

## How does Rainfall affect Stream Health?

### Background

The volume and velocity of water in a stream and how this water ebbs and flows are important influences on the health of a stream. Knowing how and why these variables change helps us understand how a stream is interacting with the land around it. The measurement of water that passes through a set point in a stream in a given amount of time is referred to as **stream discharge**. Stream discharge data collected and analyzed over time is used for water resource planning, predicting floods, managing development of buildings and roads in the watershed, restoring stream habitats, and improving water quality.

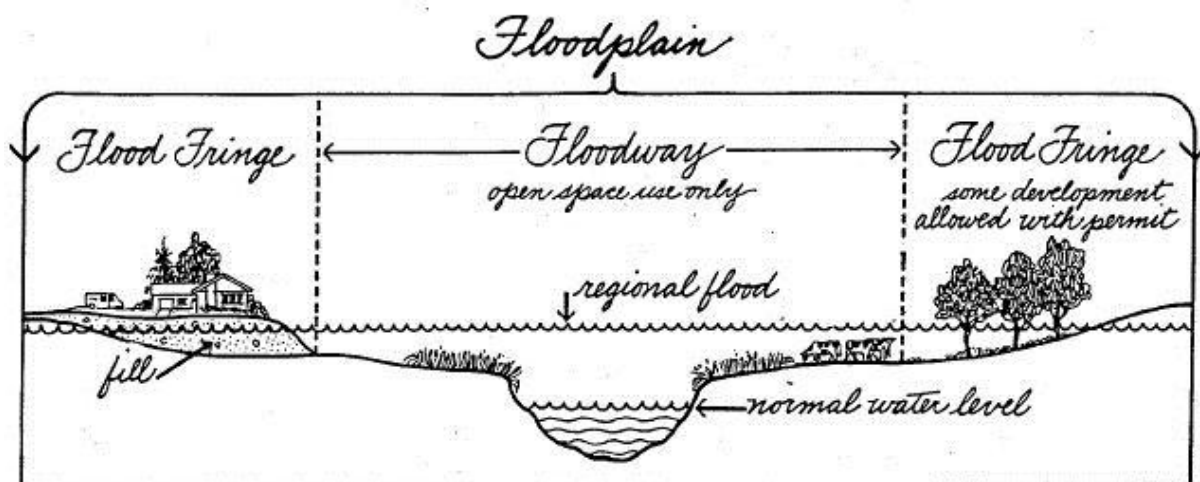
Discharge is normally expressed in units of volume per unit time (e.g., cubic meters per second). It is calculated by measuring the speed of the water and multiplying that by the cross-sectional area of the water at the same point. It can vary over short periods of time (daily, seasonally) due to rain or storm events and other factors, and over longer periods due to climate. Discharge is affected by the characteristics of the surrounding watershed, such as the amount of hard (impervious) surfaces, amount of forest or trees, the width of the riparian buffer, and the size of the watershed.

### Overview

Changing rain and snowfall patterns in Maryland combined with increasing urbanization is causing more frequent flooding and droughts in streams. Most stream channels are too small to accommodate the extra water that comes with more frequent floods and the water that pours off the land from impervious surfaces. The force of the water during big storm events changes the shape of the channel by eroding the banks and the bottom of the streams. As this happens, stream channels become deeper and wider. Many times erosion continues to the point where the stream becomes confined to a deep narrow channel that persistently erodes, and becomes disconnected from its natural floodplain (i.e., it is never able to overflow its banks when it receives extra water volume). These types of narrow and deep stream channels tend to have very little habitat for fish and other stream-dwelling animals. Large amounts of soil eroded from the stream's bank during these events is then deposited downstream where it can smother habitat. By contrast, a stream that is in balance and can spread out into its floodplain typically has little erosion and provides more habitats for stream animals. When a big rush of water comes, the water flows over its banks and is slowed down by the vegetation and terrain on the floodplain. This relationship between a stream and the floodplain is essential to a healthy stream system.

### Floodplain Connectivity

The ability of a stream to overflow its banks when the volume of water increases is critical to the health of a stream in many ways. The land bordering the bank of a stream onto which the water flows when the water rises is called the floodplain. Water entering a floodplain recharges (replenishes) our groundwater, keeping the water table elevated enough to provide water supply for wells. Floodplains also provide vital functions to our watershed



ecosystems. These include nutrient cycling, contaminant filtration, water purification, bank stabilization, stream temperature maintenance, flow stabilization, and habitat diversity<sup>1</sup>. A floodplain can only function as intended if it is connected to the waterway that it serves.

In our urban areas, to avoid problems for people, much has been done to control water flows like deepening stream channels to control flooding and stabilizing river banks by building permanent walls along stream banks. Each of these greatly reduces the ability of a river or stream to stay connected with its floodplain. When that connection is broken, biophysical processes that are essential for sustaining the river ecosystems are stopped. This can have profound effects on the health of our watersheds<sup>1</sup>.

## Climate

Climate is the long-term average of the weather in a given place. Weather varies naturally, day to day and season to season, so over short periods of time, it can be difficult to distinguish the difference between weather and climate. Overall, the average temperature on the surface of the earth is rising. These warmer surface temperatures lead to a rise in the rate of evaporation from the oceans. This creates an increase in precipitation around the world. But the heat in the atmosphere is also changing where and how this precipitation falls. The intensity of storm events may be rising because of the added heat, and conversely some parts of the earth are experiencing more severe droughts than they have in the past<sup>4</sup>. These changing precipitation patterns are in turn impacting the volume of water available in streams. This change in volume affects the speed of the water (flow or velocity) which alters the habitats available in streams.

## Stormwater

The timing and amount of precipitation falling onto a watershed affects the volume of stream discharge<sup>3</sup>. These higher stream flows often increase stream bank erosion by scouring the banks. A high and fast water flow encourages stream channelization which can then disconnect a stream from its floodplain. If a stream can't overflow its banks onto a floodplain, then the water from a storm won't slow down and infiltrate the surrounding soils. This leads to much more water rushing directly into the stream.

The population in Maryland is expected to increase by about 1.1 million people over the next 25 years which will put an additional heavy load onto our water resources<sup>2</sup>. When our land is developed, such as for buildings or roads, our hydrological cycle is changed. The removal of vegetation, soil compaction, and addition of impervious surfaces are all human impacts that make it difficult for rain to penetrate the surface soil. This stormwater then runs off the land straight into our streams and waterways without being filtered by the soil or recharging groundwater supplies<sup>2</sup>. When stormwater runs off of the land, it picks up pollutants along the way, carrying them into streams. Some of these pollutants include nitrates and phosphates from animal waste and agricultural areas, chloride from road salting, and petroleum products and trash from roads and paved surfaces. These pollutants then wash directly down our streams and rivers and into Chesapeake Bay.

## References and Resources:

1. Stream and Watershed Restoration, "Floodplain Connectivity, Flood Plain Form, Function, and Connectivity in River Restoration." Kirsty Bramlett. University of New Mexico. 2012: <http://riverrestoration.wikispaces.com/Floodplain+connectivity>
2. Maryland Department of the Environment, "Groundwater Protection Program, Annual Report to the Maryland General Assembly," written by the Water Supply Program and Water Management Administration. 2012: [www.mde.state.md.us/programs/Water/Water\\_Supply/Source\\_Water\\_Assessment\\_Program/Documents/SJR25-JR5\\_1985\(2013\).pdf](http://www.mde.state.md.us/programs/Water/Water_Supply/Source_Water_Assessment_Program/Documents/SJR25-JR5_1985(2013).pdf)
3. National Capital Region Network, "Climate Change Brief," National Park Service and the U.S. Department of the Interior. 2010: [www.nps.gov/cue/climate/NCR\\_TidalMarsh\\_Brief\\_Redesign.pdf](http://www.nps.gov/cue/climate/NCR_TidalMarsh_Brief_Redesign.pdf)
4. United States Environmental Protection Agency: "Climate Change Indicators in the United States," 2012: [www.epa.gov/climatechange/pdfs/climateindicators-full-2012.pdf](http://www.epa.gov/climatechange/pdfs/climateindicators-full-2012.pdf)
5. U.S. Geological Survey, Water Resources Division "What is Ground Water", U.S. Geological Survey Open File Report 93-643: <http://pubs.usgs.gov/of/1993/ofr93-643/>

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## Stream Flow and Volume

### "How much water is flowing in this stream?"

#### Student Worksheet

Adapted by Amanda Sullivan, Education Specialist, Maryland Department of Natural Resources, from: *The Environmental Protection Agency, Water: Monitoring and Assessment*, <http://water.epa.gov/type/rsl/monitoring/vms51.cfm>.

Stream flow, or discharge, is the volume of water that moves past a designated point over a fixed period of time. It is often expressed as cubic feet per second ( $\text{ft}^3/\text{sec}$ ) or cubic meters per second ( $\text{m}^3/\text{sec}$ ).

The flow of a stream is directly related to the amount of water moving off the watershed into the stream channel. It is affected by weather, increasing during rainstorms and decreasing during dry periods. It also changes during different seasons of the year, decreasing during the summer months when evaporation rates are high and shoreline vegetation is actively growing and removing water from the ground. August and September are usually the months of lowest flow for most streams and rivers in most of the country.

Flow is a function of water volume and velocity. It is important because of its affect on water quality and on the living organisms and habitats in the stream. Large, swiftly flowing rivers can receive pollution discharges and be little affected, whereas small streams have less capacity to dilute and degrade wastes.

To find the flow volume, you will multiply the cross-section of the stream by the velocity of the water.

There are 4 parts to this lesson:

- A. Measure and graph the cross-sectional profile of your stream.
- B. Calculate the cross-sectional Area of the water in your stream.
- C. Measure the Flow Rate (Velocity) of the water.
- D. Calculate the Volume Discharge of the stream.

#### A. Measure and graph the cross-sectional profile of your stream.

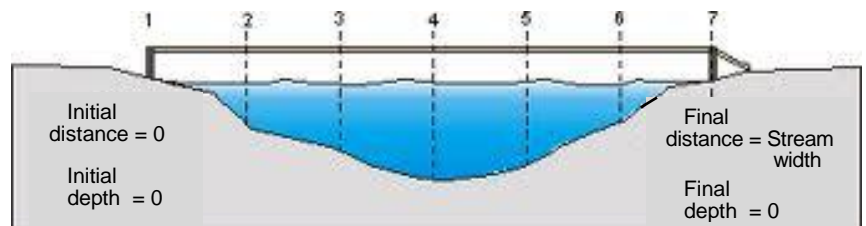
##### Materials:

- 1 clipboard per student or group
- Sharpened pencils
- 2 tent stakes
- A sturdy length of thin rope or thick string
- A horizontal level that can hang on the rope or string
- 2 meter sticks or 1 meter stick and 1 measuring tape

##### Procedure:

Choose a straight riffle in your stream to measure. A riffle is a section of the stream with shallow, faster-moving water flowing over a rocky bottom.

Pick a point in the riffle across which you will measure the cross-



Put two tent stakes in the ground perpendicular to the flow of the stream and across the stream from one another. Place the stakes on the land above the water level.

Use a length of thin rope with a level on it to make sure the stakes are at equal elevation to each other. Adjust the stakes as needed to make the rope level. Tie the rope to the stakes.

Starting at one stake, measure increments that are an even distance away from the shore and into the stream (increments may be 10 cm, 20 cm, or 50 cm apart), across to the other stake. Stretch a measuring tape across the stream, following the rope all the way across. Or use one of the meter sticks to measure the increments.

At each increment, use the meter stick to measure the distance between the rope and the ground or bottom of the stream. Hold the meter stick straight vertically. It should be perpendicular to the rope. Record the distance between the rope and the ground in the data table.

Where the meter stick goes below the surface of the water, in the third column of the data table, also record the depth of the water. The water should eventually be drawn as a straight line across your cross-section.

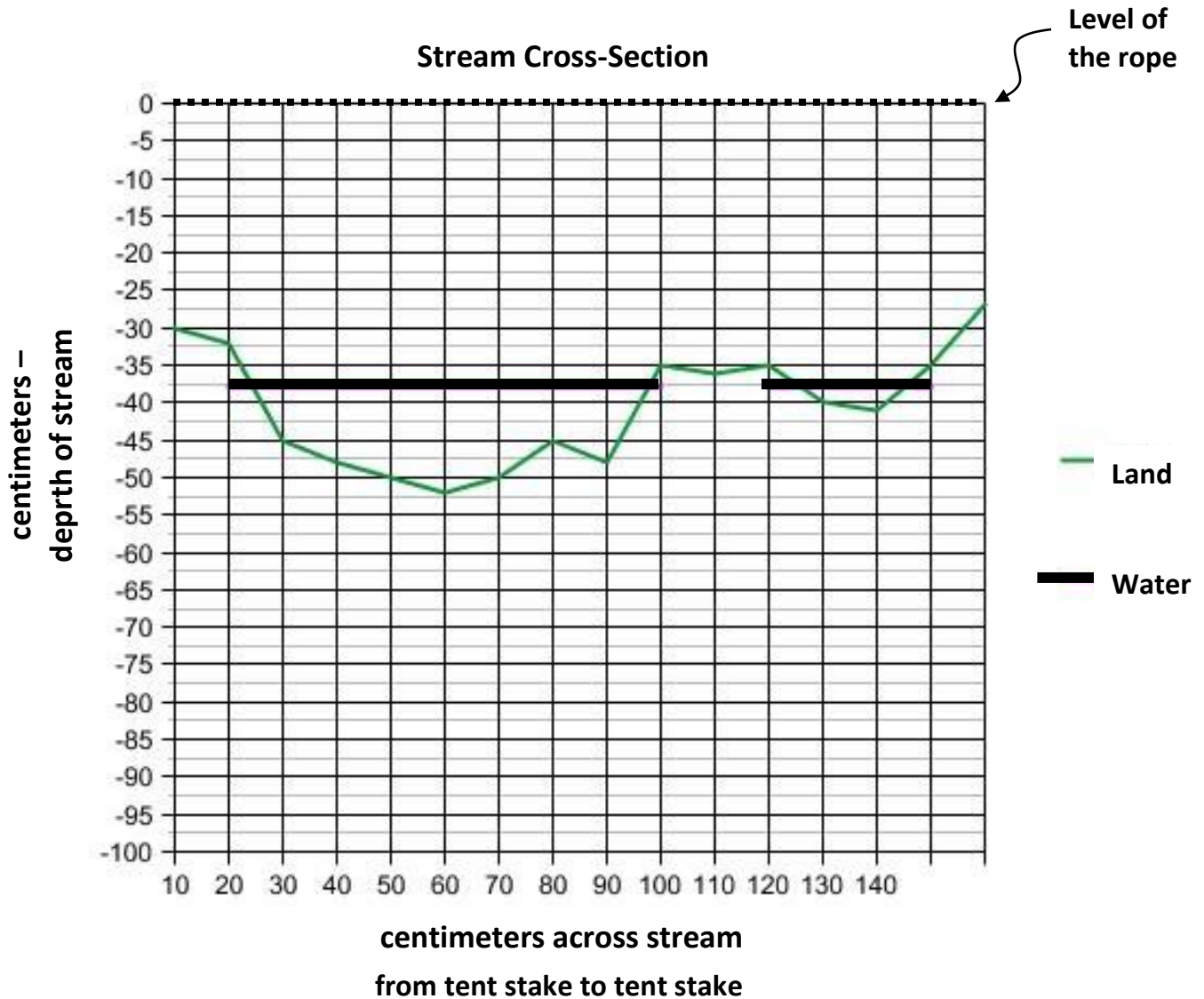
**Record your Cross-section measurements and observations:**

Distance from stake at each increment (give units of measurement)	Distance between rope and ground or stream bottom (give units of measurement)	Water depth (may be 0) (give units of measurement)	Other observations (i.e. lots of rocks, thick sediment, island, boulder, etc.):

### Graph your cross-section:

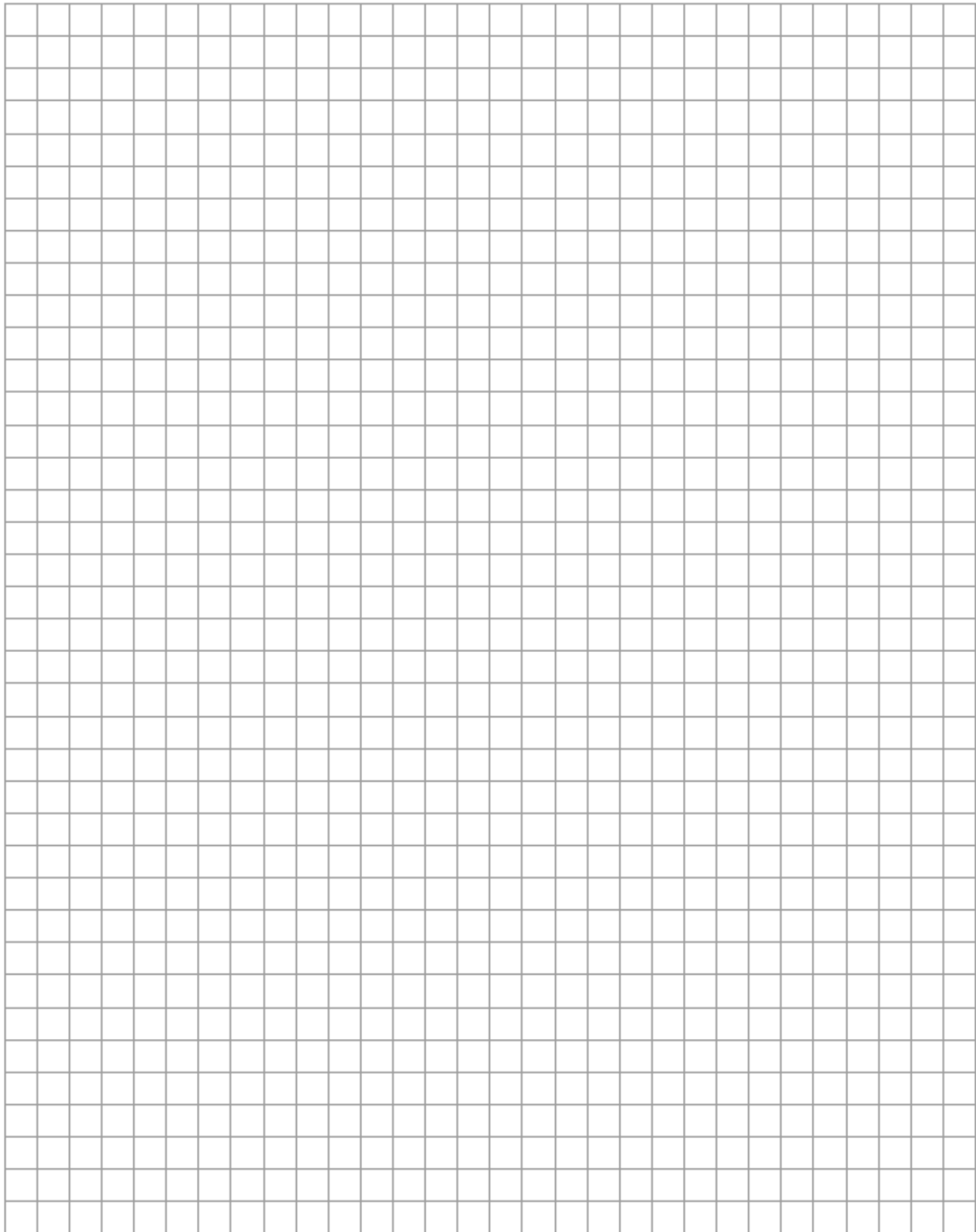
Label your graph with the X-axis as the width of the stream and the Y-axis as the measurement from the string or rope to the ground or stream bottom. The number will be shown in the graph as a negative, because it shows the decrease in elevation below the string. Students often get confused by the negative numbers, but this is necessary in order to effectively visualize your cross section, so you will need to plot your data BELOW the X-axis.

### Example:



Graph your cross-section on the next page.

**Graph your cross-section here:**

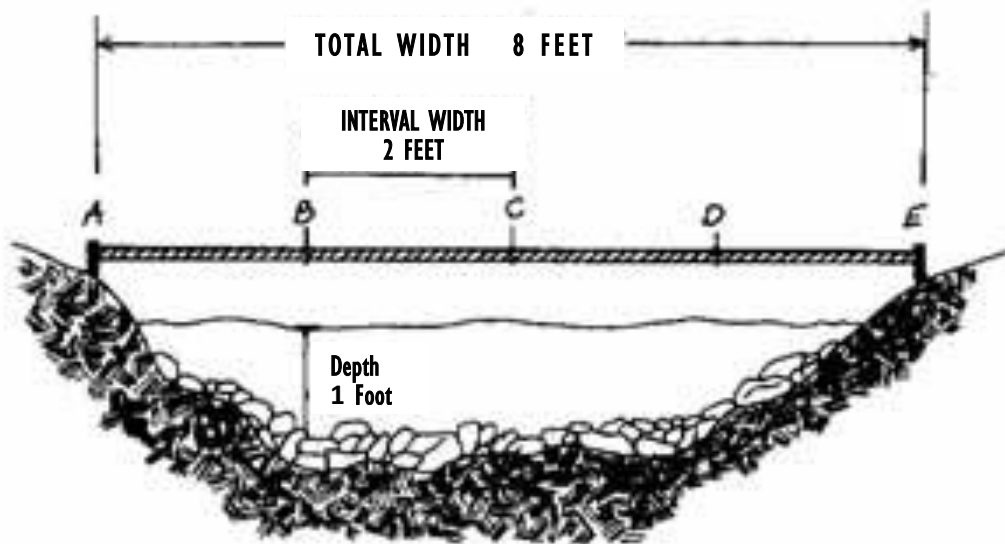


## B. Measure and calculate the Area of the water in the cross-section.

1. Record the Width of the water in the stream in centimeters: Width = \_\_\_\_\_ cm
2. Calculate the average depth of the water in the stream by adding up all of the depths of the water from your data table. Include in your calculation **one** (only one) of the zero measurements to account for the shore. Now divide the total by the number of data points you added.

Average Depth of your stream site = \_\_\_\_\_ cm

### Example:



<http://water.epa.gov/type/rsl/monitoring/vms51.cfm>

In this instance you would add the water depths of points B, C, D, and one zero measurement from either point A or E to account for the shore. Divide this by 4 (number of depth measurements) to get an average depth.

3. Multiply the Average Depth times the Width of the stream to get the Area of the cross-section, and write your answer below.

Average Depth (cm) X Width (cm) = Area (cm<sup>2</sup>) of the cross-section

**Area of cross-section** = \_\_\_\_\_ cm<sup>2</sup>

Convert the Area to square meters by dividing by 10,000:

\_\_\_\_\_ cm<sup>2</sup> ÷ 10,000 = \_\_\_\_\_ m<sup>2</sup>

### C. Measure the Flow Rate (Velocity) of the water.

Based on your knowledge of how water moves through a stream, choose a small section (called a “reach”) of the stream 3 – 10 meters long that includes the point at which you measured and graphed a cross-section profile in part A. Determine the speed of the water by timing how long it takes for an object to float from one point to another, along the stretch of stream; and then dividing the time it took by the distance the object traveled, to get a rate in meters per second (meters/second). Flow Rate is another term for the speed or velocity of the water.

**Hypothesis:** What do you predict is the speed of the water? \_\_\_\_\_ meters/second

#### **Materials per group:**

- 1 clipboard, pencil and set of student sheets
- 1 small floating object
- 1 stop watch
- 4 tent stakes
- 1 measuring tape
- Calculators or scrap paper

#### **Procedure:**

1. **Divide into groups** of at least 3 students per group. **Assign jobs** to the members of your group (some may need to have more than one job):
  - Measurer(s)
  - Stake Installer(s)
  - Floating Object Dropper
  - Timer
  - Floating Object Retriever
  - Floating Object Observer
  - Data Recorder
2. **Mark off the length of stream:**
  - **Measurers:** You may choose for the section of stream to be any length between 3 and 10 meters long. The section of the stream should include a riffle and include the point at which you measured a cross-section of the stream.
  - **Installers:** You will use four tent stakes to mark the length of stream. Two stakes on each bank of the stream will be the starting point of the measurement and the other two stakes will be the ending point that is the chosen length (3 to 10 meters) downstream.

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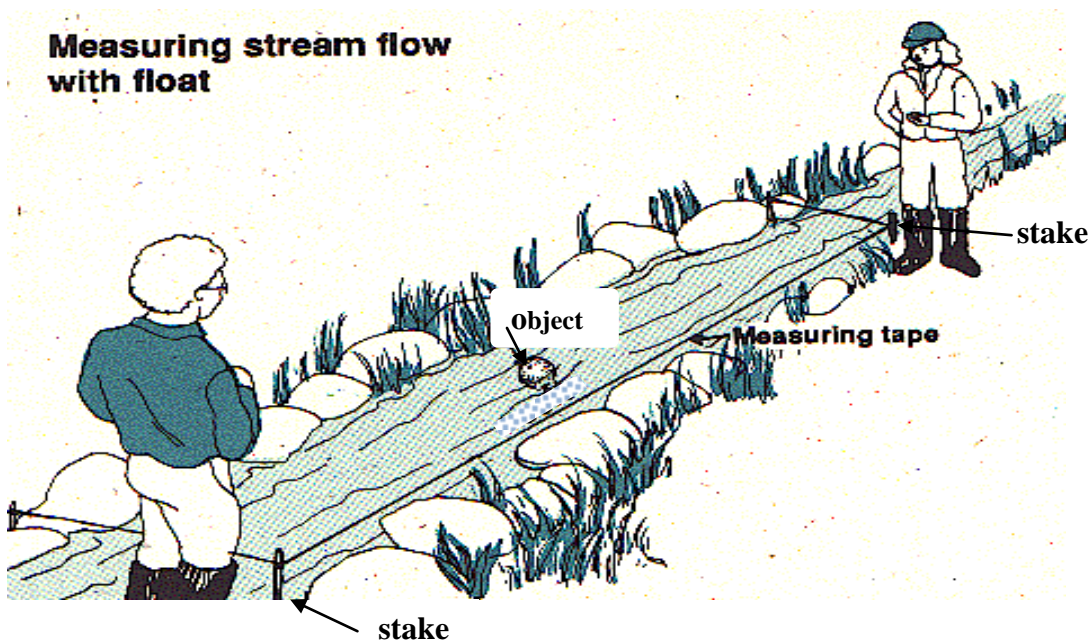


### 3. Measure the flow:

- a. **Dropper:** One student from each group should stand at the up-stream point of the stream section. When everyone is ready to begin, this student will drop a small floating object slightly upstream of the upstream tent stakes in the FASTEST part of the current.
- b. **Timer:** Another student from each group should time how long it takes in seconds for the object to float down the section of the stream. They should begin timing IMMEDIATELY when the object passes the first tent stake and STOP when it passes the second tent stake.
- c. **Retriever:** Have the third student in each group stand down-stream at the end of the section they are measuring and catch the object when it arrives (a dip net may be helpful).
- d. **Observer:** Have a student from each group walk along the bank to keep an eye on their floating object and write down the data.
- e. **Recorder:** Record the time in the table provided on the next page.

4. **Repeat the procedure 3 times.** Record your data in the data table provided.

5. **Calculate the Flow Rate (Velocity):** Determine the speed of the water using the formula provided on the next page. This is the flow rate for this part of the stream.



<http://www.ecy.wa.gov/programs/wq/plants/management/joysmanual/5float.html>

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**Results:**

(1) What was the length of your stream reach (distance the object traveled)? \_\_\_\_\_

(2) Record your data in the table:

Trial Number	Time in <b>seconds</b> it took for the object to float the section	<b>Example</b>
<b>1</b>		12 seconds
<b>2</b>		9 seconds
<b>3</b>		11 seconds
Add the seconds recorded for all 3 trails and write the <b>total</b> here:		32 seconds
Divide the total # above by 3 to get an average time for the 3 trials. This is the <b>average</b> number of seconds the object took to travel the reach.		10.67 seconds

(2) Calculate the speed of the water or the Flow Rate:

**Distance (or length) divided by Time equals Rate.** Rate is the flow rate or speed of the water, using the unit “meters per second.”

**Distance** (in meters) ÷ **Time** (in seconds) = **Rate** (in meters/second)

For example: The object travels a 5 meter length of stream in 8 seconds. Divide 5 (length traveled) by 8 (time it took to travel the distance) for an answer of .625 meters/second.

**Use your data to fill in the blanks and complete the calculation below.**

Because you did 3 trials, you will use the average time for the calculation.

**The Flow Rate for the Reach:**

**Distance** \_\_\_\_\_ meters ÷ **Time (Average)** \_\_\_\_\_ seconds = **Rate** \_\_\_\_\_ meters/second

***A little more math...***The water at the surface of a stream moves faster than the water at the bottom of the stream. There is more friction on the bottom because the water flows across rocks, gravel or sand, which slows it down. On the surface, there is less friction, so the water moves faster. In order to calculate a more accurate flow rate overall for the stream, biologists adjust for this difference. You can do this by multiplying your average speed for each section by **.85** to get your final answer. Rate (from above) x .85 = Final Flow Rate (meters/second). Record it here:

**Final Flow Rate (Velocity):** \_\_\_\_\_



**Drawing conclusions:**

1. What effect do you think the flow rate of a stream has on the animals that make their home in the stream?

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2. What physical and chemical properties of the stream may be affected by the speed of the water?

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3. Where does the water in your stream come from? Consider all possible sources.

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4. What do you think would happen to the flow rate in the stream when it rains? Why?

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5. Does the water in the stream travel at the same rate at every point in the stream? Explain why you think this is the case.

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## D. Calculate the Volume Discharge of your stream.

### To Determine Volume:

Use the Flow Rate worksheet (part C) to measure and calculate the Rate (Velocity) of the water flowing in your stream at the SAME riffle across which you measured the Area of the cross-section. Write the final Flow Rate here:

1. Flow Rate = \_\_\_\_\_ m/sec

2. Area of the water in the cross-section (from part B) = \_\_\_\_\_ meters<sup>2</sup> (or m<sup>2</sup>)

3. Now calculate the Volume of the water:

**Flow Rate (m/sec) multiplied by Area of cross-section (m<sup>2</sup>) = Volume of water (m<sup>3</sup>/sec)**

\_\_\_\_\_ m/sec X \_\_\_\_\_ m<sup>2</sup> = \_\_\_\_\_ m<sup>3</sup>/sec

This is the volume of water flowing past this point in your stream every second!

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**Extension 1:** Compare your cross-section to some common cross-sections to determine what stage your stream is in, whether it is stable, aggrading (accumulating sediment), degrading (losing sediment), or in recovery. These scenarios are found in the Anne Arundel County, Maryland Streams Protocol (prepared by the U.S. Fish and Wildlife Service Chesapeake Bay Field Office) – see page 19 in the following document:

<http://www.fws.gov/chesapeakebay/pdf/1new%20stream%20reports/s09-01.pdf>.

**Extension 2:** The United States Geological Survey monitors the volume of water flowing in streams and rivers in the major watersheds in Maryland and other states. The USGS and other state and federal agencies often use the measurement unit of cubic feet per second (feet<sup>3</sup>/second) to monitor stream and river volume.

To convert to cubic feet per second (ft<sup>3</sup>/sec) simply multiply your result in m<sup>3</sup>/second by 35.3147 to get your answer.

\_\_\_\_\_ m<sup>3</sup>/sec X 35.3147 = \_\_\_\_\_ ft<sup>3</sup>/sec

Compare the volume in your stream to the volumes of streams and rivers across Maryland at the USGS monitoring site: [http://waterdata.usgs.gov/md/nwis/current/?type=flow&group\\_key=basin\\_cd](http://waterdata.usgs.gov/md/nwis/current/?type=flow&group_key=basin_cd)

Or use the USGS Water Data for the Nation site <http://waterdata.usgs.gov/nwis> and compare your stream with waterways across the country.