DISCHARGE MEASUREMENTS AT GAGING STATIONS

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Abstract

The techniques used in making discharge measurements at gaging stations are described in this report. Most of the report deals with the current-meter method of measuring discharge, because this is the principal method used in gaging streams. The use of portable weirs and flumes, floats, and volumetric tanks in measuring discharge are briefly described.

Introduction

The U.S. Geological Survey makes thousands of streamflow measurements each year. Discharges measured range from a trickle in a ditch to a flood on the Amazon. Several methods are used, but the Geological Survey makes most streamflow measurements by current meter. The purpose of this report is to describe in detail the procedures used by the Geological Survey for making current-meter measurements and to describe briefly several of the other methods of measuring streamflow.

Streamflow, or discharge, is defined as the volume rate of flow of the water including any sediment or other solids that may be dissolved or mixed with it. Dimensions are usually expressed in cubic feet per second. Other common units are million gallons per day and acre-feet per day.

Current-Meter Measurements

A current-meter measurement is the summation of the products of the partial areas of the stream cross section and their respective average velocities. The formula

$$Q = \Sigma(a\ v) \qquad (1)$$

represents the computation where Q is total discharge, a is an individual partial cross-section area, and v is the corresponding mean velocity of the flow normal to the partial area.

In the midsection method of making a current-meter measurement it is assumed that the velocity sample at each location represents the mean velocity in a partial rectangular area. The area extends laterally from half the distance from the preceding meter location to half the distance to the next and vertically, from the water surface to the sounded depth. (See fig. 1.)

The cross section is defined by depths at locations 1, 2, 3, 4, . . . n. At each location the velocities are sampled by current meter to obtain the mean of the vertical distribution of velocity. The partial discharge is now computed for any partial section at location x as

$$q_x = v_x\left[\frac{(b_x - b_{(x-1)})}{2} + \frac{(b_{(x+1)} - b_x)}{2}\right]d_x$$

$$= v_x\left[\frac{b_{(x+1)} - b_{(x-1)}}{2}\right]d_x, \qquad (2)$$

where

q_x = discharge through partial section x,
v_x = mean velocity at location x,
b_x = distance from initial point to location x,
$b_{(x-1)}$ = distance from initial point to preceding location,
$b_{(x+1)}$ = distance from initial point to next location,
d_x = depth of water at location x.

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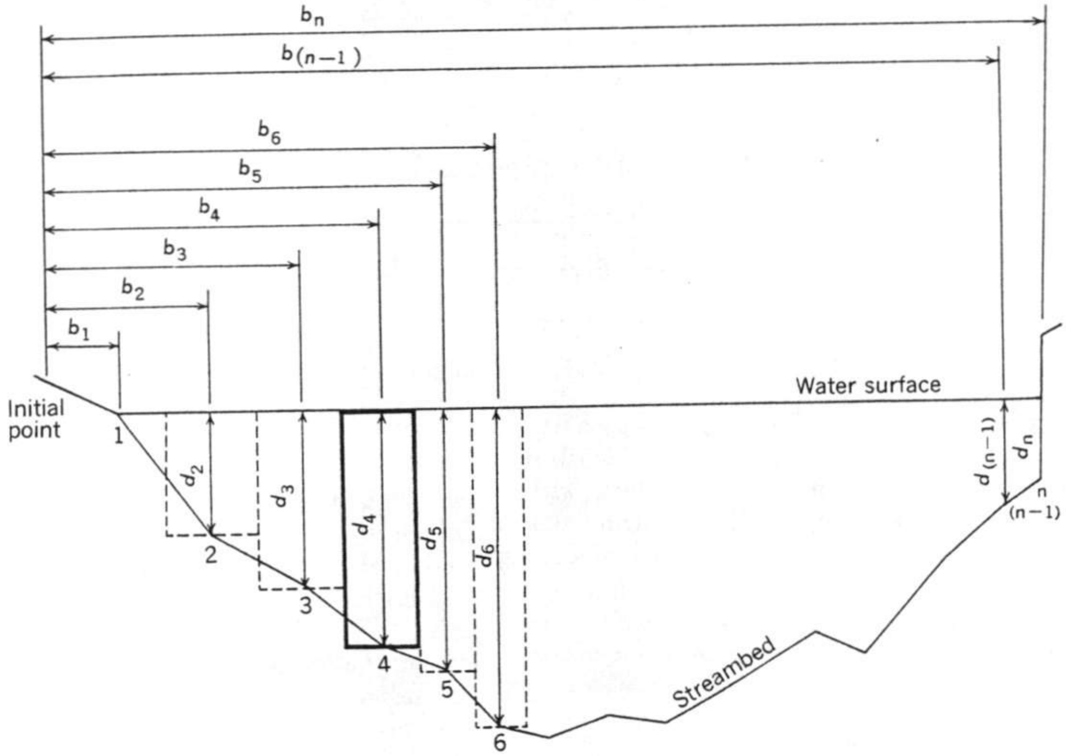


EXPLANATION

1, 2, 3, ... *n*	Observation points
$b_1, b_2, b_3, \ldots\ldots b_n$	Distance, in feet, from the initial point to the observation point
$d_1, d_2, d_3, \ldots\ldots d_n$	Depth of water, in feet, at the observation point
Dashed lines	Boundary of partial sections; one heavily outlined discussed in text

Figure 1.—Definition sketch of midsection method of computing cross-section area for discharge measurements.

Thus, for example, the discharge through partial section 4 (heavily outlined in fig. 1) is

$$q_4 = v_4\left[\frac{b_5 - b_3}{2}\right]d_4.$$

The procedure is similar when x is at an end section. The "preceding location" at the beginning of the cross section is considered coincident with location 1; the "next location" at the end of the cross section is considered coincident with location n. Thus,

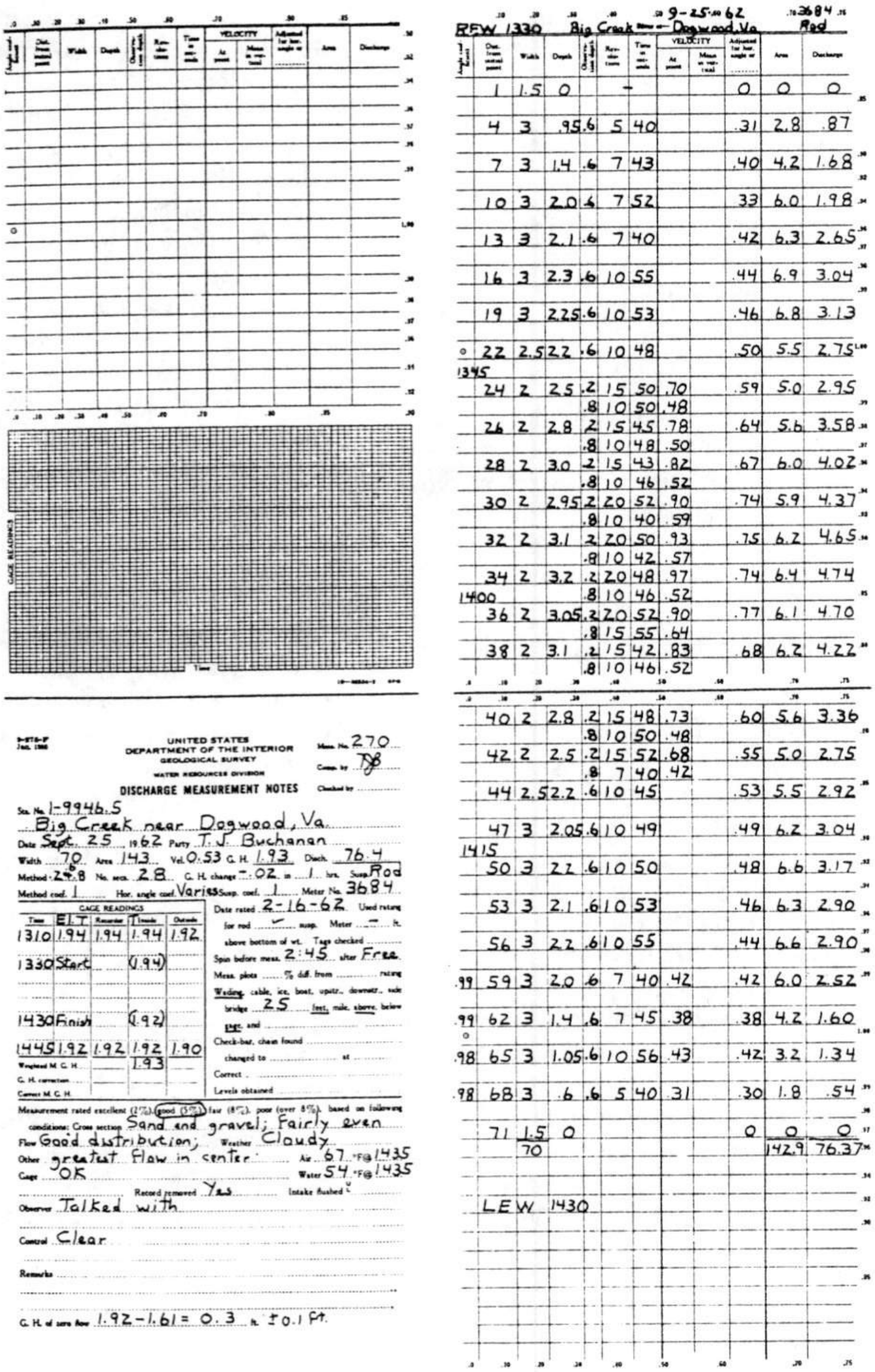
$$q_1 = v_1\left[\frac{b_2 - b_1}{2}\right]d_1, \text{ and}$$

$$q_n = v_n\left[\frac{b_n - b_{(n-1)}}{2}\right]d_n.$$

For the example shown in figure 1, q_1 is zero because the depth at observation point 1 is zero. However, when the cross-section boundary is a vertical line at the edge of the water as at location n, the depth is not zero and velocity at the end section may or may not be zero. The formula for q_1 or q_n is used whenever there is water only on one side of an observation point such as at piers, abutments, and islands. It usually is necessary to estimate the velocity at an end section as some percentage of the adjacent section because it normally is impossible to measure the velocity accurately with the current meter close to a boundary. There also is the possibility of damage to the equipment if the flow is turbulent.

The summation of the discharges for all the partial sections is the total discharge of the stream. An example of the measurement notes is shown in figure 2.

The mean-section method used by the Survey prior to 1950 differs from the midsection method in computation procedure. Partial discharges are computed for partial sections between successive locations. The velocities and depths at successive locations are each averaged, and



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
DISCHARGE MEASUREMENT NOTES

Meas. No. 270
Comp. by TJB
Checked by

Sta. No. 1-9946.5
Big Creek near Dogwood, Va.
Date Sept. 25 1962 Party T. J. Buchanan
Width 70 Area 143 Vel. 0.53 G. H. 1.93 Disch. 76.4
Method .2-.8 No. secs. 28 G. H. change -.02 in 1 hrs. Susp. Rod
Method coef. 1 Hor. angle coef. Varies Susp. coef. 1 Meter No. 3684

GAGE READINGS				
Time	ELT	Recorder	Inside	Outside
1310	1.94	1.94	1.94	1.92
1330	Start		(1.94)	
1430	Finish		(1.92)	
1445	1.92	1.92	1.92	1.90
Weighted M. G. H.			1.93	
G. H. correction				
Correct M. G. H.				

Date rated 2-16-62 Used rating for rod ✓ susp. Meter – ft. above bottom of wt. Tags checked
Spin before meas. 2:45 after Free
Meas. plots % diff. from rating
Wading, cable, ice, boat, upstr., downstr., side bridge 25 feet, mile, above, below gage, and
Check-bar, chain found changed to at
Correct
Levels obtained

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section Sand and gravel; Fairly even
Flow Good distribution; Weather Cloudy
Other greatest flow in center Air 67 °F @ 1435
Gage OK Water 54 °F @ 1435
Record removed Yes Intake flushed
Observer Talked with
Control Clear
Remarks
G. H. of zero flow 1.92-1.61 = 0.3 ft. ±0.1 ft.

REW 1330 Big Creek near Dogwood, Va. 9-25-62 3684 Rod

Angle coef.	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted for hor. angle	Area	Discharge
	1	1.5	0		–				0	0	0
	4	3	.95	.6	5	40			.31	2.8	.87
	7	3	1.4	.6	7	43			.40	4.2	1.68
	10	3	2.0	.6	7	52			33	6.0	1.98
	13	3	2.1	.6	7	40			.42	6.3	2.65
	16	3	2.3	.6	10	55			.44	6.9	3.04
	19	3	2.25	.6	10	53			.46	6.8	3.13
	22	2.5	2.2	.6	10	48			.50	5.5	2.75
1345											
	24	2	2.5	.2	15	50	.70		.59	5.0	2.95
				.8	10	50	.48				
	26	2	2.8	.2	15	45	.78		.64	5.6	3.58
				.8	10	48	.50				
	28	2	3.0	.2	15	43	.82		.67	6.0	4.02
				.8	10	46	.52				
	30	2	2.95	.2	20	52	.90		.74	5.9	4.37
				.8	10	40	.59				
	32	2	3.1	.2	20	50	.93		.75	6.2	4.65
				.8	10	42	.57				
	34	2	3.2	.2	20	48	.97		.74	6.4	4.74
1400				.8	10	46	.52				
	36	2	3.05	.2	20	52	.90		.77	6.1	4.70
				.8	15	55	.64				
	38	2	3.1	.2	15	42	.83		.68	6.2	4.22
				.8	10	46	.52				
	40	2	2.8	.2	15	48	.73		.60	5.6	3.36
				.8	10	50	.48				
	42	2	2.5	.2	15	52	.68		.55	5.0	2.75
				.8	7	40	.42				
	44	2.5	2.2	.6	10	45			.53	5.5	2.92
	47	3	2.05	.6	10	49			.49	6.2	3.04
1415											
	50	3	2.2	.6	10	50			.48	6.6	3.17
	53	3	2.1	.6	10	53			.46	6.3	2.90
	56	3	2.2	.6	10	55			.44	6.6	2.90
.99	59	3	2.0	.6	7	40	.42		.42	6.0	2.52
.99	62	3	1.4	.6	7	45	.38		.38	4.2	1.60
.98	65	3	1.05	.6	10	56	.43		.42	3.2	1.34
.98	68	3	.6	.6	5	40	.31		.30	1.8	.54
	71	1.5	0						0	0	0
		70								142.9	76.37

LEW 1430

Figure 2.—Computation notes of a current-meter measurement by the midsection method.

the section extends laterally from one observation point to the next. Discharge is the product of the average of two mean velocities, the average of two depths, and the distance between locations. A study by Young (1950) concluded that the midsection method is simpler to compute and is a slightly more accurate procedure than the mean-section method.

Current-meter measurements usually are classified in terms of the means used to cross the stream during the measurement, such as wading, cableway, bridge, boat, or ice.

Instruments and equipment

Current meters, timers, and counting equipment are used when making conventional types of measurements. Additional equipment used depends on the type of measurements being made. Instruments and equipment used in making current-meter measurements are described in this section under the following categories: current meters, sounding equipment, width-measuring equipment, equipment assemblies, and miscellaneous equipment.

Current meters

A current meter is an instrument used to measure the velocity of flowing water. The principle of operation is based on the proportionality between the velocity of the water and the resulting angular velocity of the meter rotor. By placing a current meter at a point in a stream and counting the number of revolutions of the rotor during a measured interval of time, the velocity of water at that point is determined.

The number of revolutions of the rotor is obtained by an electrical circuit through the contact chamber. Contact points in the chamber are designed to complete an electrical circuit at selected frequencies of revolution. Contact chambers can be selected having contact points that will complete the circuit twice per revolution, once per revolution, or once per five revolutions. The electrical impulse produces an audible click in a headphone or registers a unit on a counting device.

The counting intervals are measured by a stopwatch.

Current meters generally can be classified into two main types, those meters having vertical-axis rotors and those having horizontal-axis rotors. The comparative characteristics of these two types are summarized below:

1. Vertical-axis rotor with cups or vanes.
    a. Operates in lower velocities than do horizontal-axis meters.
    b. Bearings are well-protected from silty water.
    c. Rotor is repairable in the field without adversely affecting the rating.
    d. Single rotor serves for the entire range of velocities.
2. Horizontal-axis rotor with vanes.
    a. Rotor disturbs flow less than do vertical-axis rotors because of axial symmetry with flow direction.
    b. Rotor is less likely to be entangled by debris than are vertical-axis rotors.
    c. Bearing friction is less than for vertical-axis rotors because bending moments on the rotor are eliminated.

Vertical-axis current meters

The most common type of vertical-axis current meter is the Price meter, type AA. (See fig. 3.) This meter is used extensively by the Geological Survey. The standard Price meter has a rotor 5 inches in diameter and 2 inches high with six cone-shaped cups mounted on a stainless-steel shaft. A pivot bearing supports the rotor shaft. The contact chamber houses the upper part of the shaft and an an eccentric contact that wipes a bead of solder on a slender bronze wire (cat's whisker) attached to the binding post. A separate reduction gear (pentagear), wire, and binding post provide a contact each time the rotor makes five revolutions. A tailpiece keeps the meter pointing into the current.

In addition to the standard type AA meter for general use there is a type AA meter for low velocities. No pentagear is provided. This modification reduces friction. The shaft usually has two eccentrics making two contacts per revolution. The low-velocity meter normally is rated from 0.2 to 2.5 fps (feet per second) and is recommended when the mean velocity at a cross section is less than 1 fps.

In addition to the type AA meters, the Geological Survey uses a Price pygmy meter

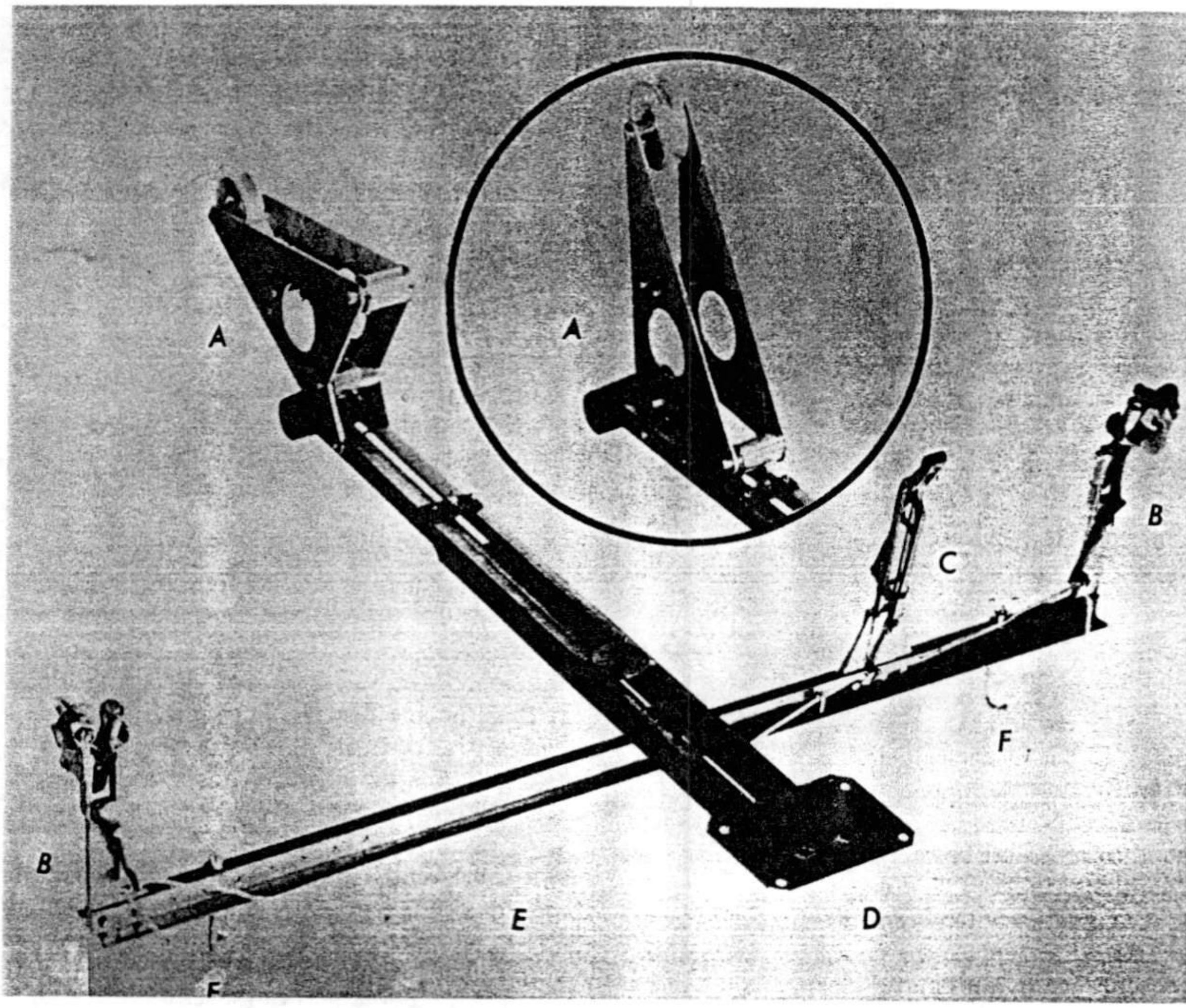


Figure 48.—Boom and crosspiece for use on boats. **A**, retractable end of boom; **B**, guide sheave and clamp for attaching to tag line; **C**, clamp to prevent movement of the boat along the tag line; **D**, plate to accommodate reel; **E**, rope to release clamps (**B**) to free boat from tag line; and **F**, clamps to attach crosspiece to boat.

but is not generally adapted to routine discharge measurements because of the extra time required to collect field data and to compute the mean velocity.

Two-point method

In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the surface. The average of these two observations is taken as the mean velocity in the vertical. This method is based on many studies of actual observation and on mathematical theory. Experience has shown that this method gives more consistent and accurate results than any of the other methods except the vertical-velocity curve method. (See p. 31.) The two-point method is the one generally used by the Geological Survey.

The two-point method is not used at depths less than 2.5 feet because the current meter would be too close to the water surface and to the streambed to give dependable results.

Six-tenths-depth method

In the 0.6-depth method, an observation of velocity made at 0.6 of the depth below the surface in the vertical is used as the mean velocity in the vertical. Actual observation and mathematical theory has shown that the 0.6-

Figure 49.—Measuring equipment set up in a boat.

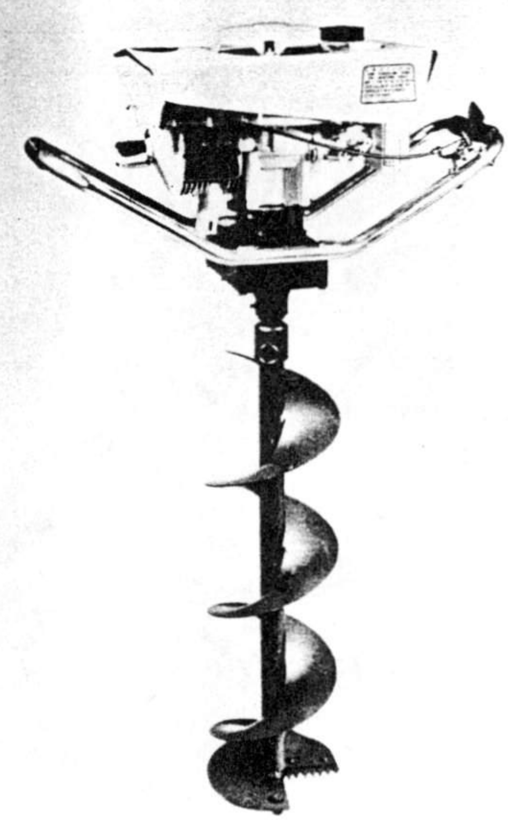


Figure 50.—Gasoline-powered ice drill. Photograph by permission of General Equipment Co.

depth method gives reliable results and is used by the Geological Survey under the following conditions:

1. Whenever the depth is between 0.3 foot and and 2.5 feet.
2. When large amounts of slush ice or debris make it impossible to observe the velocity accurately at the 0.2 depth. This condition prevents the use of the two-point method.
3. When the meter is placed a distance above the sounding weight which makes it impossible to place the meter at the 0.8 depth. This circumstance prevents the use of the two-point method.
4. When the stage in a stream is changing rapidly and a measurement must be made quickly.

Two-tenths-depth method

The two-tenths-depth method consists of observing the velocity at 0.2 of the depth below the surface and applying a coefficient to this observed velocity to obtain the mean in the vertical. It is used mainly during times of high water when the velocities are great, making it impossible to obtain soundings or to place the meter at the 0.8 or the 0.6 depth.

A standard cross section or a general knowledge of the cross section at a site is used to compute the 0.2 depth when it is impossible to obtain soundings. A sizeable error in an assumed 0.2 depth is not critical because the slope of the vertical-velocity curve at this point is usually nearly vertical. (See fig. 56.) The 0.2 depth is also used in conjunction with the sonic sounder for flood measurements. (See p. 16.) The two-point method and the 0.6-depth method are preferred over the 0.2-depth method because of their greater accuracy.

The measurement is normally computed by using the 0.2-depth velocity observations without coefficients as though each were a mean in