Manual of Fisheries Survey Methods II: with periodic updates

Chapter 19: Measurement of Stream Velocity and Discharge

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Chapter 19: Measurement of Stream Velocity and Discharge

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There can be a number of reasons to measure stream flow characteristics:

- To describe the habitat of fish and benthic invertebrates in relation to current preferences;
- To determine the amounts (weight) of materials being transported in the stream (sediment load, nutrient mass);
- To estimate land runoff rates (discharge per unit of watershed area) for agriculture and flood predictions;
- For river basin development in terms of (a) flood control, (b) industrial and domestic water supply potential, and (c) irrigation projects.

The pattern of stream flow is based on several hydrologic features inherent to natural stream channels. Stream velocities are not uniform in all parts of a traverse section but are reduced near the surface due to friction with the surface tension and along the bottom or sides of the channel due to friction with a solid surface (Figure l9.1). For this reason, in studies of organisms that reside on the bottom, one may find velocities at the bottom interface are more important than the average velocity of the stream. Methods for current measurements very close to a surface are not well established and are often considered imprecise. However, for biological studies in streams such measurements may be critical. Hynes (1970) cites a number of such methods.

The maximum velocity in streams is usually found in the upper one-third of the water column (Figure 19.2). However, in shallow streams the region of maximum velocity is near the surface and in deep rivers the maximum is usually at the one-third point. The mean velocity at any point across a stream is ordinarily at 0.55 to 0.65 of the depth. The velocity at 0.6 of the depth is usually within 5% of the mean velocity.

The exact distribution of velocities in natural streams is governed by several factors operating simultaneously. These are:

- Shape of the channel;
- Roughness of the channel;
- Size of the channel;
- Slope of the channel.

Details of how these factors interact to determine the velocity of water are discussed in Hynes (1970) and Whitton (1975).

Velocity measurements with mechanical current meters (e. g., Price-Gurley meters) are usually taken at 0.4 of the depth for shallow streams and at both 0.4 and 0.6 of the depth (then averaged) for rivers or streams having bottom obstructions. Ice cover reduces surface velocity more than air. Therefore, under ice conditions, mean velocity is taken as the average of velocities at the 0.2 and 0.8 points of depth.

Stream discharge (units of volume/time) is dependent upon the product of two somewhat independent measurements: velocity (units of distance/time) and cross-sectional area (an area measure). Current velocity and discharge may be estimated in a variety of ways.

19.1 Methods for Current Measurement

Current velocity may be measured using various types of meters and devices. Apparatus and procedures are described in more detail in Welch (1948) and Buchanan and Sommers (1973). A brief discussion of these methods follows.

19.1.1 Embody Float Method

One of the simplest ways of measuring velocity and discharge in a stream is to use a floating object (Davis 1938). The best objects float just beneath the surface and avoid wind effects. Oranges serve as good floats because they have the right buoyancy and are quite visible. By measuring the time such a float takes to travel downstream over a known distance, one obtains an estimate of the surface velocity. Repeating the float measurement over the same stretch of stream but at various distances from shore will give, when averaged, a rough estimate of the average surface velocity. To obtain an estimate of discharge, measure the average time (t, usually in seconds) for the float to travel the known distance (l) of stream, and measure average depth (d) and average width (w) (preferably made at two or more stream transects). With these data, discharge (Q) is given by:

$$Q = \frac{w\,d\,l\,a}{t}$$

The constant "a" of this formula is a correction factor that relates surface velocity to overall stream mean velocity. This constant varies with the degree of roughness of the stream bottom from 0.9 for sand or mud to 0.8 for coarse gravel or loose rock.

19.1.2 Current Meters (Price-Gurley)

The best known and most dependable mechanical current meter for measuring stream flow is the Price pattern Gurley meter manufactured by the W. and E. Gurley Company. The original Gurley current meter was designed in 1882; the latest model is called Type AA. Stream velocities are measured with a carefully balanced bucket wheel mounted on a pivot. Upon each rotation of the bucket wheel, or every fifth turn depending on the contact setting, an electrical impulse is produced. The impulse may be heard as a click over headphones or recorded on a counter. By noting the number of impulses per unit time, velocity may be determined by consulting the special rating chart prepared for each instrument. The Type AA is capable of accurately measuring velocities from 0.1 to 10 ft/sec. A smaller version of this meter, called the Pygmy Gurley current meter, allows closer measurements to the stream bottom and operates at somewhat slower velocities.

The Type AA Gurley current meter or the Pygmy Gurley may be suspended from either a wading rod assembly or a flexible cable assembly employing a 15-pound torpedo-shaped lead weight.

Use of these current meters with a headphone apparatus requires the operator to count the number of clicks produced by the instrument over a known length of time. Thus, a stopwatch or watch with a second hand is needed. One should select a location in the stream where there is a minimum of turbulence (no eddy currents). When using the current meter for the most accurate work, attach the directional fins available with the unit. These fins allow one to determine both current rate and current direction. This is important because flow does not always move straight downstream, parallel to the banks, so a correction is required. With the fins attached, the angle of deviation from parallel can be measured and looked up in a table of correction coefficients ("K"). The K coefficient multiplied by velocity gives an exact measure of current moving directly downstream at the sampled site. Details of this procedure are best left for the instructions included with each meter.

Alternatively, one can obtain a more approximate estimate of discharge with the current meter by ignoring directional variability of flow. In this simpler method, omit the fins and measure the current at 0.6 of the depth at selected intervals along a transect line. The arithmetic average of these values gives an overall mean velocity across that transect. If one also records, along the same transect, water depth at selected intervals and total stream width, these results can be plotted on graph paper. This width-depth plot can be used to estimate the stream's cross-sectional area by simply counting squares on the graph and applying an appropriate weighting factor for each square. Multiplying cross-sectional area by mean velocity produces an estimate of discharge at that transect. One should measure discharge at two or more transects in close proximity to estimate the average discharge of the river in a particular reach.

19.1.3 Cone and Rubber Bag Method

A simple, inexpensive device for measuring current velocity has been described by Hynes (1970). The device consists of a truncated cone with a small opening (less than 10 mm diameter) which has a rubber bag attached to its base. It is helpful if the bag is surrounded by a clear, open-ended plastic cylinder (Figure 19.3). A suitable cone is a small, plastic garden hose attachment. Balloons are suitable rubber bags; they should be long and relatively large. A balloon is easily attached to the garden hose cone using the rubber washer that is supplied with the cone.

19.1.3.1 Operation.–Close the cone opening with a finger and place the device, facing into the current, at the point where a measurement is to be made. (This should be a measured distance from the bottom for precision and replication). Remove the finger for a few seconds (precisely timed—usually 5 seconds or less, depending upon the size of the cone opening, the size of the bag, and the current velocity) and then replace it. Measure the volume of water collected with a graduated cylinder. The measurement should be repeated several times at each sampling point. An average of four or five measurements should always be used; use more for precise work.

Sampling time should be chosen so that the bag does not become full. In relatively fast currents (more than 50 cm/s), this necessitates the use of either short sampling times or fairly large bags. The latter is preferable because more error is associated with measuring short time intervals. Be sure the bag is empty between measurements. Air should be expelled by squeezing the bag before placing a finger over the opening.

19.1.3.2 Calculations.–Current velocity is determined using the discharge relationship:

$$V = \frac{Q}{A} \; ,$$

where: V = velocity (cm/s);

$$Q = \frac{\text{volume of water sampled in milliliters (ml)}}{\text{time for sample in seconds (s)}} \; ,$$

$$A = \pi \left(\frac{D}{2} \right)^2 \text{, with } D \text{ the diameter of the cone opening in centimeters (cm).}$$

This gives V in units of cm/s (30.5 cm/s = 1 ft/s). D should be measured as precisely as possible. Since Q is a linear function of V (with slope A), a plot of Q versus V can be prepared and used to provide a quick estimate of V in the field.

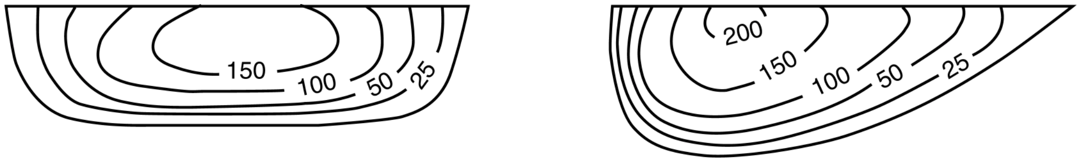

Figure 19.1–Idealized diagrams of the patterns of flow in cross-section of open channels: left shows the pattern on a straight reach, right shows the pattern on a bend. The units on the lines of equal flow-rate could be centimeters per second. (modified from Hynes 1970)

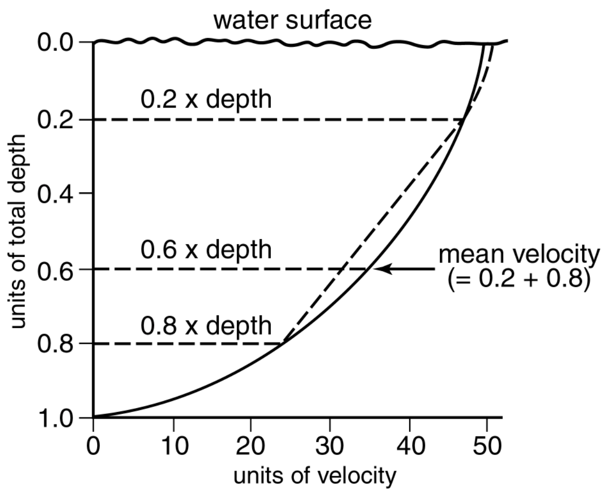

Figure 19.2–The rate of flow of water at different depths in an open channels, and depths at which the mean flow can be measured. (modified from Hynes 1970)

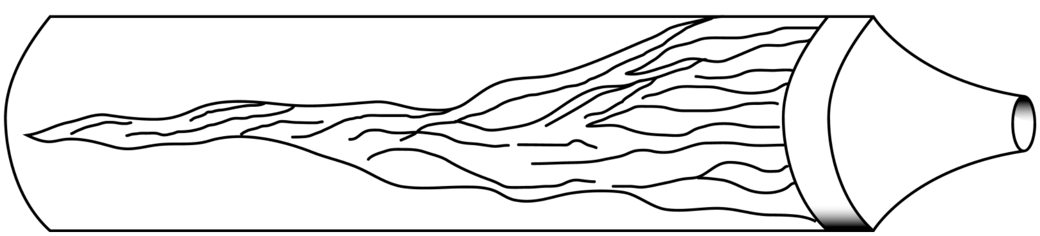

Figure 19.3–A rubber-bag current meter. (from Hynes 1970)

19.2 References

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