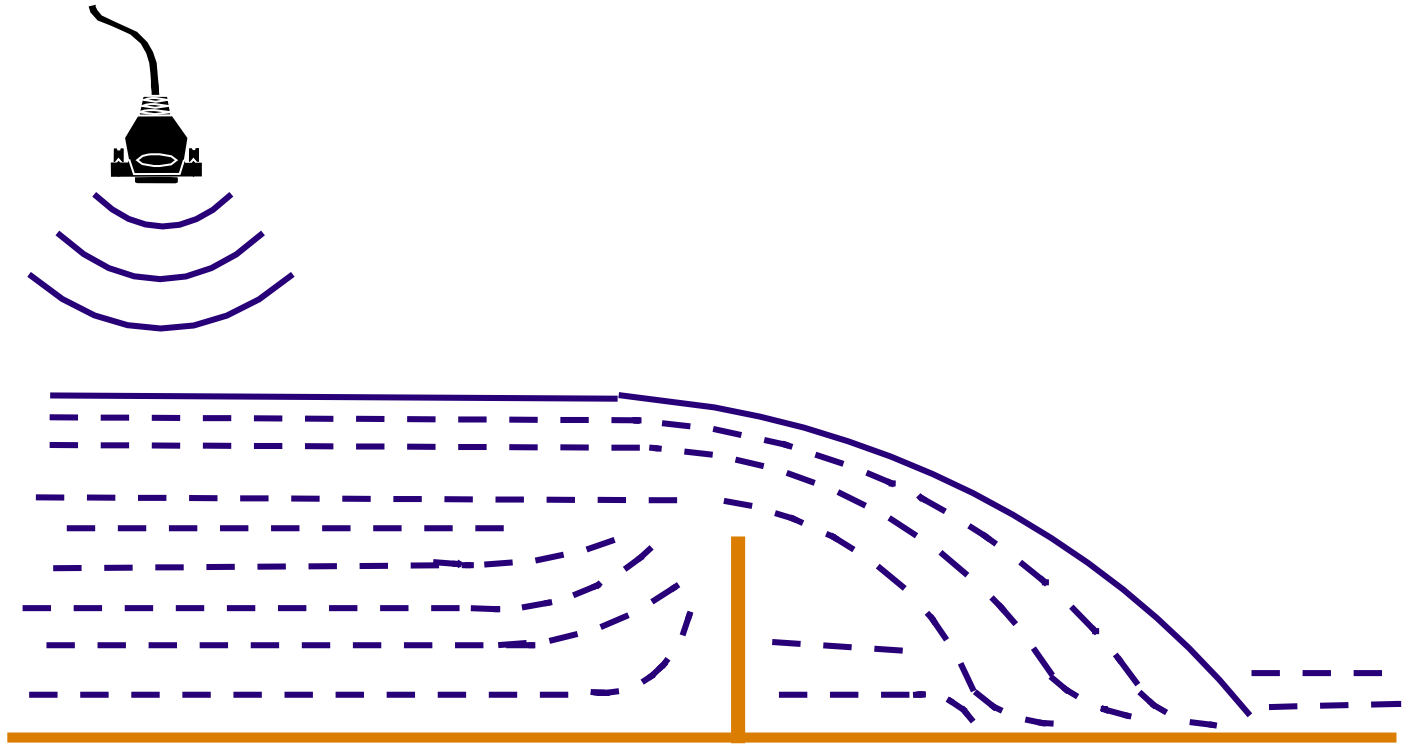
Understanding Flow Measurement



Why is it important to have accurate flow at the effluent discharge?

- Permit requirement
- Provides data for mass loading calculations
- Critical for long-term planning and design
- Provides operating and performance data

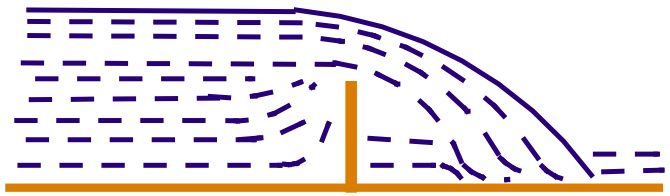
Permit & NPDES Manual Requirements

Flow measurement systems should be calibrated by a third party source at least once a year

The flow meter should record to an accuracy of ±10 percent of actual flow

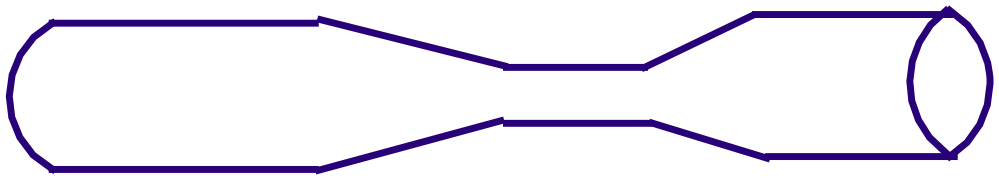
Common Flow Devices:

1. Open Channel Systems



Flumes

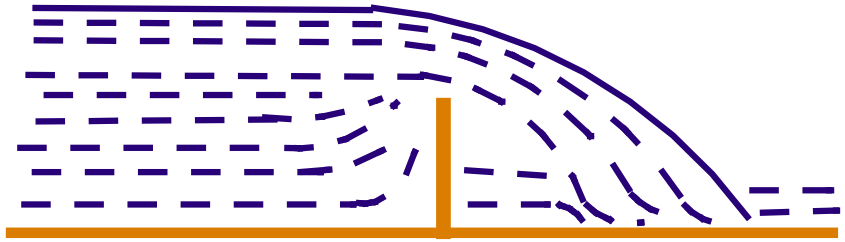
2. Closed Channel Systems



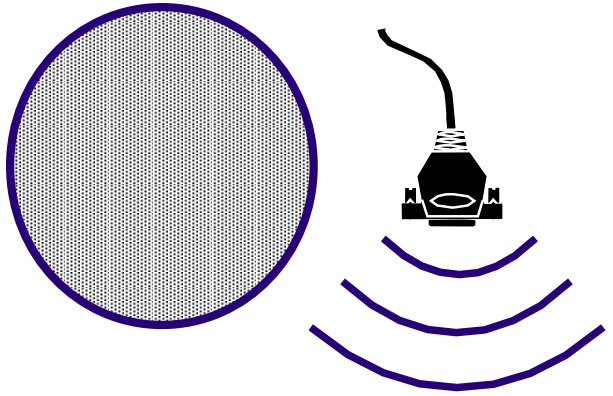
Venturi, Magnetic, Doppler

Flow Measurement Systems Components

- Primary Device



- Secondary Device



Flow Measurement System

Primary Device (Parshall Flume)

Secondary Device: (Flow sensor, Chart Recorder and Totalizer)

Common Open Channel Devices

- **Flumes**

Common flumes:

- Parshall Flume
- Palmer-Bowlus Flume
- H-Flume

- **Weirs**

Common weirs:

- Rectangular Weir
- V-notch Weir
- Trapezoidal (Cipoletti) Weir

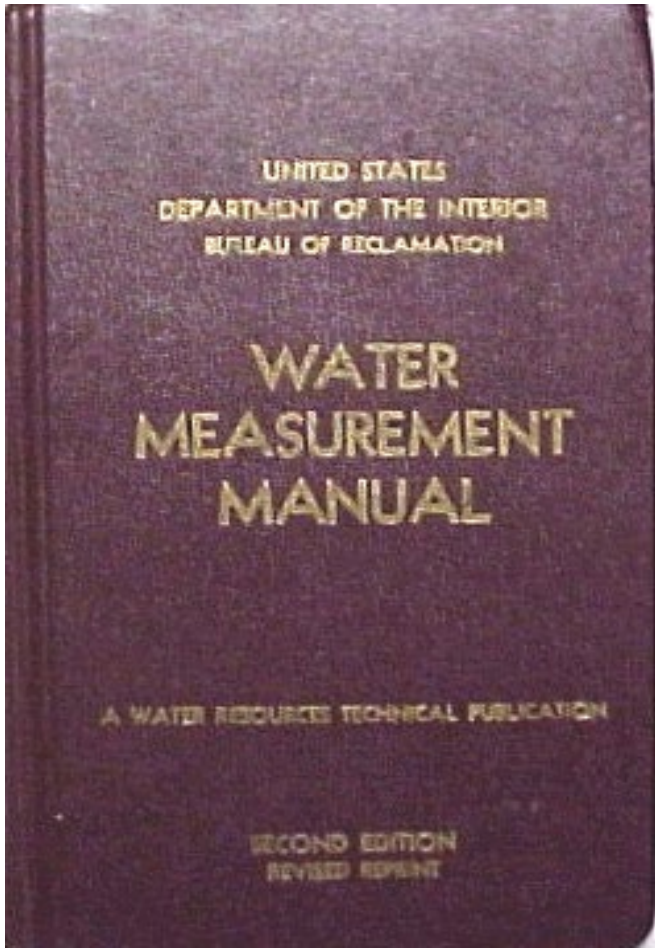
Poll Question

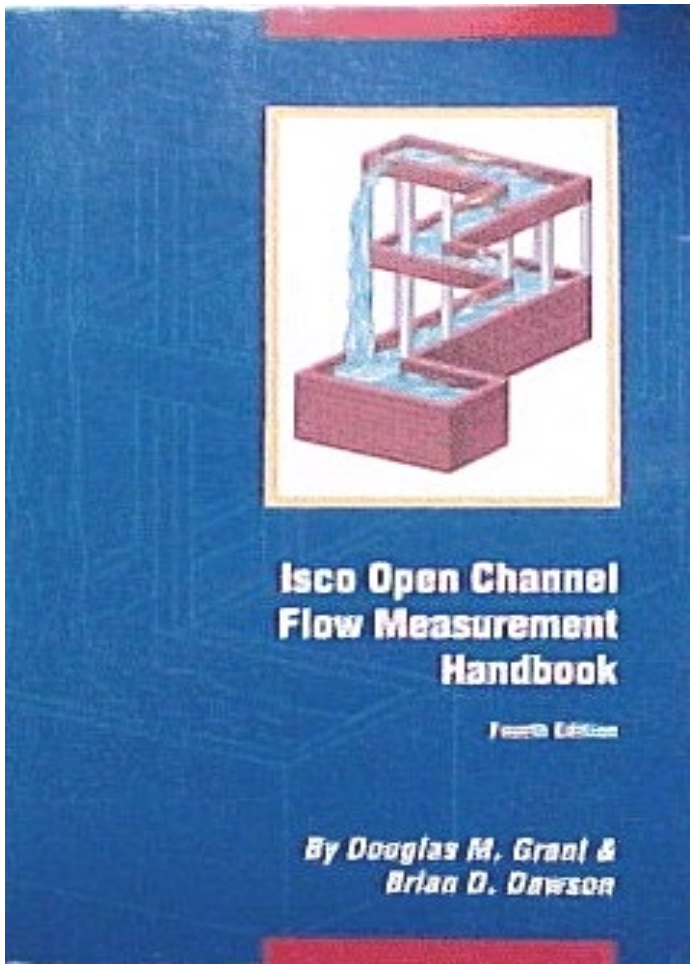
What is your Primary device?

A. Parshall Flume
B. Palmer Bowlus Flume
C. H-Flume
D. Other Flume
E. V-Notch Weir
F. Rectangular Weir
G. Trapazoidal Weir
H. Other Weir

USDI Water Measurement Manual (Cited Reference)

ISCO Flow Measurement Handbook (Guidance)

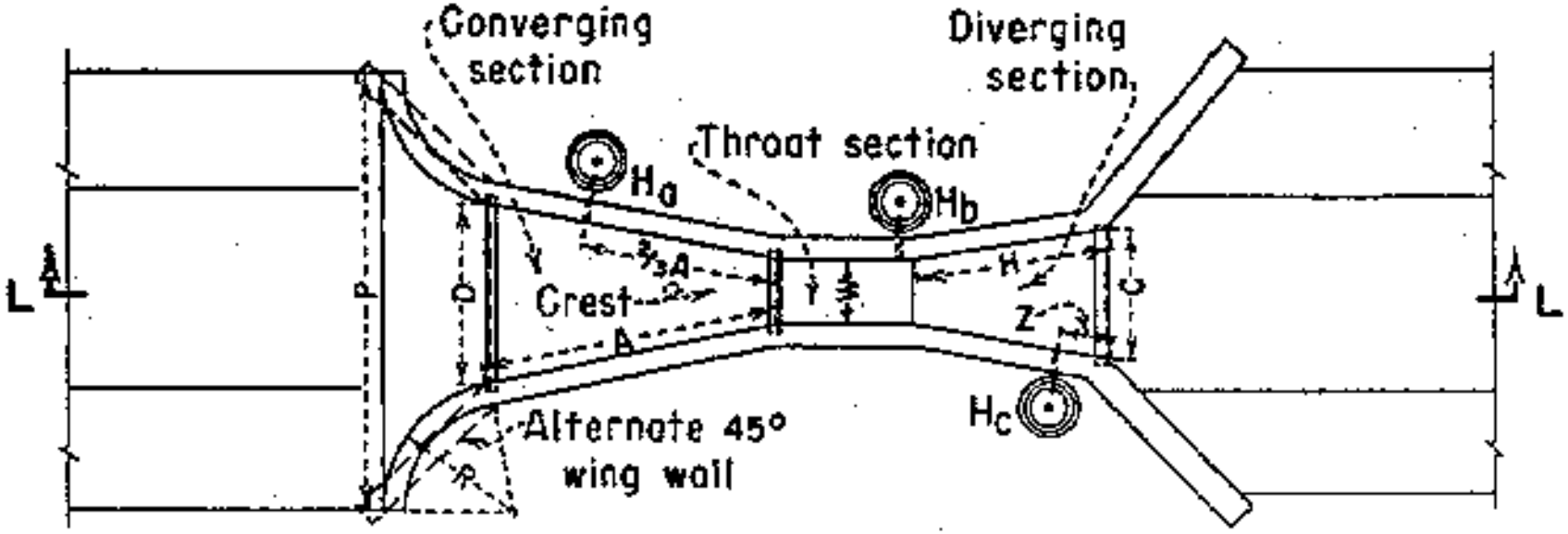




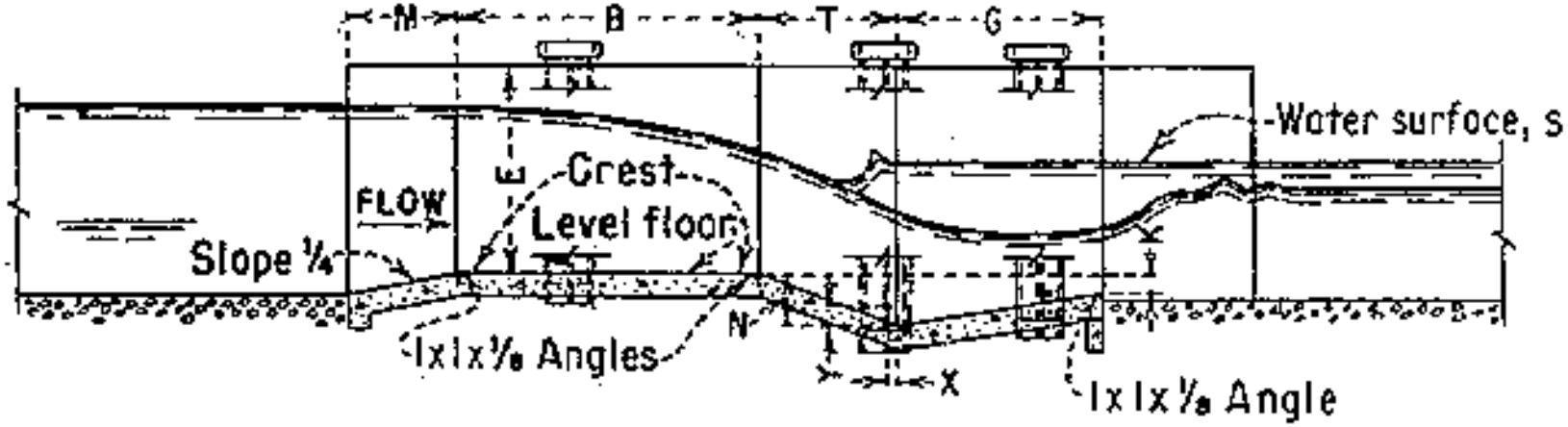
www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/cover.html

Parshall Flumes

- Very common in WTPPs
- Self-cleaning
- Operate under wide range of flows
- Simple to check for calibration



PLAN



SECTION L-L

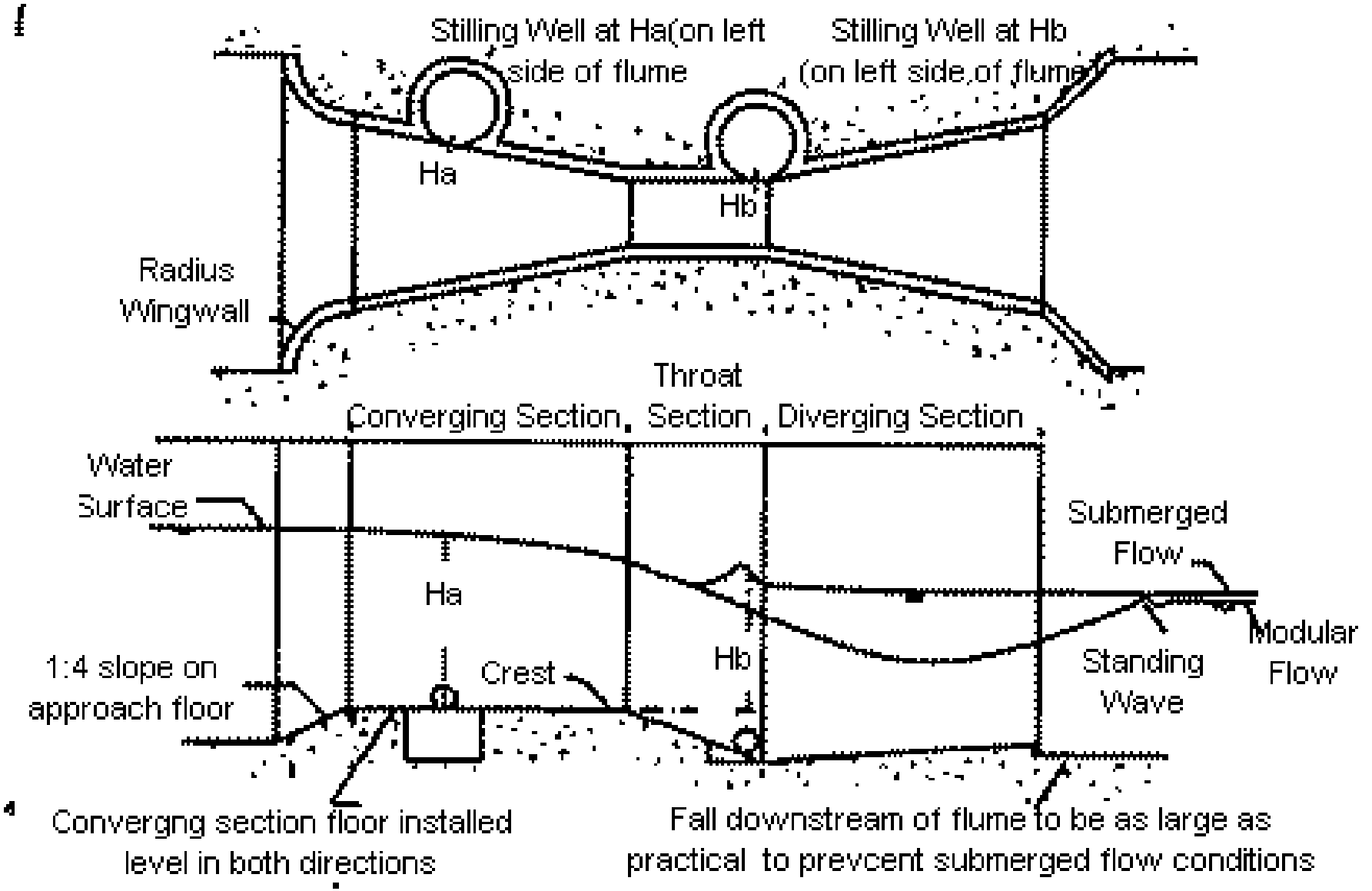
	W		A		$\frac{2}{3}$A		B		C		D		E		T		G		H		K		M		N		P		R		X		Y		Z		FREE-FLOW CAPACITY	
																																					MINIMUM	MAXIMUM
	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	FT.	IN.	SEC.-FT.	SEC.-FT.
[2]	0	1[1]	1	$2\frac{3}{32}$	0	$9\frac{17}{32}$	1	2	0	$3\frac{27}{32}$	0	$6\frac{19}{32}$	0	6 to 9	0	3	0	8	0	$8\frac{1}{8}$	0	$\frac{3}{4}$	-	-	0	$1\frac{1}{8}$		-	-		0	$\frac{5}{16}$	0	$\frac{1}{2}$	0	$\frac{1}{8}$	0.01	0.19
		$2^{1/2}$	1	$4\frac{5}{16}$		$10\frac{7}{8}$	1	4		$5\frac{5}{16}$		$8\frac{13}{32}$		6 to 10		$4\frac{1}{2}$		10		$10\frac{1}{8}$		$\frac{7}{8}$		-		$1\frac{11}{16}$		-	-			$\frac{3}{8}$		1		$\frac{1}{4}$	.02	.47
		3[1]	1	$6\frac{3}{8}$	1	$\frac{1}{4}$	1	6		7		$10\frac{3}{16}$	1 to $1\frac{1}{2}$			6	1	0	1	$\frac{5}{32}$		1	-			$2\frac{1}{4}$		-	-			1		$1\frac{1}{2}$		$\frac{1}{2}$	.03	1.13
[3]	0	6	2	$\frac{7}{16}$	1	$4\frac{5}{16}$	2	0	1	$3\frac{1}{2}$	1	$3\frac{5}{8}$	2	0	1	0	2	0	-		0	3	1	0	0	$4\frac{1}{2}$	2	$11\frac{1}{2}$	1	4	0	2	0	3	-		.05	3.9
		9	2	$10\frac{5}{8}$	1	$11\frac{1}{8}$	2	10	1	3	1	$10\frac{5}{8}$	2	6	1	0	1	6	-			3	1	0		$4\frac{1}{2}$	3	$6\frac{1}{2}$	1	4		2		3	-		.09	8.9
	1	0	4	6	3	0	4	$4\frac{7}{8}$	2	0	2	$9\frac{1}{4}$	3	0	2	0	3	0	-			3	1	3		9	4	$10\frac{3}{4}$	1	8		2		3	-		.11	16.1
	1	6	4	9	3	2	4	$7\frac{7}{8}$	2	6	3	$4\frac{3}{8}$	3	0	2	0	3	0	-			3	1	3		9	5	6	1	8		2		3	-		.15	24.6
	2	0	5	0	3	4	4	$10\frac{7}{8}$	3	0	3	$11\frac{1}{2}$	3	0	2	0	3	0	-			3	1	3		9	6	1	1	8		2		3	-		.42	33.1
	3	0	5	6	3	8	5	$4\frac{3}{4}$	4	0	5	$1\frac{7}{8}$	3	0	2	0	3	0	-			3	1	3		9	7	$3\frac{1}{2}$	1	8		2		3	-		.61	50.4
	4	0	6	0	4	0	5	$10\frac{5}{8}$	5	0	6	$4\frac{1}{4}$	3	0	2	0	3	0	-			3	1	6		9	8	$10\frac{3}{4}$	2	0		2		3	-		1.3	67.9
	5	0	6	6	4	4	6	$4\frac{1}{2}$	6	0	7	$6\frac{3}{8}$	3	0	2	0	3	0	-			3	1	6		9	10	$1\frac{1}{4}$	2	0		2		3	-		1.6	85.6
	6	0	7	0	4	8	6	$10\frac{3}{8}$	7	0	8	9	3	0	2	0	3	0	-			3	1	6		9	11	$3\frac{1}{2}$	2	0		2		3	-		2.6	103.5
	7	0	7	6	5	0	7	$4\frac{1}{4}$	8	0	9	$11\frac{3}{8}$	3	0	2	0	3	0	-			3	1	6		9	12	6	2	0		2		3	-		3.0	121.4
	8	0	8	0	5	4	7	$10\frac{1}{8}$	9	0	11	$1\frac{3}{4}$	3	0	2	0	3	0	-			3	1	6		9	13	$8\frac{1}{4}$	2	0		2		3	-		3.5	139.5
[4]	10	0	-		6	0	14	0	12	0	15	$7\frac{1}{4}$	4	0	3	0	6	0	-		0	6	-		1	$1\frac{1}{2}$	-		-		0	9	1	0	-		6	200
	12	0	-		6	8	16	0	14	8	18	$4\frac{3}{4}$	5	0	3	0	8	0	-			6	-		1	$1\frac{1}{2}$	-		-			9	1	0	-		8	350
	15	0	-		7	8	25	0	18	4	25	0	6	0	4	0	10	0	-			9	-		1	6	-		-			9	1	0	-		8	600
	20	0	-		9	4	25	0	24	0	30	0	7	0	6	0	12	0	-		1	0	-		2	3	-		-			9	1	0	-		10	1000
	25	0	-		11	0	25	0	29	4	35	0	7	0	6	0	13	0	-		1	0	-		2	3	-		-			9	1	0	-		15	1200
	30	0	-		12	8	26	0	34	8	40	$4\frac{3}{4}$	7	0	6	0	14	0	-		1	0	-		2	3	-		-			9	1	0	-		15	1500
	40	0	-		16	0	27	0	45	4	50	$9\frac{1}{2}$	7	0	6	0	16	0	-		1	0	-		2	3	-		-			9	1	0	-		20	2000
	50	0	-		19	4	27	0	56	8	60	$9\frac{1}{2}$	7	0	6	0	20	0	-		1	0	-		2	3	-		-			9	1	0	-		25	3000

[1] Tolerance on throat width (w) ± 1/64 inch; tolerance on other dimensions ± 1/32 inch. Sidewalls of throat must be parallel and vertical.

[2] From Colorado State University Technical Bulletin No. 61.

[3] From U.S. Department of Agriculture Soil Conservation Circular No. 843.

[4] From Colorado State University Bulletin No. 426-A


Stilling Well at Ha(on left side of flume
Stilling Well at Hb (on left side,of flume
Ha
Hb
Radius Wingwall
Throat
Converging Section
Section
Diverging Section
Water Surface
Submerged Flow
Ha
Modular Flow
Standing Wave
Hb
1:4 slope on approach floor
Crest
Convergng section floor installed level in both directions
Fall downstream of flume to be as large as practical to prevcent submerged flow conditions

Free Flow & Submergence

- Free Flow
- Hydraulic Jump
- Submergence compensation

P 8-46 Water Measurement Manual 3rd Ed.

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Requirements for Parshall Flumes:

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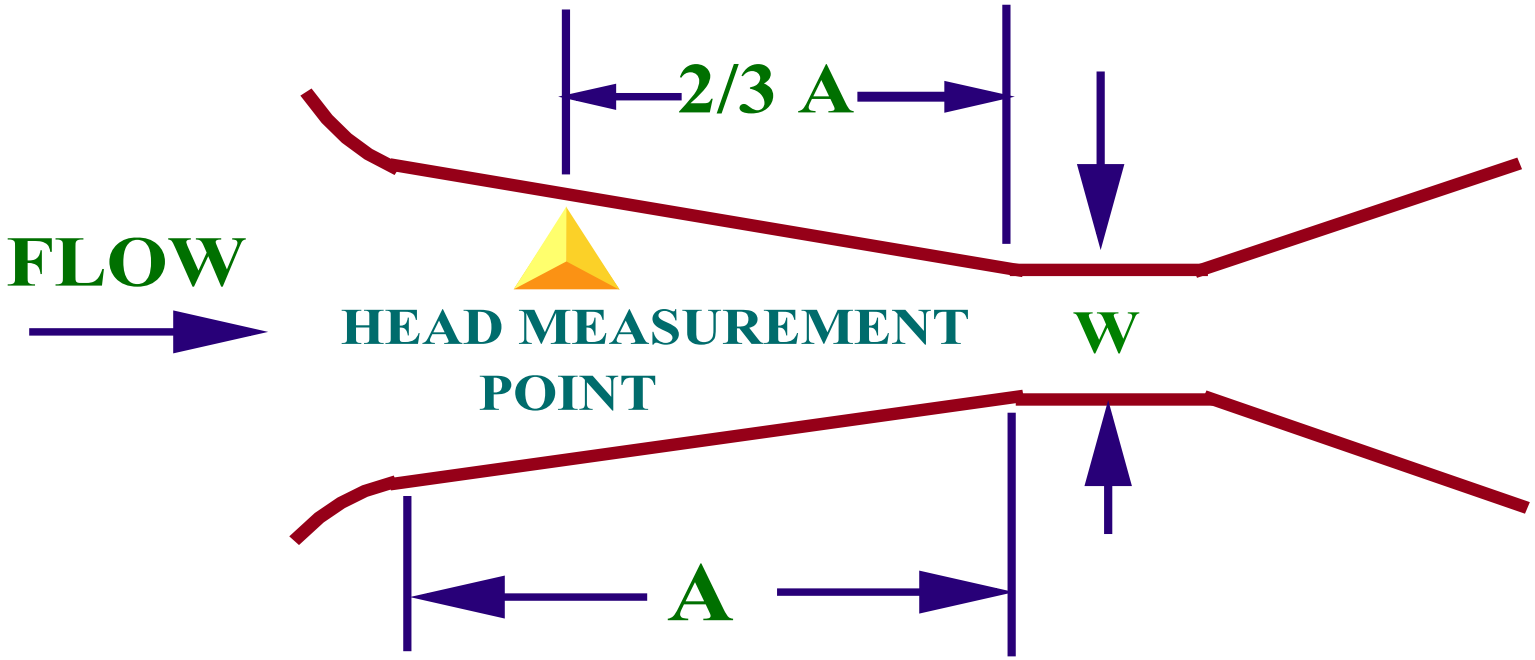
- The approach channel should be straight and uniform

Parshall Flume

Head Measurement: Parshall Flumes



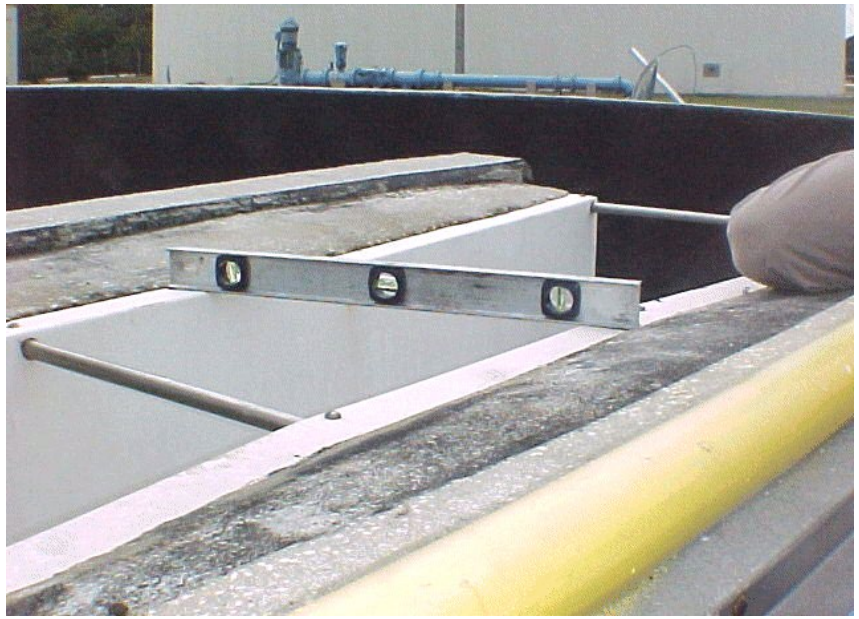
- TOP VIEW -

**Also see attached table (4-1A)

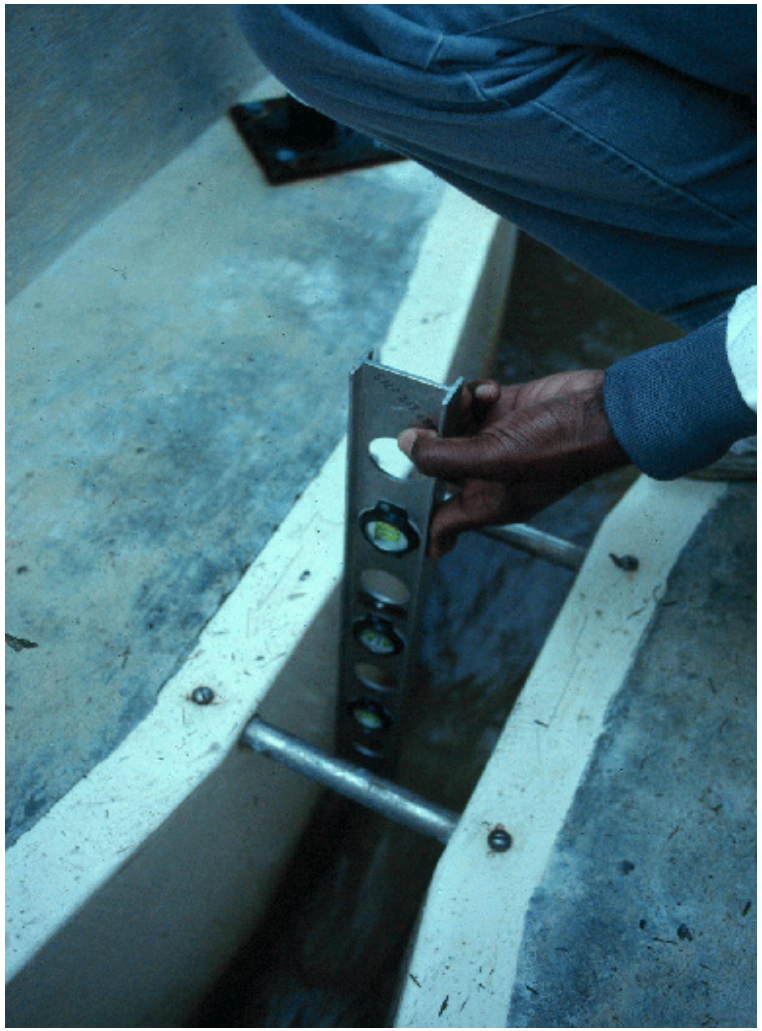
Throat width measurement of a Parshall Flume

Measurement of the “2/3 A” location

The flume should be level and the sidewalls vertical.



Parshall Flume




30
20
10

12-9: 3 ft. Parshall Flume Discharge Table

Formulas: $CFS = 12.00H^{1.566}$ $GPS = CFS \times 7.481$

$GPM = CFS \times 448.8$ $MGD = CFS \times 0.6463$

Head Feet	CFS	GPS	GPM	MGD
0.01	0.0089	0.0662	3.974	0.0057
0.02	0.0262	0.1961	11.77	0.0169
0.03	0.0495	0.3701	22.20	0.0320
0.04	0.0776	0.5807	34.84	0.0502
0.05	0.1101	0.8236	49.41	0.0712
0.06	0.1465	1.096	65.74	0.0947
0.07	0.1865	1.395	83.69	0.1205
0.08	0.2298	1.719	103.2	0.1485
0.09	0.2764	2.068	124.0	0.1786
0.10	0.3260	2.439	146.3	0.2107
0.11	0.3784	2.831	169.8	0.2446
0.12	0.4337	3.244	194.6	0.2803
0.13	0.4916	3.678	220.6	0.3177
0.14	0.5521	4.130	247.8	0.3568
0.15	0.6151	4.602	276.1	0.3975
0.16	0.6805	5.091	305.4	0.4398
0.17	0.7483	5.598	335.8	0.4836

Head Feet	CFS	GPS	GPM	MGD
0.51	4.181	31.27	1876	2.702
0.52	4.310	32.24	1934	2.785
0.53	4.440	33.22	1993	2.870
0.54	4.572	34.20	2052	2.955
0.55	4.705	35.20	2112	3.041
0.56	4.840	36.21	2172	3.128
0.57	4.976	37.23	2233	3.216
0.58	5.113	38.25	2295	3.305
0.59	5.252	39.29	2357	3.394
0.60	5.392	40.34	2420	3.485
0.61	5.534	41.40	2483	3.576
0.62	5.676	42.46	2548	3.669
0.63	5.820	43.54	2612	3.762
0.64	5.966	44.63	2677	3.856
0.65	6.112	45.73	2743	3.950
0.66	6.260	46.83	2810	4.046
0.67	6.409	47.95	2877	4.142

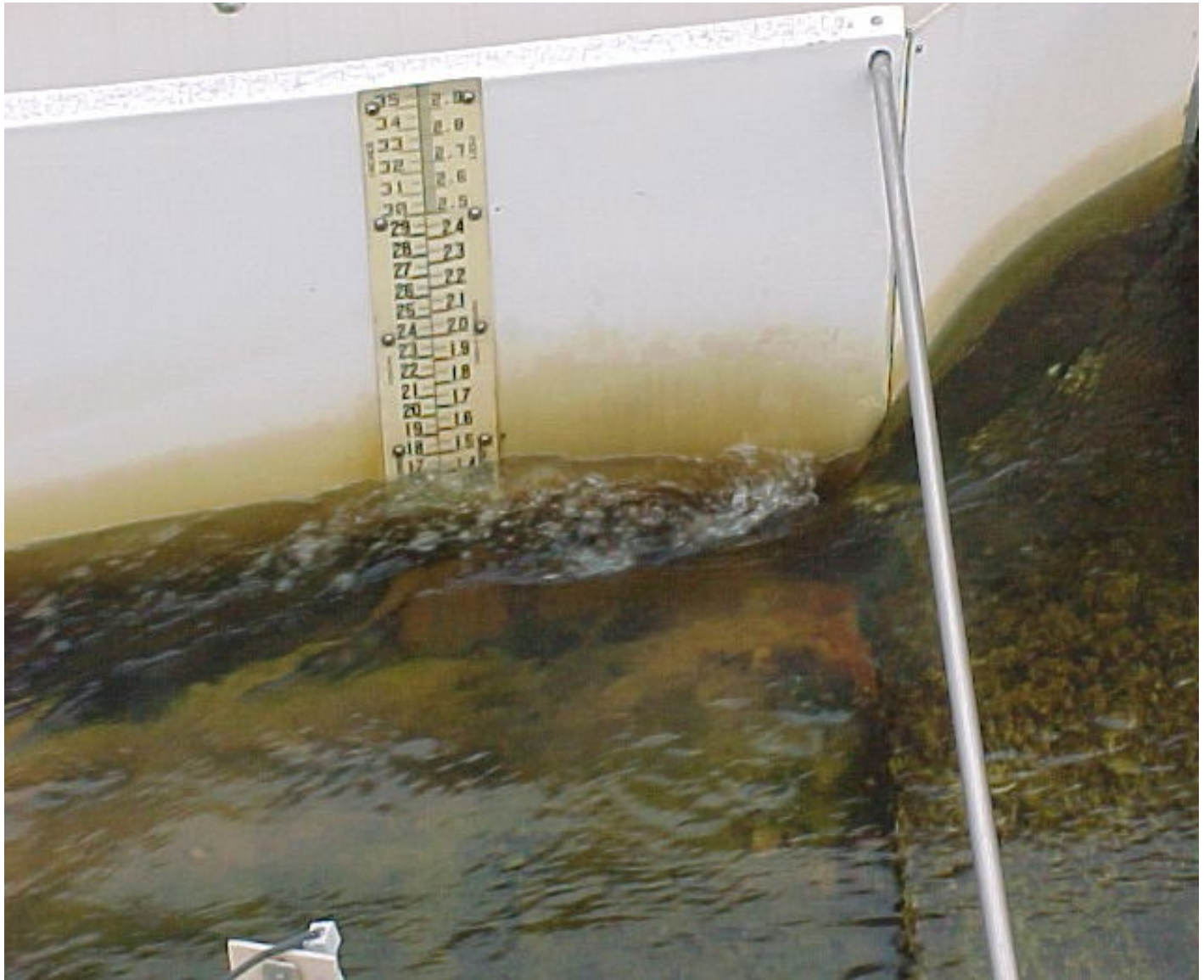
***

Common Flume Deficiencies

***

•Turbulent Flow Conditions

•Turbulent Flow Conditions



- Grating creates an obstruction, making flow measurements inaccurate.

Poll Question

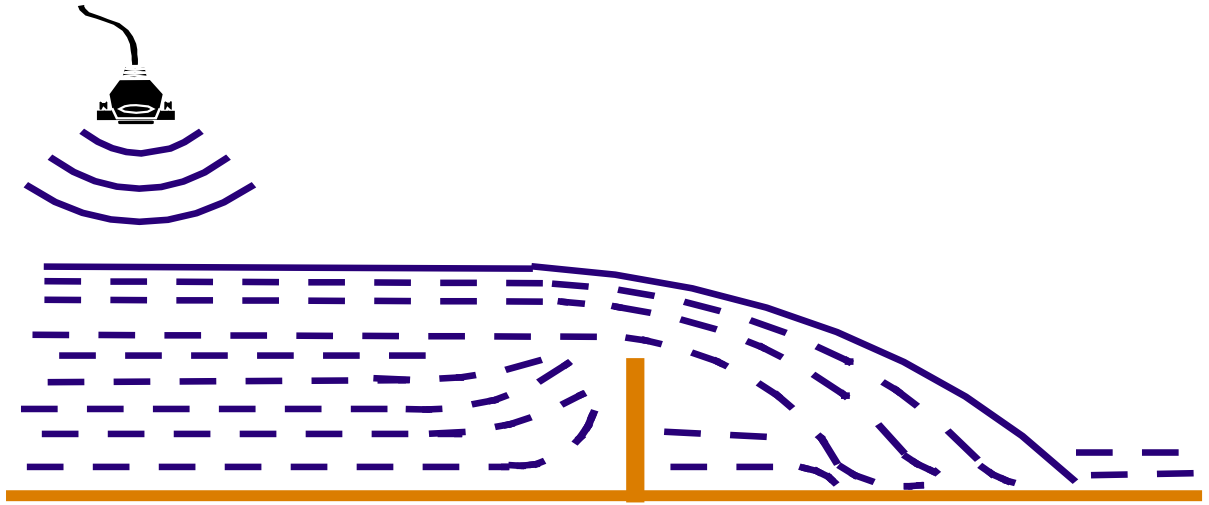
What is your secondary device?

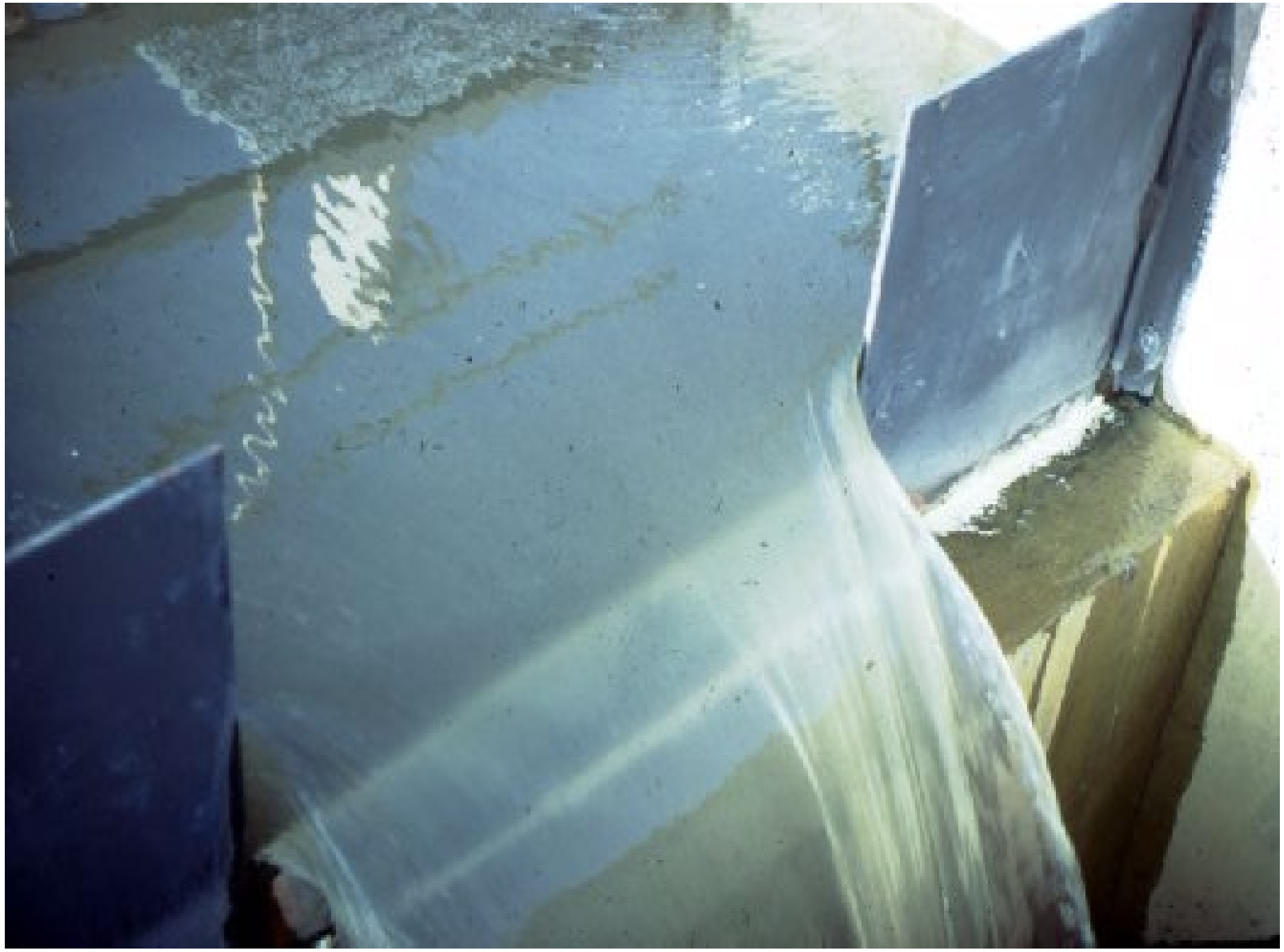
A. Area Velocity Sensor
B. Ultrasonic Sensor
C. Other

What does this look like in reality

Weirs

- One of the most common open channel flow devices
- Simple to install and inexpensive
- Simple to check for calibration

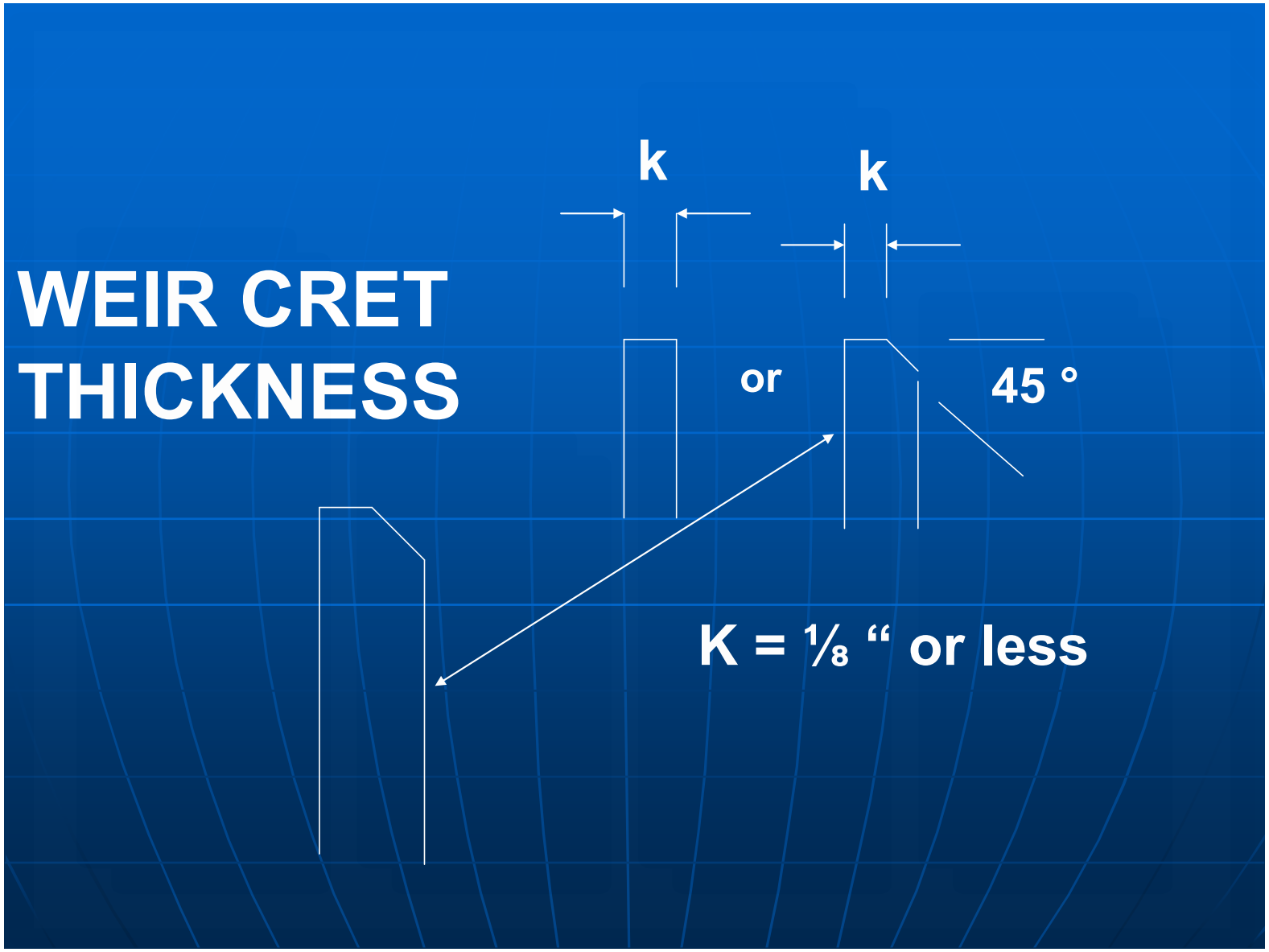




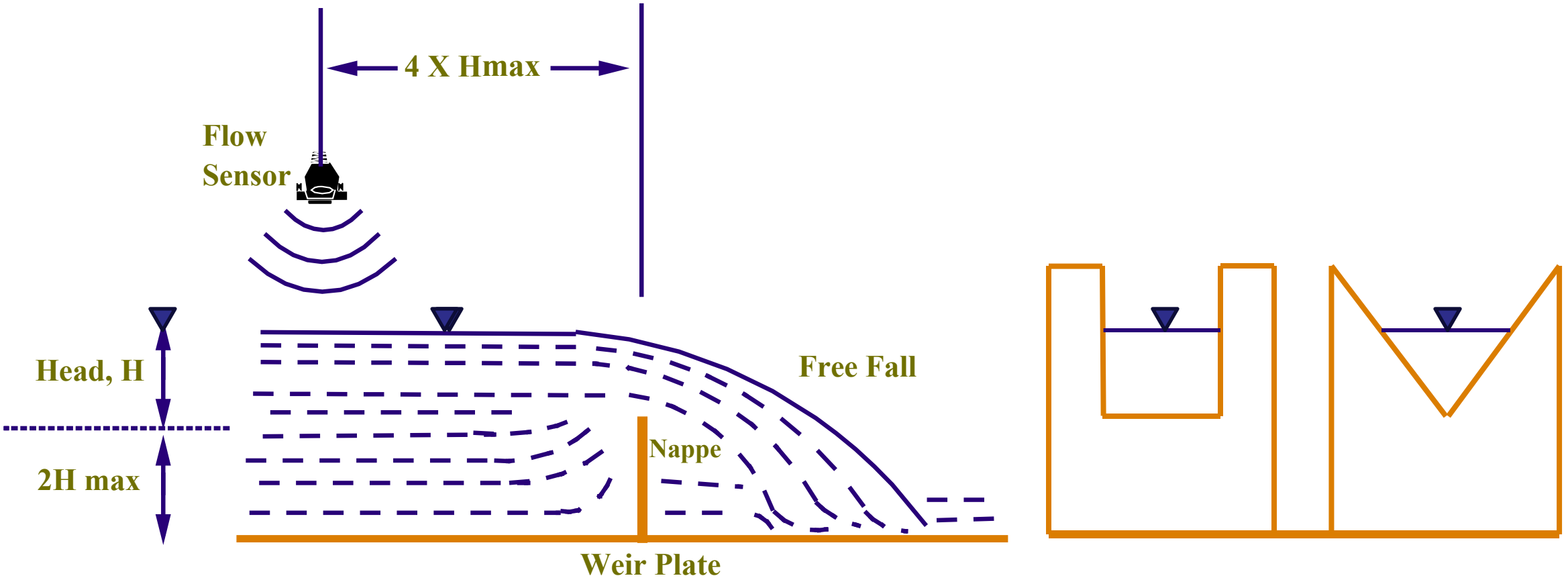
Requirements for Sharp Crested Weirs

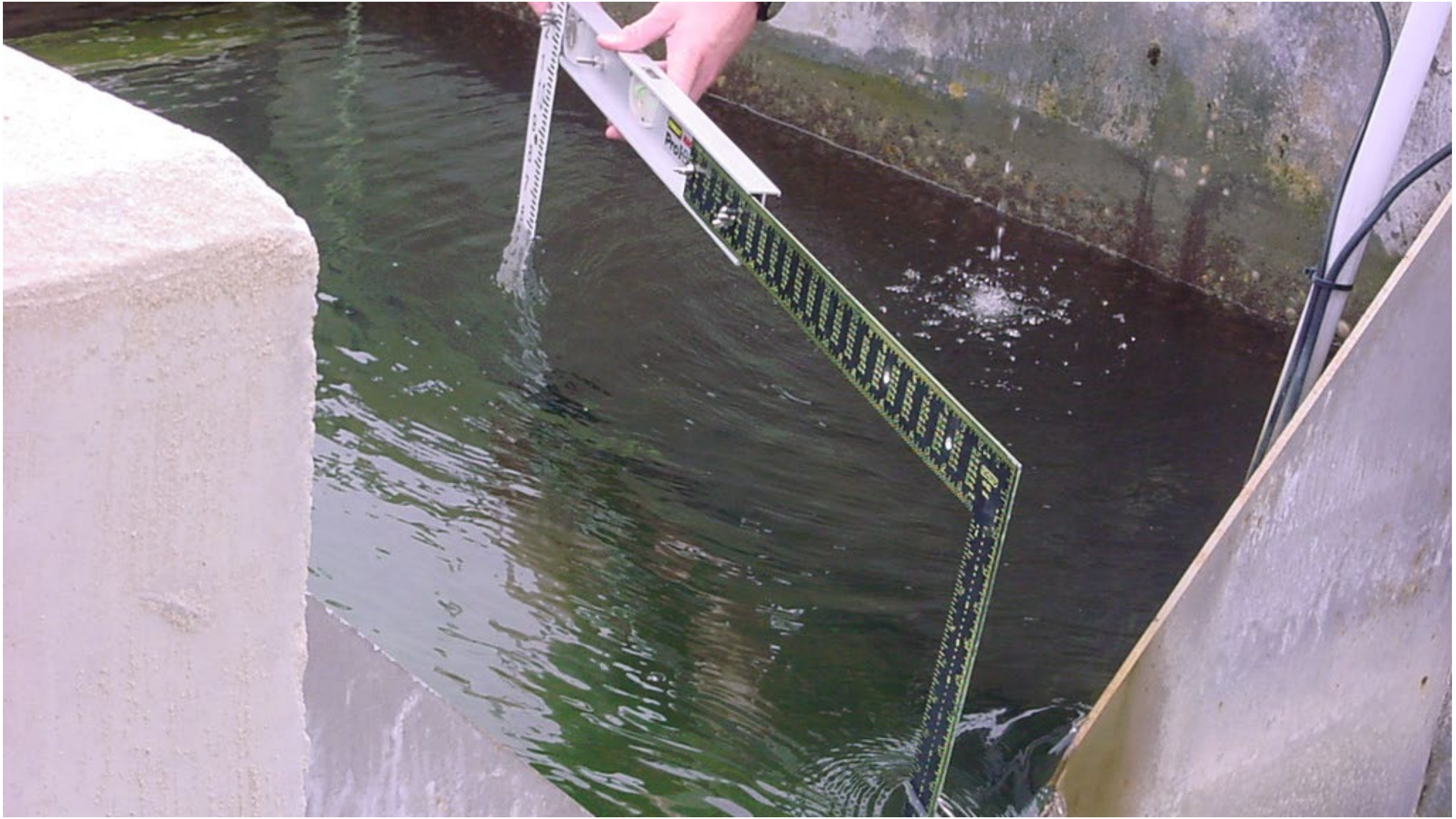
Weir crest should be

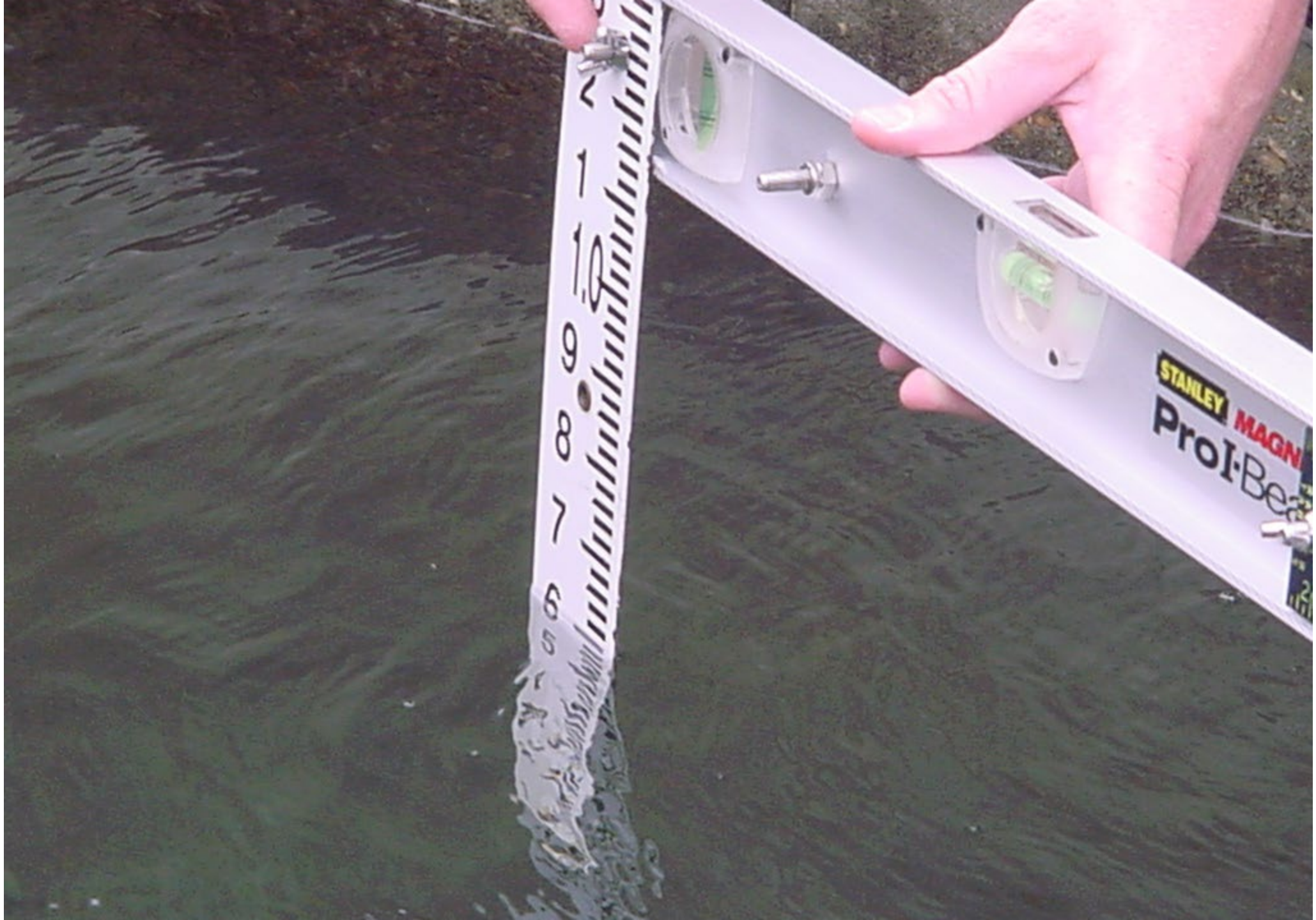
- 1/8-inch thick or less, or
- chamfered at 45 degrees so that the water springs free of the weir



Standard Weir Specifications






STANLEY
MAGN
ProI·Be

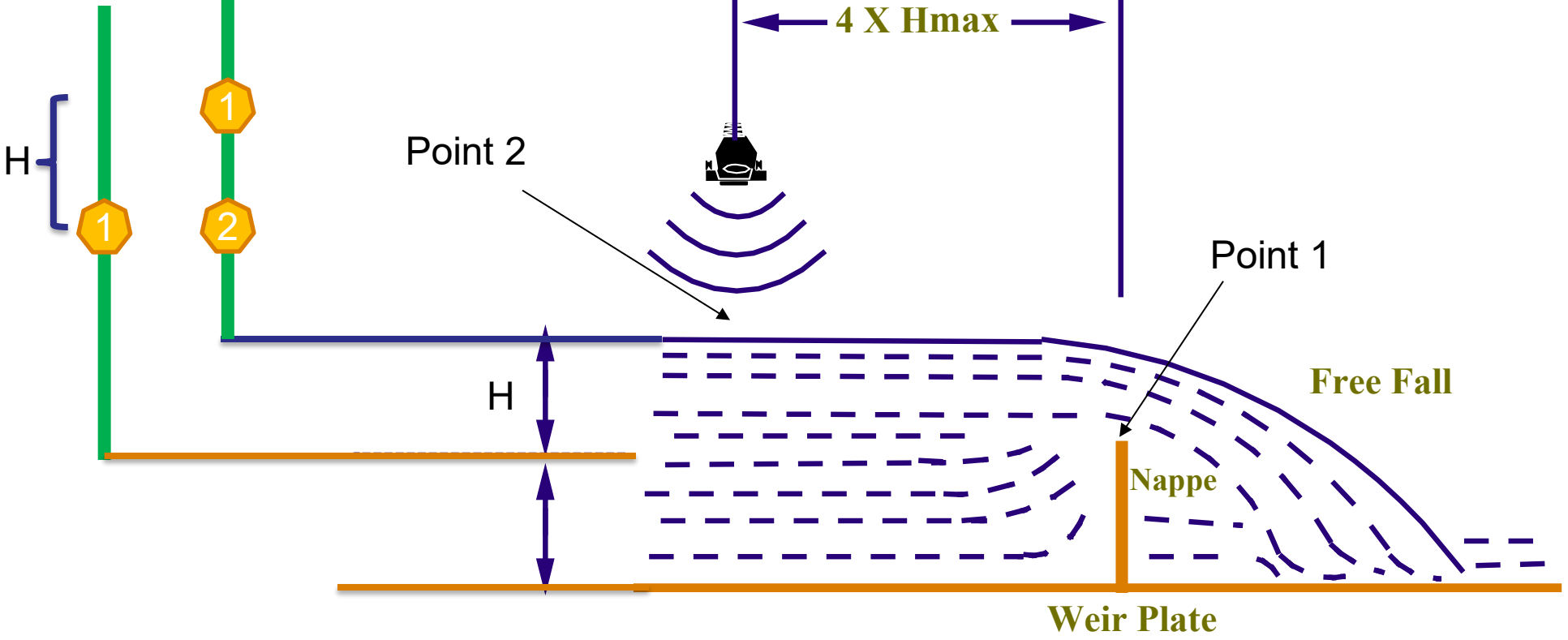
Using a level

Using Survey Equipment For Head Measurement

Level

Point 1

Point 2



***

DEFICIENCIES WITH WEIRS

***

Approach Too Short!

The inlet is too close to the outlet.

To get an accurate measurement the flow must be smooth. Here the waves from the inlet flow are rippling around the basin. Thus, the surface is not smooth, and an accurate flow cannot be determined.

Weir Too Broad

Remember the crest of a weir has to be less than 1/8 of an inch or chamfered at 45 degrees after the first 1/8 of an inch.

Broad-crested Weir

Broad-crested Weir Formula

Q = cLH1.5

Q = cubic feet/second

L = length of crest (feet)

H = Head (feet)

C = Coefficient

- specific to the weir shape and varies with water elevation.

Typically used where maintenance and structural integrity are issues i.e. dams and rivers.

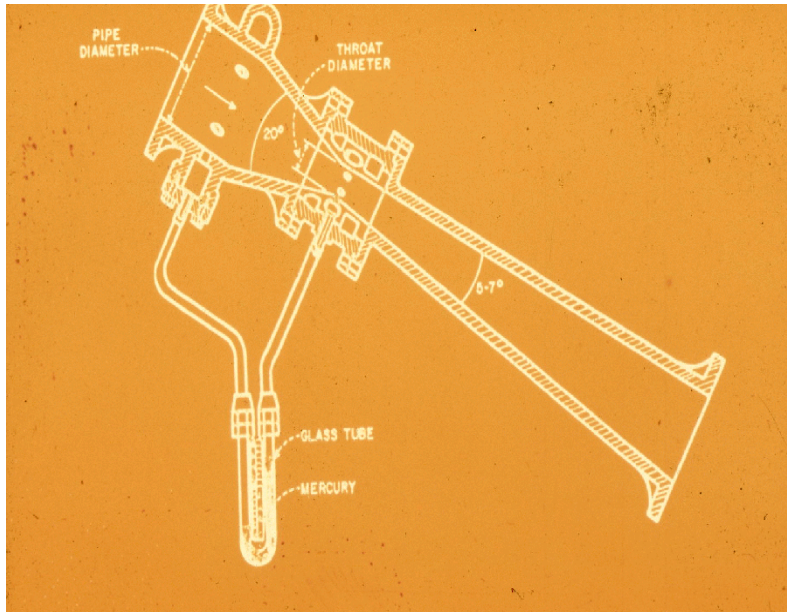
Common Closed Channel Systems

Venturti Meters

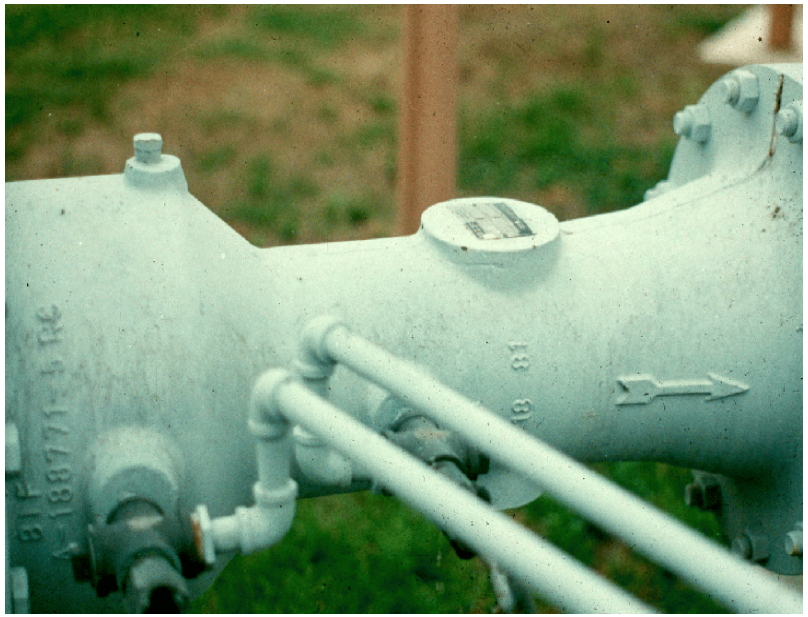
Doppler Flow Meters

Magnetic Flow Meters

Venturi Meters

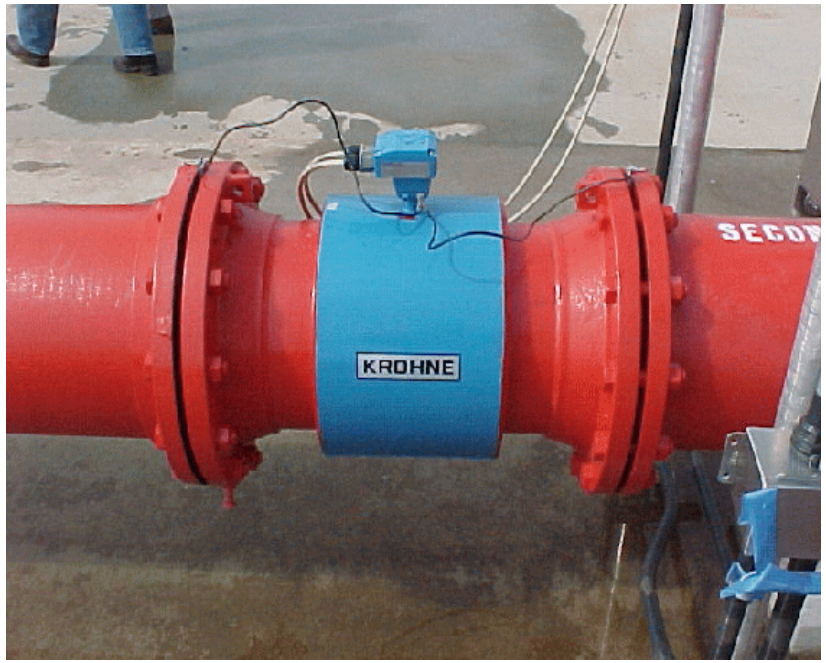


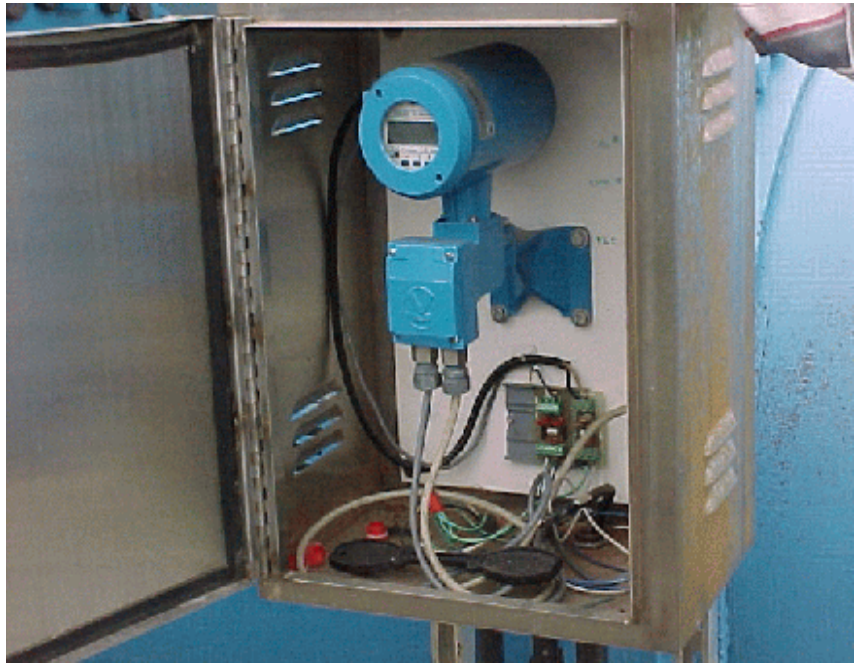
Cross-section of a Venturi Meter



Venturi meter in operation

Magnetic Flow Meter





- Magnetic Flow Meter

- https://www.youtube.com/watch?v=lRSjYjg9WRo

Ultrasonic / Transit Time

- https://youtu.be/NQWNYARWmB8?si=OSYjb4nxspJyXth6

General Requirements: Closed Channel Systems

- Full pipe flow conditions
- Straight length of pipe for 5 to 20 diameters
- Accuracy checked annually

Poll Question

True or False:

Doppler meters need dirty water to function correctly?

***

Questions

***