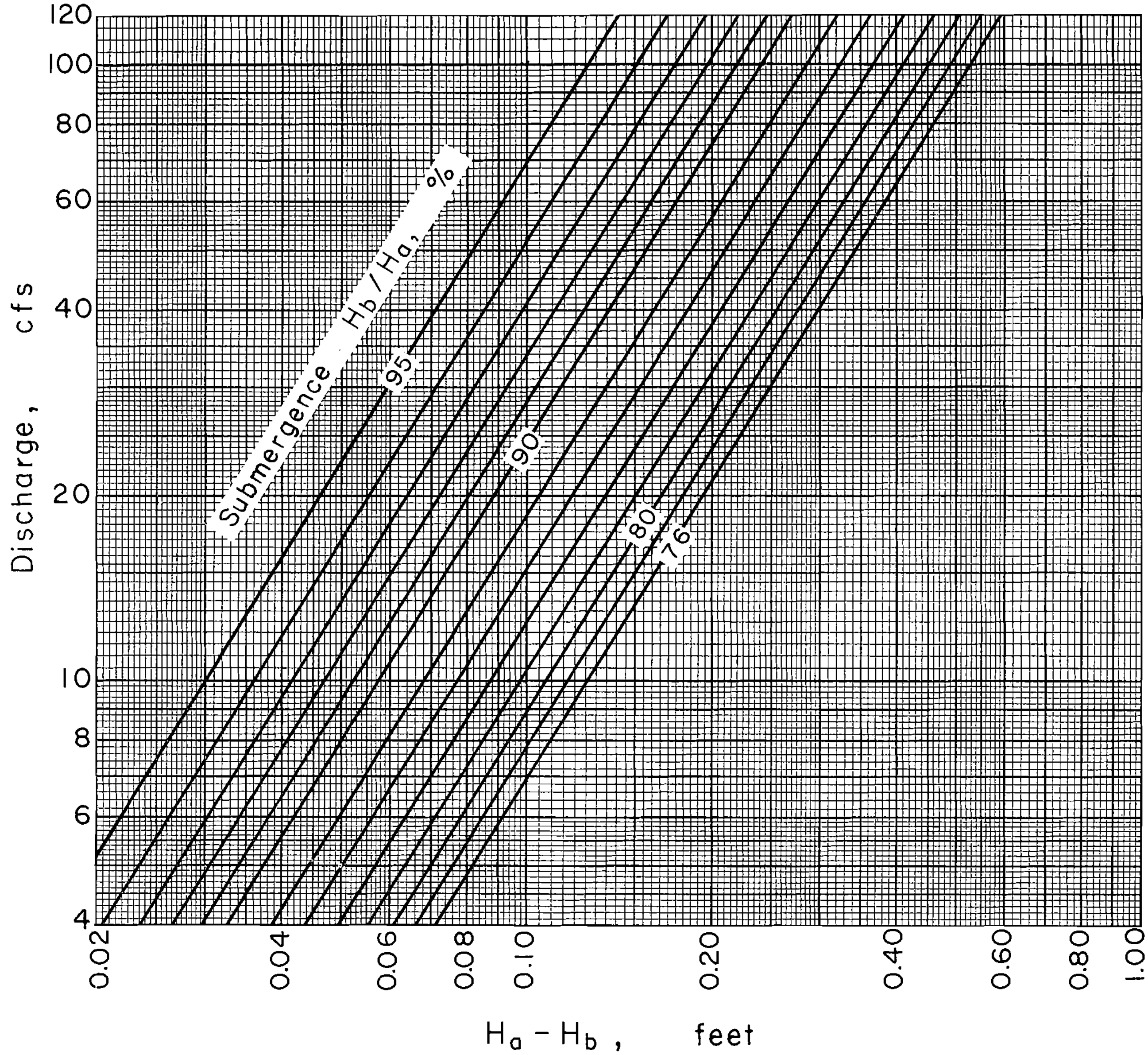
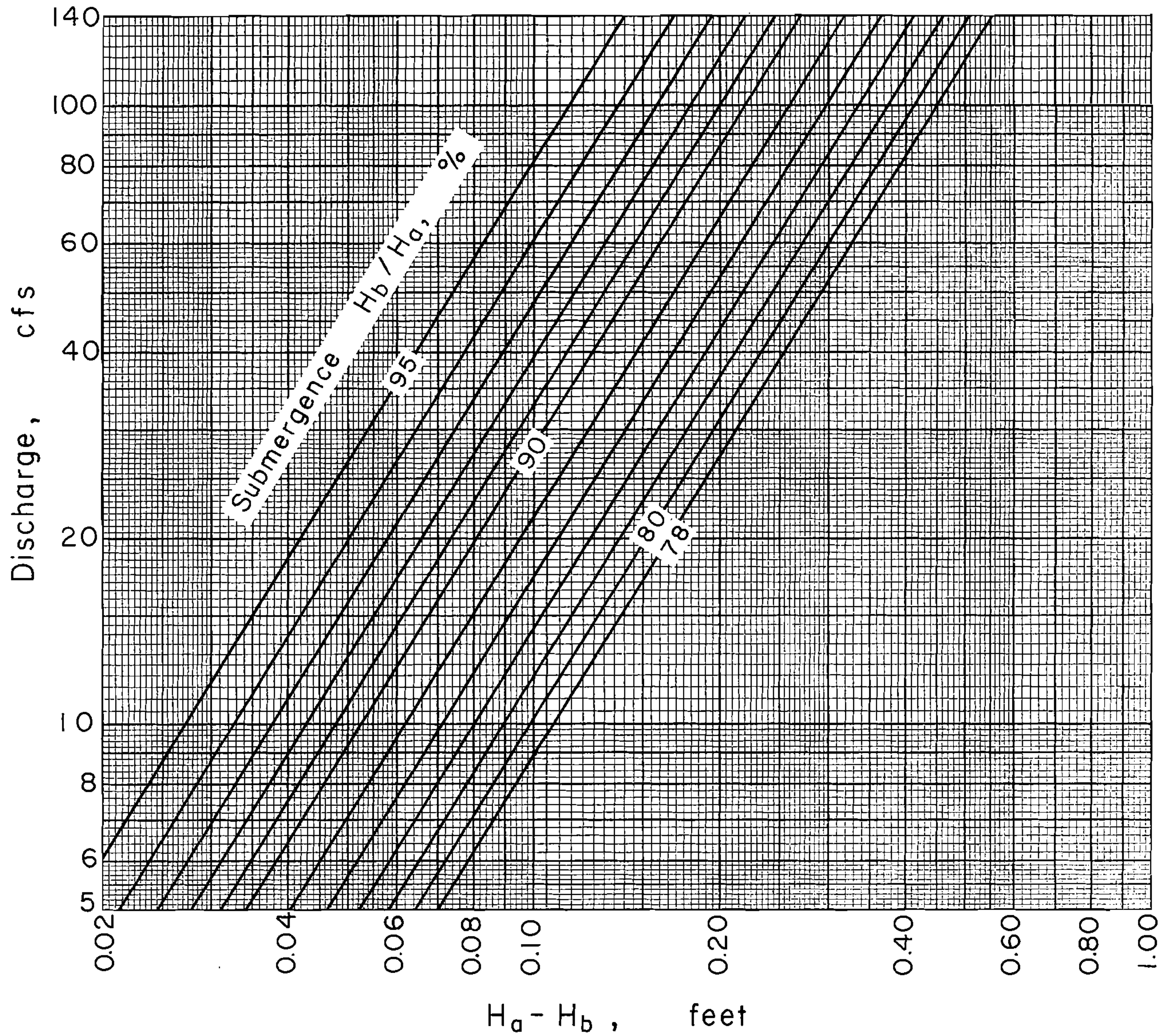


Figure 18. Submerged flow calibration curves for 8-foot Parshall flume.



INSTALLATION OF PARSHALL FLUMES

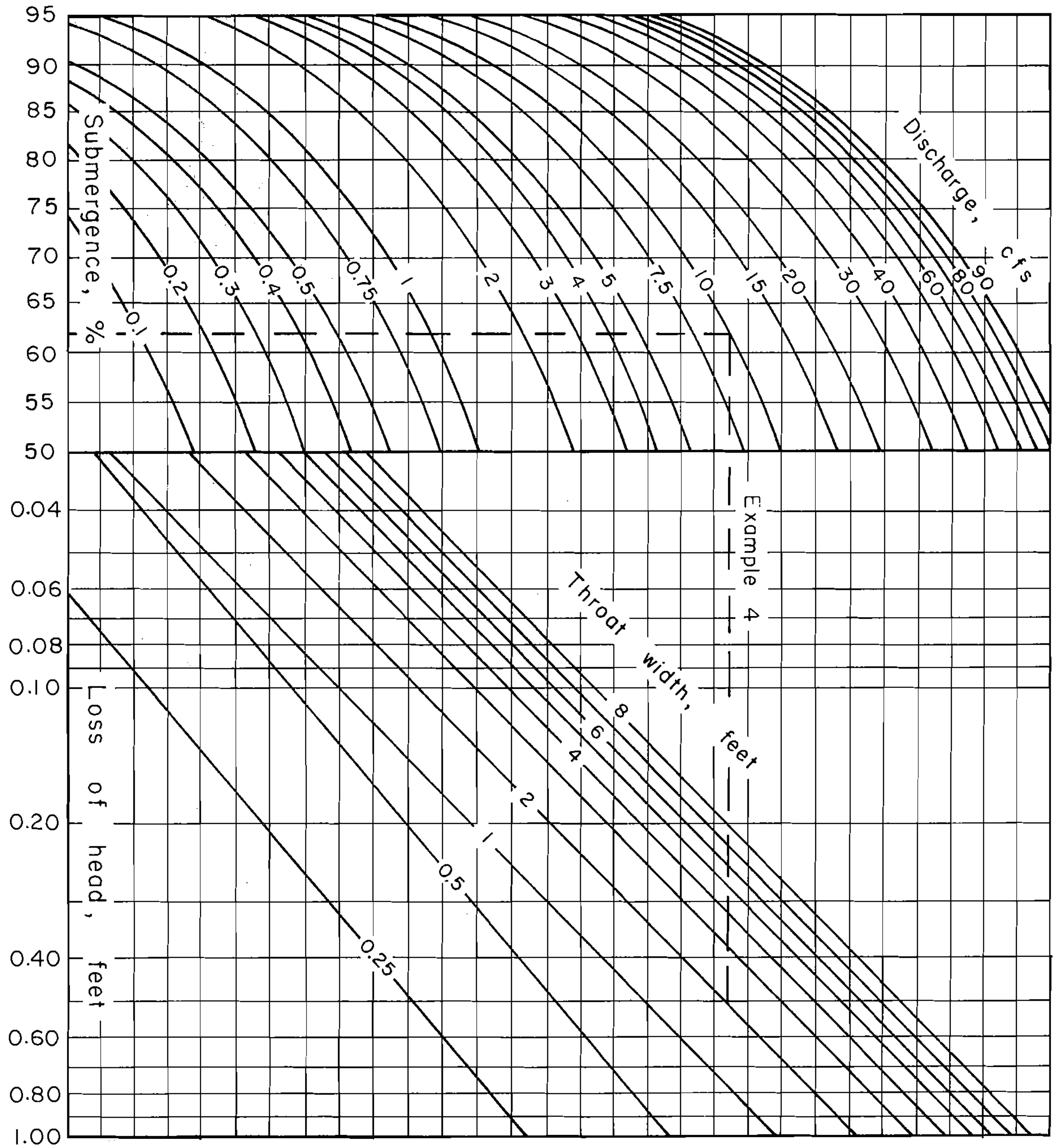
The Parshall flume, like any other water-measuring structure, must be properly installed to give best results.

First, consideration should be given to the location or site of the structure. The flume should be located in a straight section of channel and, for convenience, near a point of diversion or a regulating gate if operating conditions require frequent changing of the discharge. However, the flume should not be placed too near a gate because of unbalanced flow or surging effects which result from gate operation.

After selecting the site for the Parshall flume, it is necessary to determine the maximum quantity of water to be measured, the maximum depth of flow corresponding to this quantity of water, and the amount of head loss which can be allowed through the flume. For practical purposes, the head loss is the change in water surface elevation between the entrance (inlet) and exit (outlet) of the flume. After installation of a Parshall flume, the depths of flow downstream remain essentially the same as prior to installation, whereas the flow depths upstream from the flume are increased by the same amount as the head loss. The change in flow depths in a canal after installation of a Parshall flume is illustrated in Figure 20. The amount of head loss that can be allowed through a flume is often limited by the height of the canal banks upstream from the flume. The diagram shown in Figure 19 has been prepared to assist you in the selection of the proper size of flume. Use of this diagram may best be·illustrated by an example:

> Example 4. Let's assume we need to find the smallest size flume necessary to measure a maximum discharge of 10 second feet with a corresponding maximum flow depth of 0.8 feet and a head loss not exceeding 0.5 feet. Thus, after installation, the maximum downstream flow depth would be 0.8 feet and the maximum upstream flow depth 1.3 feet (0.8 = 0.5 = 1.3). The maximum submergence would be 62 percent (0.8/1.3 = 0.62). Enter Figure 19 at the lower left and follow vertically on the 62 percent submergence line until the curved discharge

Figure 19. Head loss through Parshall flumes.



line of 10 cfs is reached. At this point move horizontally to the right until the vertical line representing 0.50 feet of head loss is intersected. Note that this point is very near the diagonal line marked 2-foot throat width. Thus, a 2-foot Parshall flume would be used.

In some circumstances, several flume sizes may be considered for measurement of the water, but the selection is usually based on economic factors. Normally, the throat width of the flume will be from one-third to one-half the width of the channel.

The Parshall flume may be constructed of almost any material depending on the intended use and desired durability. The most commonly used materials are timber, steel, and concrete. When timber is used, it is important to allow for swelling (1/8-inch space between planks is advisable) and some effort must be made to preserve the timber. If greater permanency is desired, steel or concrete should be used. For the larger (10-50 foot) Parshall flumes, reinforced concrete is usually used. However, the forms should be carefully set to insure exact dimensions.

It's important that the crest of the flume is set at the correct elevation with reference to the channel bed. This elevation depends upon the size of the flume used, and the quantity of water to be measured. Setting the crest at the proper elevation isn't difficult if sufficient fall is available, but if fall or grade of the channel is very flat, difficulty may be encountered and it may be necessary to operate under submerged flow conditions. The crest of the Parshall flume should be straight and level, and the flume floor should be installed so that the converging entrance section is level longitudinally and laterally.

The flume should be built to the exact dimensions given in Table 1, especially the entrance and throat sections. If throat width is not constructed as specified, adjustments can be made to the discharge tables or curves to arrive at the appropriate flow rate passing through a flume.

Example 5. Let's assume a two-foot Parshall flume is to be constructed using concrete. After the concrete has been poured and the forms removed, a check measurement shows the throat width is 2.10 feet. Consequently, the discharge values obtained from the free flow table (Table 3), or the submerged flow calibration curves (Fig. 11) for a two-foot Parshall flume, must be multiplied by a factor of 1.05 (2.10/2 = 1.05). For free flow then, the discharge for a two-foot flume would be 27.0 cfs if the H_a gage reading were 2.19 feet, whereas the discharge is 28.4 cfs (27.0 x 1.05 = 28.35) for a throat width of 2.10 feet.

The rate of flow through a Parshall flume is determined by the water depths in the entrance and throat sections. For free flow, only the depth, H_a, needs to be measured, and a staff gage set vertically at the specified location on the inside face of the converging entrance wall, can be used to determine the head, H_a, with fair accuracy. The staff gage for measuring H_a must be carefully referenced to the elevation of the flume crest, which is the elevation of the flume floor at the end of the entrance section, or beginning of the throat. For submerged flow, the depth of flow in the throat, H_b, must also be measured. Since the flow in the throat is quite turbulent, causing the water surface to fluctuate considerably, it is difficult to accurately measure H_b with a staff gage. Consequently, a stilling well placed just outside the flume wall is usually necessary. To connect the stilling well with the point in the throat for measuring H_b, as specified in Table 1, a short length of pipe is used. A staff gage can be placed vertically on the inside face of the stilling well and the zero point of the gage referenced to the elevation of the flume crest. If desired, a stilling well may also be used for the H_a reading. Stilling wells have the advantage of providing a more accurate measurement of the flow depths than staff gages. Also, stilling wells are necessary if continuous recording instruments are to be used. For submerged flow, two stilling wells placed adjacent to one another are very desirable, if a double head recording instrument continuously records the water depths H_a and H_b is to be used.

Installation to Insure Free Flow

In most cases it is preferable to have a Parshall flume operate under free flow conditions. The principal advantage is that only the upstream flow depth, H_a, need be measured to determine discharge. Another advantage is, if a continuous recorder is to be used, it is less expensive to purchase a recorder that only measures one flow depth (H_a) rather than two (H_a and H_b), which would be required if the flume were submerged. The procedure for installing a Parshall flume in a canal to insure free flow is listed below.

1. Establish the maximum flow rate to be measured.

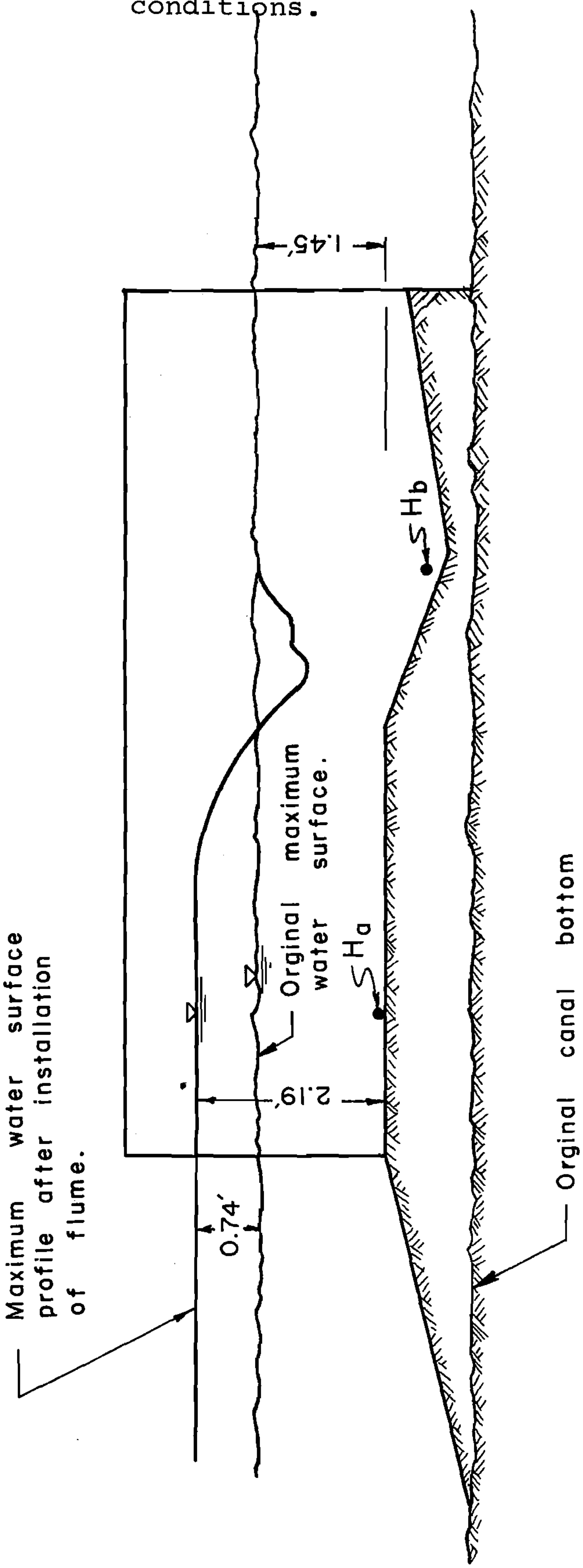
2. Locate the high water line on the canal bank where the flume is to be installed and determine the maximum depth of flow.

3. Select from the free flow discharge table (Table 3), the proper depth of water, H_a, that corresponds with the maximum discharge capacity of the canal. For example, assuming that a 2-foot flume is to be used and the maximum discharge is 27.0 second-feet, the depth of water, H_a, on the crest is 2.19 feet.

4. Place the floor of the flume at a depth which does not exceed the transition submergence times, H_a, below the high water line (Fig. 20). In general, the floor of the flume should be placed as high in the canal as grade and other conditions permit.

> Example 6. A two-foot Parshall flume is shown in Figure 20. The transition submergence for the two-foot flume is 66 percent. The maximum discharge in the canal is 27.0 cfs, which for free flow conditions has a H_a value equal to 2.19 feet. Multiplying H_a (2.19) by the submergence (o.66), gives a depth to flume floor of 1.45 (2.19 x 0.66 = 1.45). Therefore, the flume crest should be set no lower than 1.45 feet below the original maximum water surface (Fig. 20). The loss of head through the structure will be the difference between 2.19 feet and 1.45 feet, which is 0.74 feet, as shown in Figure 20. If the amount of head loss is too great, then a larger flume could be used with a resulting decrease in the head loss.

Figure 20. Illustration of the installation of two-foot Parshall flume to operate under free flow conditions.



Installation for Submerged Flow

Some conditions exist, such as insufficient grade, where it is impossible or impractical to set the flume for operation under a free flow condition. Where this is the case, the flume may be placed in the canal to operate under submerged flow conditions. The principal advantage in using submerged Parshall flumes is that a smaller head loss occurs through the flume. The savings in head loss (as compared with free flow), may mean that canal banks upstream from the flume do not have to be raised in order to maintain the same maximum flow capacity in the canal that existed prior to the installation of the flume. Also, for submerged flow, the floor of the flume may be placed at the same elevation as the canal bottom, thus allowing quicker drainage of the canal section upstream from the flume, and reduced seepage losses upstream from the flume particularly for flow rates less than the maximum discharge. The procedure to follow in placing a Parshall flume in a canal to operate under submerged flow conditions is listed below.

1. Establish the maximum flow rate to be measured.

2. Locate high water line on the canal bank where the flume is to be installed, and determine maximum depth of flow.

3. Taking into account the amount of freeboard in the canal at maximum discharge and maximum flow depth, determine how much higher the water surface can be raised in the canal above the location for the flume.

4. Select the required size of flume from the submerged flow calibration curves using trial and error. With the floor of the flume being placed at nearly the same elevation as the bottom of the canal, maximum depth of flow (item 2) can be used as H_b, and the amount that the water surface in the canal can still be raised (item 3), can be used as $H_a - H_b$. With this information, the submergence, H_b/H_a, can be computed. Knowing $H_a - H_b$ and H_b/H_a allows the size of flume to be selected from the submerged flow calibration curves. The trial and error procedure for selecting the size of flume is illustrated in the example that follows.

Example 7. A site for a Parshall flume has been selected in a canal having a maximum discharge of 27 cfs. Maximum depth of water in the canal corresponding to this flow rate is 1.8 feet. With the amount of existing freeboard in the canal, it is felt that the water surface should not be raised more than 0.2 feet, thereby resulting in a maximum flow depth of 2.0 feet (1.8 + 0.2 = 2.0) upstream from the flume after installation. Therefore, for purposes of selecting the flume size:

$H_b = 1.8$ feet

$H_a = 2.0$ feet

$H_a - H_b = 2.0 - 1.8 = 0.2$ feet

$H_b/H_a = 1.8/2.0 = 0.90 = 90\%$

As a beginning point, enter the submerged flow calibration curves for a two-foot Parshall flume (Fig. 11). With the value of $H_a - H_b = 0.20$ feet, move vertically to the submergence line for 90%, and then read the discharge to the left as 18.5 cfs. Since this flow rate (18.5 cfs) is less than the maximum flow rate (27 cfs), a larger flume is required.

Entering the submerged flow calibration curves for a 30-inch Parshall flume (Fig. 12) with $H_a - H_b = 0.20$ feet, move vertically to the 90% submergence line, and read the discharge as 22.8 cfs. Again, the flow rate is less than the design maximum flow rate of 27 cfs, and a larger Parshall flume is required.

Entering the submerged flow calibration curves for a 3-foot Parshall flume (Fig. 13) with $H_a - H_b = 0.20$ feet, move vertically to the 90% submergence line, and read the discharge as 27.8 cfs. Since this flow rate (27.8 cfs) is larger than the maximum flow rate in the canal (27 cfs), a 3-foot Parshall flume may be used.

After a Parshall flume has been properly installed periodic maintenance is required to insure satisfactory operation. Moss may collect on the walls of the entrance section and must be removed. In certain channels, debris material may collect on the floor of the entrance section, and should be removed. Walls of steel Parshall flumes may become encrusted and should be removed with a steel-wire brush. Once the walls have been scraped clean, applying asphaltic paint will add to the life of the flume and delay the build-up of encrustation.

It is very common for Parshall flumes to "settle" after being in operation for a period of time. So it's wise to check the levelness of the entrance floor after a few months of operation, and again at the end of the season or year.

Either "settling" or improper installation, can cause a flume to tilt sideways as illustrated in Figure 21. If the settling is minor, discharge can still be estimated with fair accuracy by measuring the depths of flow on both sides of the flume. The discharge can be determined by using the average of the two readings and the rating tables or calibration curves.

Settlement near the entrance section of a Parshall flume is illustrated in Figure 22. And again, if the settlement is not too great, discharge can be estimated with fair accuracy. For this particular situation, the flume crest is the controlling point. If a staff gage is being used to measure H_a, zero should be set at the same elevation as the flume crest.

Settlement occurs most commonly near the exit section, as illustrated in Figure 23. It is more likely at the outlet, because of channel erosion immediately downstream from the flume due to jetting action of the water. Use of the flow depths H_a or H_a and H_b to obtain discharge from the tables or curves, will yield values less than the true discharge. This discrepancy between the estimated discharge and the true discharge becomes greater as the amount of settlement increases. Satisfactory solutions to this problem include: raising the lower end of the flume so that it is level again; placing a new level floor in the flume; and purchasing a plastic or fibreglass Parshall flume liner, placing it inside the existing flume, then grouting it into place.

Figure 21. Parshall flume tilted sideways.

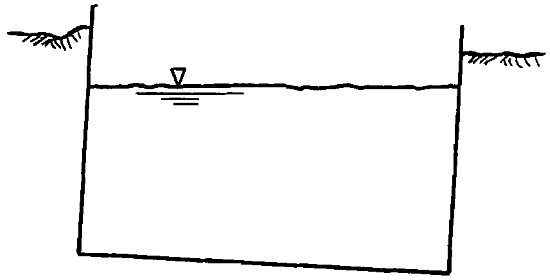


Figure 22. Settlement of Parshall flume in vicinity of inlet section.

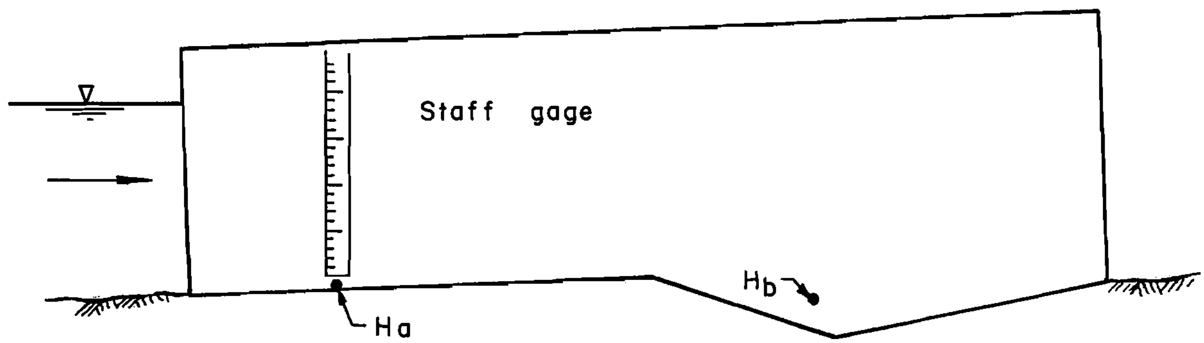
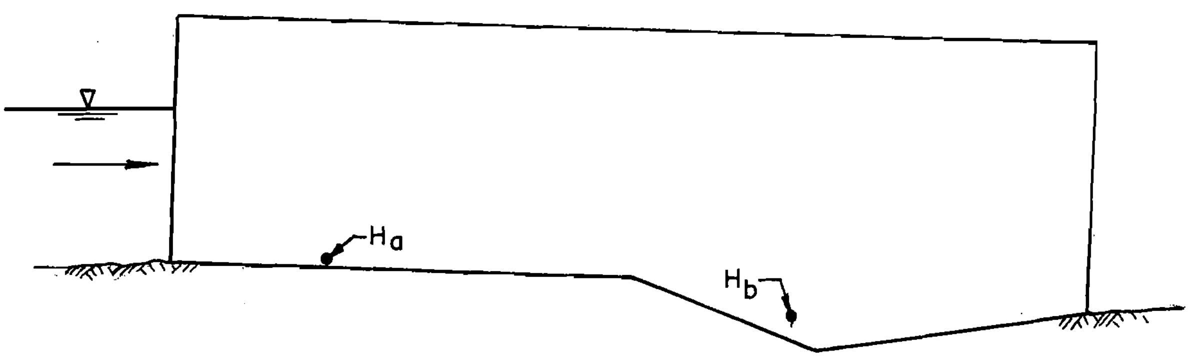


Figure 23. Settlement of Parshall flume at exit section.



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