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construction and use of A Velocity Head Rod *for* Measuring Stream Velocity and Flow

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U. S. DEPARTMENT OF THE INTERIOR
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Use common sense for safety when measuring streams in unfamiliar areas or where waters flow faster than 9 feet per second. Be careful in streams deeper than 3-1/2 feet or those that have rocky beds or steep banks. Where flow velocities are more than 5 feet per second and the water is more than 2 feet deep, wear a flotation vest and use a safety rope.

Workers are urged to use the buddy system when making stream surveys

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Construction and Use of

A VELOCITY HEAD ROD

For Measuring Stream Velocity and Flow

Introduction

For aquatic habitat surveys, biologists need to measure the stream being studied and the speed or velocity at which the water flows.

Several instruments that may be used to measure stream flow velocity are the current meter, the floating chip, and the velocity head rod.

Several years ago, technicians at the USDA Forest Service Equipment Development Center, San Dimas, California, devised a method for calculating stream discharge measurements. They constructed a velocity head rod that is dependable, strong, and economical to make and use. The rod is particularly useful in gauging small volumes of stream flow that have varying amounts of bedload and silt. The basic velocity head rod was developed in 1944 by Wilm and Storey.

Although the principle used to design the rod is not new, the rod is simple, portable, easy to construct, and accurate within practical limits. It is a useful tool for habitat surveys on streams on public lands administered by the Bureau of Land Management (BLM).

The construction and use of the rod are described in this technical report, with grateful acknowledgment of the source of the information, the USDA Forest Service Equipment Development Center.

Construction of the Velocity Head Rod

Materials and Tools

One wooden stick--preferably mahogany--1"x4"x5'

Glue (epoxy resin)

Varnish, water seal, or white paint

2 dozen 1/2" brass brads

One metal foot plate or metal cap for base of rod, and screws for attaching it

Two sets of porcelain enameled iron gauges, also called staff gauges (available from forestry or engineering supply stores with either standard or metric measure)

You will need only ordinary tools, including a hammer, screw driver, power drill with 1/4" chuck, metal bits, metal cutting blade for sabre saw, paint brushes, and a sander. A radial arm, table, skill, or sabre saw may be used to shape the rod's knife edge.

Method

Figure 1 shows several views of the rod. Begin construction by preparing the wood if necessary. Mahogany is preferred because it is water resistant. Other strong woods can be used. They should be kiln dried and painted with several coats of water seal, varnish, or white paint.

If funds allow and a machine shop is available, the rod may be made of aluminum.

Measure the center point of one edge at one end of the rod. Next, draw a 2-1/2-inch line from this center point on each side and cut as shown in Fig. 1,C. This leaves a sharp edge on side of the rod (called the knife edge).

Next, attach the stream gauge sections vertically to each side of the knife edge of the rod (see Fig. 1,C). The gauges do not come in 4-foot lengths, so you will need two sections of gauges for each of two sides of the rod. One section is 1.06 feet long; the other is 3.33 feet long. Cut the 1.06-foot section to fit the 3.33-foot section to form a 4-foot gauge. Current cost is $12.50 per pair.

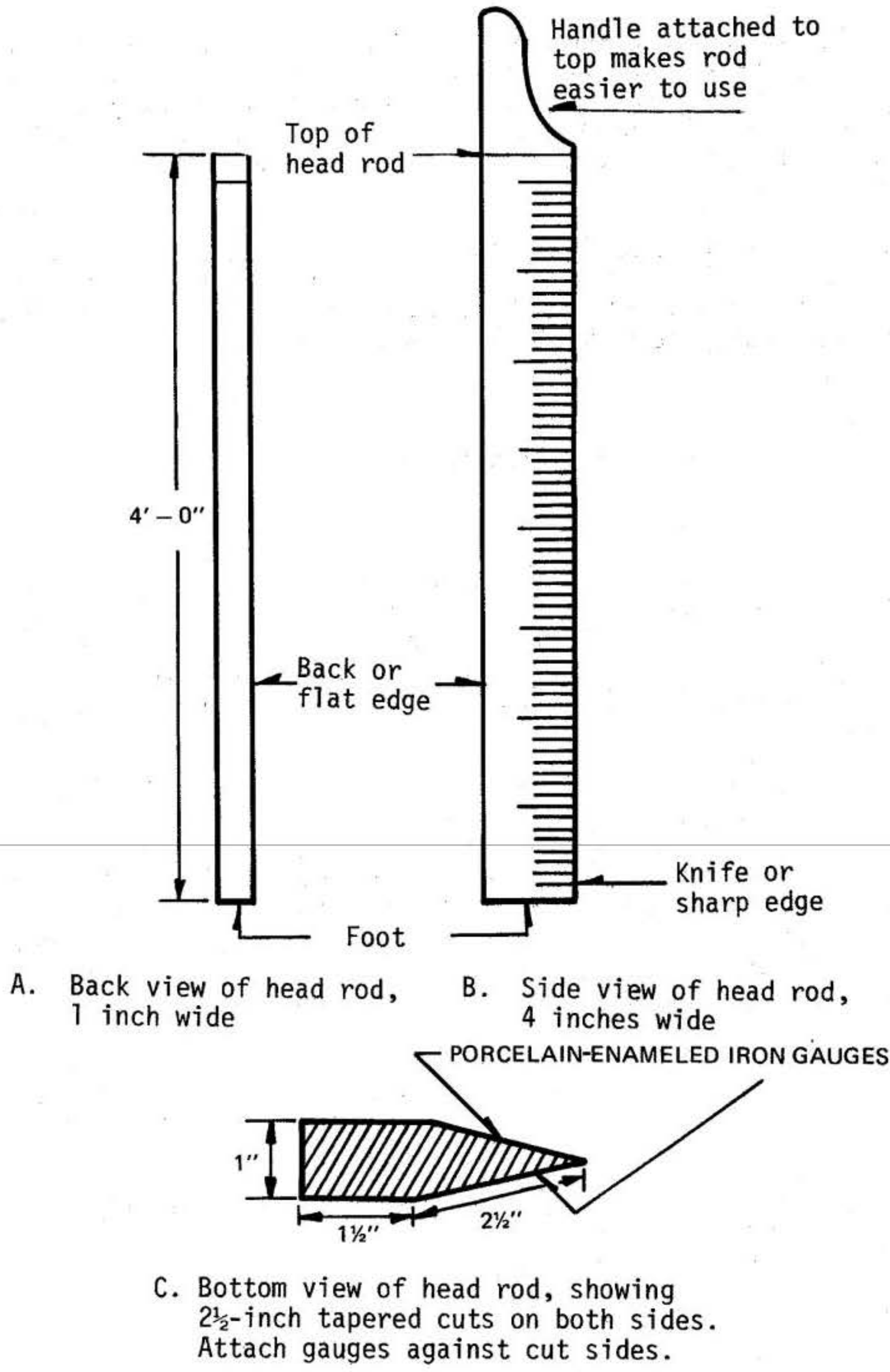

Fig. 1. Back, side, and bottom views of the velocity head rod.

It is important to use both epoxy resin and brass brads to attach the gauge sections vertically to each side of the knife edge of the rod. If the sections have grommets, remove them. The gauge section surfaces must be smooth and free from obstructions that might distort stream flow measurements.

After you have attached the gauge sections, fasten the foot plate to the bottom of the rod with screws. You may wish to attach a small swivel plate with which to turn the rod when measuring stream flows. See Fig. 1,C for foot plate shape.

How to Use the Velocity Head Rod

Measurements from this rod are most accurate when the stream bottom is solid. Place the foot of the rod firmly on the stream bottom and hold the rod upright, with the knife or sharp edge facing directly upstream as shown in Fig. 2,A. The stream depth at this point is indicated by the water elevation that occurs most frequently at the knife edge. Record this measurement.

Revolve the rod 180 degrees so the back or flat edge is opposed to the stream flow. Maintain the same location--even a slight change in rod location can cause large errors. The increase in water elevation is caused by the impingement of water against the broad edge of the rod. See Fig. 2, B. The most frequent water elevation measures the total energy content of the stream at this point. The difference between the readings, expressed in feet, is the actual velocity head.

Using Table 1, you can calculate the velocity in feet per second. The procedure for making computations is presented in Table 2.

Velocity head rod measurements can be made using either the U.S. customary system or the metric system by converting measurements to fit the system selected.

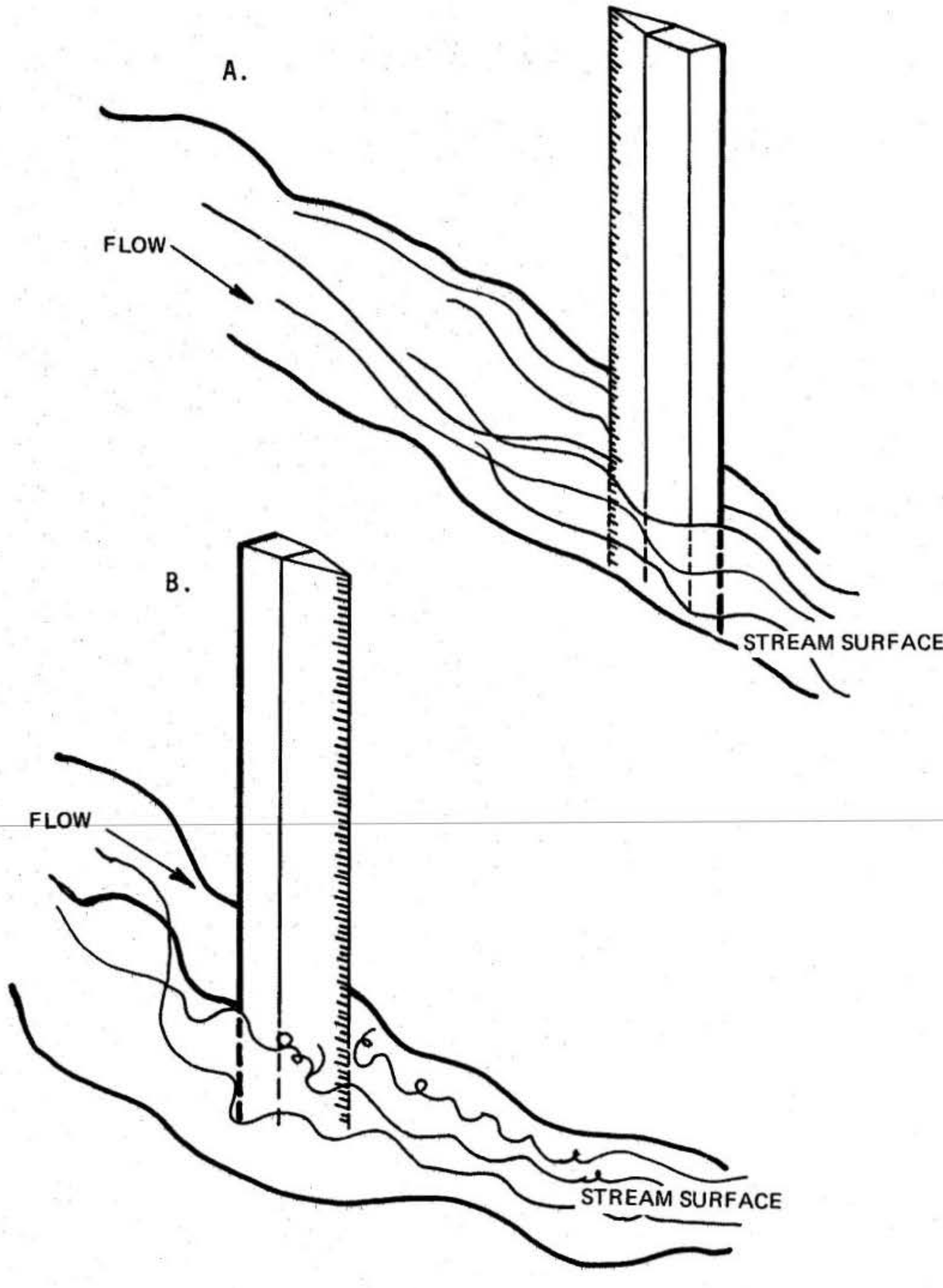

Fig. 2. How to take measurements with the head rod for computing stream velocity.

Table 1. Velocity Head to Velocity Conversion Table.

Column I	Column 2
Velocity head, feet	Velocity, feet/second
0.01	0.80
0.02	1.13
0.03	1.39
0.04	1.60
(g) 0.05	1.79 (h)
0.06	1.96
0.07	2.12
0.08	2.27
0.09	2.41
0.10	2.54
0.15	3.11
0.20	3.59
0.25	4.01
0.30	4.39
0.35	4.74
0.40	5.07
0.45	5.36
0.50	5.67
0.60	6.21
0.70	6.71
0.80	7.17
0.90	7.61
1.00	8.02
1.10	8.41
1.20	8.79
1.30	9.14
1.40	9.46
1.50	9.82

Table 2. Example of Stream Flow Computation Using the Velocity Head Rod.

Rod reading	Rod knife edge upstream (a)	Rod broad edge upstream (b)
	feet	feet
No. 1	0.40	0.42
No. 2	1.60	1.68
No. 3	0.70	0.75
Total.	2.70	2.85
Average.	.90 (c)	0.95 (d)

Stream width = 3.6 feet (e)

Channel area (sq ft) = 3.6x0.90=3.24 [(c)x(e)=(f)]

Velocity head (ft/sec) = 0.95-0.90=0.05 [(d)-(c)=(g)]

Volume (ft^3/sec) = 1.79x3.24=5.80 [(h)x(f)=(i)]

Explanation: Take three measurements with the rod's knife edge upstream (a) and three measurements with the rod's back or broad edge upstream (b). Total each set of measurements; then figure the average for each, (c) and (d) in the table above.

Multiply stream width (e) by the most frequent depth (c) to find stream cross-sectional area in square feet (f).

The difference between (c) and (d) is the velocity head (g). In column 1, Table 1, find the number; for this example it is 0.05. In column 2, Table 1, opposite (g) find the constant (h); in this example, 1.79. Multiply (h)x(f) to find the stream flow volume in cubic feet per second; or average velocity (h) x area in sq ft (f) = flow in ft^3/ sec (i).

The derivation of Table 1 is as follows:

$V = \sqrt{2gh}$ or $V = \sqrt{8.02}$ h, where h is the velocity head. These formulas enable you to compute V for values of h not shown in Table 1.

To compute stream velocity using measurements from the metric head rod, subtract readings taken with the knife edge upstream from readings with knife edge downstream (Fig. 2, A and B). The result equals head (h) in centimeters (cm) or meters (m). In the following computation, g = gravity and V = velocity.

$$h = \frac{V^2}{2g} = \text{Head} \qquad \text{Gravity} = 32.18 \text{ ft/sec/sec}$$
$$9.807 \text{ m/sec/sec}$$
$$V = \sqrt{2gh} \qquad 980.7 \text{ cm/sec/sec}$$
$$9807.0 \text{ mm/sec/sec}$$

More than three measurements should be made for streams wider than 15 feet. The method is shown in Fig. 3 and an example of how to calculate flow of water through a stream cross section using three metric measurements is presented in Table 3.

Measurements may be recorded on a form such as Fig. 4.

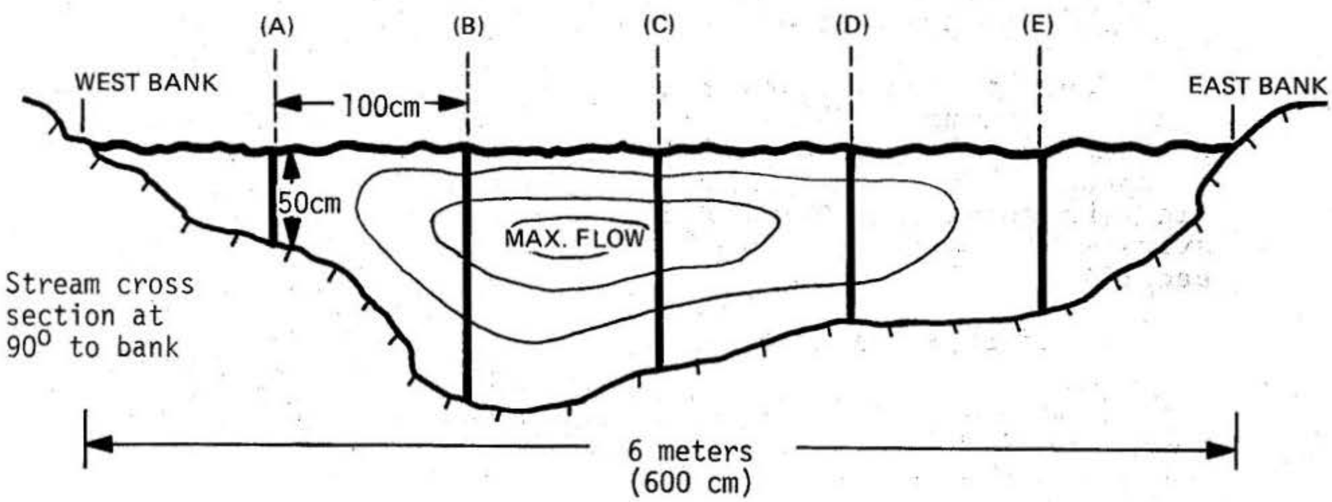

Fig. 3. Example of how to take measurements of a stream cross section. Calculate the flow of water through the cross section as shown in Table 3.

Table 3. Method for Calculating Waterflow Through Stream Cross Sections Using the Formula Q = AV*

	Stream depth† (cm)	water elevation†† (cm)	Velocity (cm/s)	Area (cm^2)		Q (cm^3/s)
(A)	50.0	55.3	102.0	(west) $\frac{0 + 50}{2}$ x 100=	2,500.0	255,000
(B)	131.6	138.7	118.0	$\frac{50 + 131.6}{2}$ x 100=	9,080.0	1,071,440
(C)	111.3	114.5	79.2	$\frac{131.6+111.3}{2}$ x 100=	12,145.0	961,884
(D)	90.5	92.8	67.2	$\frac{111.3+ 90.5}{2}$ x 100=	10,090.0	678,048
(E)	86.2	87.1	42.0	$\frac{90.5+ 86.2}{2}$ x 100=	8,835.0	371,070
			42.2	86.2 + 0 (east)x100=	4,310.0	181,882
					Average =	586,554

Q = 586,554 cm^3/s (20.7 ft^3/s)

*Q = Flow of water through a cross section of a stream; A = Cross section area; V = stream velocity.
†Measured with knife edge of head rod.
††Measured with back or broad edge of head rod.

Limitations

The choice of a cross-section location is especially critical to the successful use of a velocity head rod. Heede (1974) suggests that the cross section have a fairly smooth channel with an approximately prismatic channel geometry,close to plain geometric figures. The flow should be as uniform as possible with little diverging flow. If some flow divergence exists, the rod should be held so that flow lines are intercepted perpendicularly by the velocity head rod. High gradient, boulder-strewn streams with highly turbulent flows pose a particular problem for the velocity head rod. In these situations, the gauged section should be modified to obtain uniform flow conditions.

According to Heede (1974), the velocity head rod is comparable in accuracy to the 1-point current meter method, where the channel is modified properly for velocity head rod measurement.

References

Wilm, H. G., and H. C. Storey. 1944. Velocity-head rod calibrated for measuring streamflow. Civil Engr. 14:475-476.

Heede, B. H. 1974. Velocity-head rod and current meter use in boulder-strewn mountain streams. USDA Forest Service Research Note RM-271. 4 pp.

PERMANENT RECORD FOR MEASURED STREAM FLOW

Stream name ______________________________

Stream location: Sec. ________ Twp. ________ Rg. ________ Mile ________

Head rod reading (feet)	Stream: Rod thin edge upstream	Rod flat edge upstream	Stream: Rod thin edge upstream	Rod flat edge upstream	Stream: Rod thin edge upstream	Rod flat edge upstream	Stream: Rod thin edge upstream	Rod flat edge upstream
No. 1								
No. 2								
No. 3								
No. 4								
No. 5								
Total feet								
Average feet								
Stream width (ft)								
Channel area (sq ft)								
Velocity head (ft/sec)								
Volume (cu ft/sec)								

Remarks:

Exact location of
gauging station:
Recorder:
Date:

Fig. 4. Suggested form for recording stream measurements.

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