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Measuring Discharge in Wadeable Streams

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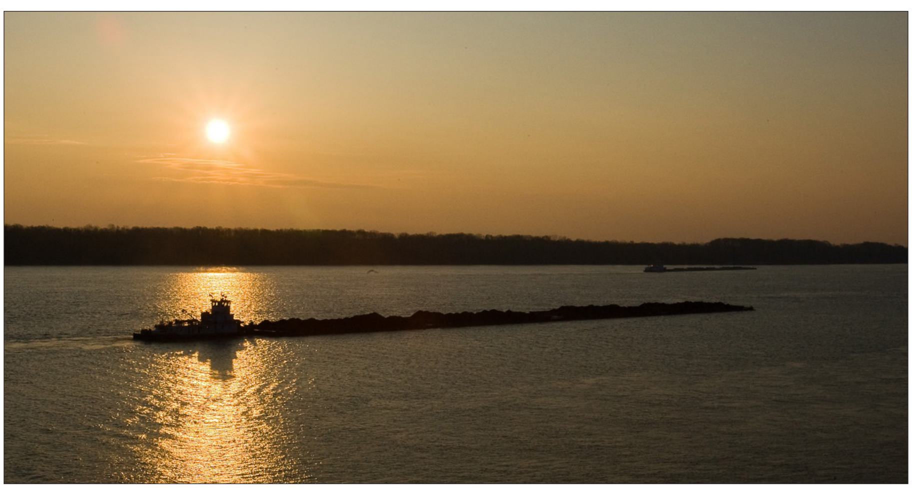
Streams and rivers are plentiful in Kentucky from small mountain brooks to large rivers such as the Mississippi River along the Commonwealth's western border and the Ohio River along its northern border (Figure 1). Kentucky has more than 90,000 miles of streams and contains more navigable water than any other state except Alaska. These streams provide important ecological services such as transporting water, sediment and nutrients and providing habitats to aquatic organisms such as fish and macroinvertebrates and terrestrial ones such as deer and birds. Streams also provide societal services, including drinking water, transportation and recreation. Careful management of these waterbodies is therefore important.

Figure 1. Kentucky has thousands of miles of (a) streams (Upper Beaver Dam Creek, Perry County, Kentucky) and (b) and rivers (Ohio River, Paducah, Kentucky).

(a) *Source: Carmen Agouridis*



(b) *Source: Stephen Patton, Agricultural Communications*

Knowing the amount of water flowing in a stream can improve management practices such as those related to streambank erosion, pollutant loading and transport, and flood control. Streamflow or discharge is defined as the volume of water moving past a specific point in a stream for a fixed period of time. In the U.S., discharge is commonly expressed in units of cubic feet per second (ft^3/s or cfs). Factors that affect the amount of discharge in a stream include drainage area, weather, and water withdrawals. As drainage area increases, the amount of discharge also increases as more land contributes runoff to the stream. Large storm events produce more runoff than smaller ones. Water withdrawals related to irrigation, industrial uses, or even evapotranspiration by riparian or streamside vegetation can decrease streamflow.

Who Measures Discharge?

The U.S. Geological Survey (USGS) is responsible for measuring discharge on many of the nation's streams. The USGS installed its first stream gages in 1889 on the Rio Grande River in New Mexico. Now the USGS maintains nearly 8,000 stream gages throughout the U.S. Discharge data from the USGS are available at www.usgs.gov. Other groups that monitor streamflow, often for short periods of time, include researchers at universities, citizen groups, and other government agencies involved in land and water management and protection.

How is Discharge Measured?

To measure a stream's discharge, information on the shape of the stream and the speed of the flowing water is needed. Discharge (Q, ft^3/s) is the product of area (A, ft^2) and velocity (v, ft/s) as shown in Equation 1.

$$Q = A \cdot v \qquad \textbf{Eqn. 1}$$

Area is the product of width (w, ft) and depth (d, ft). Velocity represents the speed of the flowing water in the stream. Velocity measurements are typically taken in a straight section of the stream. Such sections are often stable and uniform in shape which are important factors in determining discharge over longer periods of time.

Discharge measurements are often taken using the velocity-area method, which involves dividing the stream's cross-section into multiple subsections (Figure 2). Within each subsection, area is determined by measuring the width and depth of the subsection. The average velocity in each subsection is also measured, which typically involves using a current meter (Figure 3). For each subsection, the width, depth and velocity measurements are multiplied. The discharge values for each subsection are summed to arrive at the total discharge for the stream cross-section.

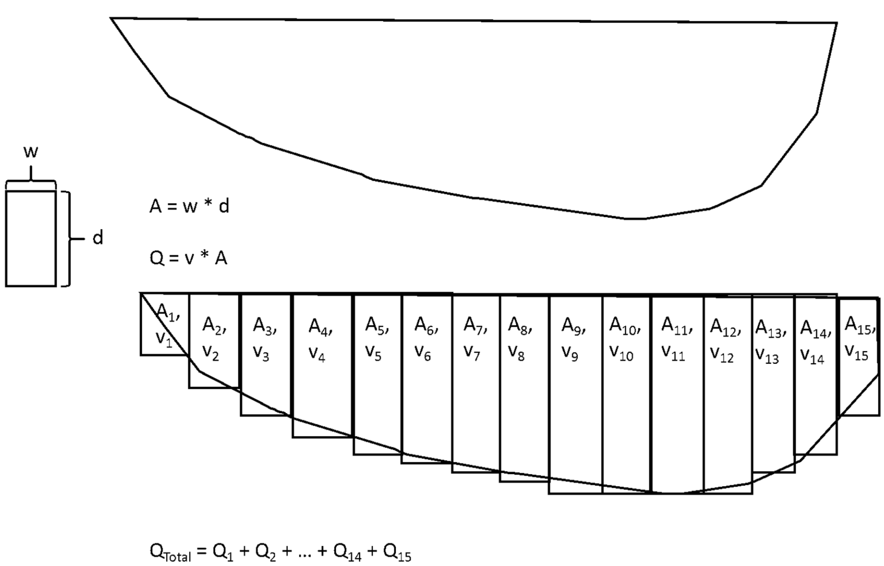
Figure 3. Velocity is often measured using a current meter (Ledbetter Creek, Calloway County, Kentucky).

Source: Alan Fryar, Earth and Environmental Sciences

Stage-Discharge Rating Curves

Continuously measuring discharge in a stream is not practical. Instead, it is common to measure water level or stage continuously and relate stage to discharge (Figure 4). Such a relationship, which is termed the stage-discharge relationship or rating curve, allows for the development of a continuous record of discharge. Rating curves are site-specific because the relationship between stage and discharge depends on factors such as the shape and size of the stream. Rating curves developed for one location cannot be used for another. Because streams are dynamic systems, it is important to regularly check and update stage-discharge relationships. The USGS develops rating curves for its active stream gages. These rating curves are available at the USGS Ratings Depot.

Figure 2. The velocity-area method is used to estimate discharge. The cross-section is divided into many subsections.



Structures

For small watersheds, a common method of measuring streamflow is with a weir or flume (Figure 5). A weir is a structure that is used to obstruct the flow in a stream and direct it through an opening of a defined shape. A flume is designed to be installed in the channel using a specific shape (e.g. trapezoidal) that closely matches the shape of the original channel. The stage behind the weir or within the flume is measured and converted to discharge based on a known stage-discharge relationship for that particular structure.

Figure 4. Example of a stage-discharge rating curve. Each circle represents a concurrent stage and discharge measurement. Stage of 2 ft means discharge is about 17 ft^3/s.

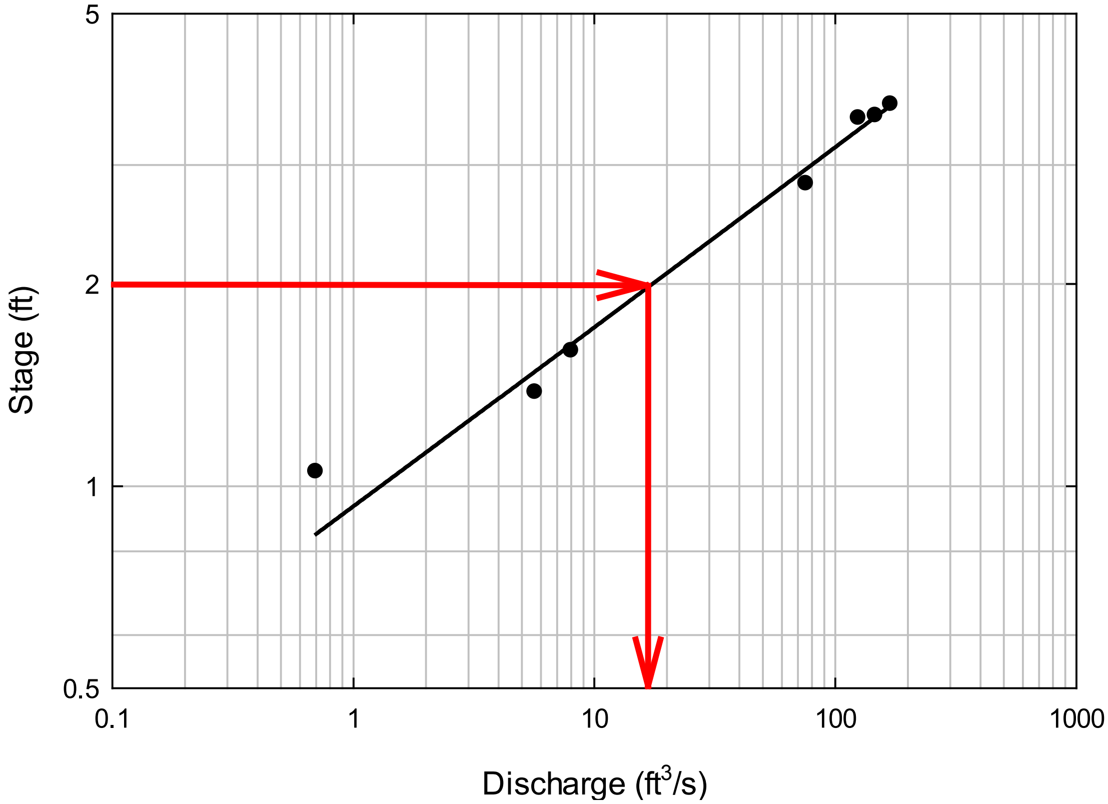


Figure 5. Structures such as (a) weirs and (b) flumes are used to measure streamflow (Camden Creek, Woodford County, Kentucky).

(a) *Source: Matt Barton, Agricultural Communications*

(b) *Source: Carmen Agouridis, Biosystems and Agricultural Engineering*

Floating Objects

One method to quickly estimate a stream's discharge is measure its width and average depth with a tape measure and estimate velocity using a floating object such as an orange peel. Measure the width of the channel at the water surface elevation (i.e. where the water surface intersects the left and right banks). Take 3-4 measurements of the water depth and average these measurements. Velocity is estimated by recording the time it takes the floating object to travel a known distance. Discharge is the product of width, depth and velocity. Because velocity varies across the stream channel, this method has a lower level of accuracy.

A simple way to measure velocity is by using a float such as an orange peel, a tape measure, and a stop watch.

1. Use a tape measure to mark a section of stream at least 20 ft in length.
2. Drop the orange peel about 5 ft above the start of the marked section. Try to drop the orange peel in the center of the stream.
3. When the orange peel reaches the beginning of the marked section, start the stopwatch.
4. When the orange peel reaches the end of the marked section, stop the stopwatch.
5. Repeat at least two more times.
6. Add all of the times and divide by the number of repetitions to obtain an average time.
7. Divide the length of the marked section by the average time to get an average surface velocity and then multiple by 0.8. The 0.8 correction accounts for the fact that the velocity of water at the surface is faster than water along the streambed.

Example:

A 50 foot distance is marked off along a stream. The times it takes for an orange peel to travel the marked distance are 12, 10, and 11 seconds giving an average time of 11 seconds.

$$(12+10+11)/3 = 11 \text{ s}$$

For a distance of 50 feet and an average time of 11 seconds, using the 0.8 correction, the average velocity is 3.6 feet per second.

$$(50/11)*0.8=3.6 \text{ ft/s}$$

References

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