Methods of Streamflow Analysis
Recent boosts in urbanization and technology to meet society’s ever-increasing demands have added to the growing awareness of and concern for the environment. Research, planning, design, operation, maintenance, and enforcement of laws with respect to water conservation and water quality control, all rely on flow measurements. Hence, strict legislation and continuing public interest in conservation and environmental matters have highlighted the significance of flow measurements.

Understanding the flow of water into and through stream channels is critical to the development of stream restoration initiatives. At a minimum it is helpful to know whether a stream is perennial, intermittent, or ephemeral and the relative contributions of baseflow and stormflow to stream discharge. Other desirable information include the relative frequency and duration of extreme high and low flows and the duration of certain stream levels.

Streamflow or discharge (Q) is the flow of water in streams. Specifically, it is the volume of water passing a point in a given time, and it is comprised of baseflow and stormflow. Streamflow is measured at a location along the stream from the water velocity and the cross-sectional flow area. The main objective of this chapter is to describe various common techniques for measuring streamflow.
II. SPECIFIC METHODS

Measuring Techniques

**Floating Objects:** One of the simplest ways to measure discharge is to observe the time it takes a floating object to travel a given distance. A measurement of the cross-sectional area of the stream should be made simultaneously, such that,

\[ Q = VA \]

where \( Q \) = discharge (\( \text{m}^3/\text{sec} \)); \( V \) = velocity (\( \text{m/sec} \)); and \( A \) = cross-sectional area (\( \text{m}^2 \)).

This method is not always accurate, especially for large streams, since velocity varies from point to point with depth and width over the cross-section of the stream. Generally, actual velocity is about 80-85% of surface velocity.

**Stream Gauging:** If the cross-section of a stream is divided into finite vertical sections, the velocity profile can be approximated by individually measuring the mean velocity of each section using a flow meter. The area of each section can be determined, and the mean discharge of the entire stream is then computed as follows:

\[ Q = \sum VA \]

The greater the number of subsections, the more accurate the value of \( Q \) will be.

a) **Depths > 0.5m**, two measurements made at 20 and 80% of the stage (the height of a stream’s water surface above a reference elevation (sea level, gauge level)) and averaged

b) **Depths < 0.5m**, one measurement made at 60% depth
Developing Rating Curves: Simply put, rating curves are developed by stream gauging multiple times, at different flows, seasons etc. Float gauges use a buoyant ball which rises and falls with increases and decreases in water surface level. Pressure transducers can be installed below the water surface to monitor increasing pressure as the water level rises and decreasing pressure as the water level falls. These devices can be connected to data loggers to record the water level over time.

Rating Curves

Stream discharge will decrease as stream stage and cross-sectional area decreases. The relationship between stage and discharge is unique for a gauging station. A graph of measured stream stages and discharges at the gauging station defines this relationship. A curve that best represents the position of the data points is called a best-fit curve. This curve is referred to as the stream’s rating curve. The rating curve is crucial because it allows the use of stream stage, which is usually easily determined, to estimate the corresponding streamflow.
**Precalibrated Structures:** On small watersheds, (<800 ha), precalibrated structures are often used because of their convenience and accuracy. The most common of these are *weirs* and *flumes*.

1) *Weirs:* Weirs are structures built into the stream that force the water to flow through an opening of a known size and shape. A weir includes all components of a stream-gauging station as well as a notch control. The notch can be V-shaped, rectangular or trapezoidal. Building a weir in a stream essentially involves damming it. Weirs may be constructed of any material that blocks flow, such as concrete. It is important that water flows through the notch, as the height of flow through the notch must be measurable. Leakage around the sides and bottom of the weir must be eliminated or minimized.

2) *Flumes:* Flumes are artificial open channels built to contain flow within a designed cross section and length. There is no impoundment, but the height of water in the flume is measured with a stilling well. An example of a flume is the Parshall flume. Measurement of the height of water in the flume allows one to calculate discharge. Other examples include, the HS-, H- and HL-type flumes used for measuring intermittent runoff; the Venturi flume used for measuring irrigation water; and the San Dimas Flume which measures debris-laden flows in mountain streams.
Often times, streamflow data is needed where there are no gauges, especially in rural areas. An estimation of streamflow is often necessary in order to predict flow or approximate past flows in these areas. One of the main interests is flood flow. However, it should be noted that no matter how sophisticated the estimation method is; direct measurements are always better.

**Manning’s Equation**: Manning’s Equation is a common empirical method used to estimate discharge at known depths of flow. \((\text{Recall } Q = VA)\)

\[
V = \frac{1.49}{n} \left( R_h^{2/3} \right) \left( s^{1/2} \right)
\]

Where, \(n\) = a roughness coefficient (see table below); \(R_h\) = the hydraulic radius (ft) = \(A/WP\) (WP = wetted perimeter (ft)); \(s\) = energy slope as approximated by the water surface slope (ft/ft).

<table>
<thead>
<tr>
<th>Type of Channel and Description</th>
<th>Minimum</th>
<th>Normal</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural streams - minor streams (top width at floodstage &lt; 100 ft)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Main Channels</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. clean, straight, full stage, no rifts or deep pools</td>
<td>0.025</td>
<td>0.030</td>
<td>0.033</td>
</tr>
<tr>
<td>b. same as above, but more stones and weeds</td>
<td>0.030</td>
<td>0.035</td>
<td>0.040</td>
</tr>
<tr>
<td>c. clean, winding, some pools and shoals</td>
<td>0.033</td>
<td>0.040</td>
<td>0.045</td>
</tr>
<tr>
<td>d. same as above, but some weeds and stones</td>
<td>0.035</td>
<td>0.045</td>
<td>0.050</td>
</tr>
<tr>
<td>e. same as above, lower stages, more ineffective slopes and sections</td>
<td>0.040</td>
<td>0.048</td>
<td>0.055</td>
</tr>
<tr>
<td>f. same as &quot;d&quot; with more stones</td>
<td>0.045</td>
<td>0.050</td>
<td>0.060</td>
</tr>
<tr>
<td>g. sluggish reaches, weedy, deep pools</td>
<td>0.050</td>
<td>0.070</td>
<td>0.080</td>
</tr>
<tr>
<td>h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush</td>
<td>0.075</td>
<td>0.100</td>
<td>0.150</td>
</tr>
<tr>
<td><strong>Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. bottom: gravels, cobbles, and few boulders</td>
<td>0.030</td>
<td>0.040</td>
<td>0.050</td>
</tr>
<tr>
<td>b. bottom: cobbles with large boulders</td>
<td>0.040</td>
<td>0.050</td>
<td>0.070</td>
</tr>
</tbody>
</table>
III. SUMMARY

Streams are dynamic and complex systems. Healthy stream systems are dependent on streamflow. The flow of water in stream channels is responsible for the transport of sediment, nutrients, and pollution downstream. However, streamflow varies with precipitation, temperature and other climatic factors. As such, the ability to accurately measure streamflow is key to effectively managing our water resources as well as predicting floods and estimating long term trends in water and sediment discharges.

Food for Thought
a. Consider each technique for measuring streamflow. Where is error introduced into the calculations?
b. What precautions should be taken to obtain the best estimates of mean depth and velocity, when choosing stream gauging to calculate streamflow?
c. Describe the relationship between streamflow and society.
IV. References