Flowing Streams

Adapted from: *Field Exercise: Stream Flow Dynamics & Sedimentation* by Daniel J. Bisaccio and Donald L. Woodrow. http://www.beliot.edu

Grade Level: Advanced

Duration: 45 minutes

Setting: Stream & classroom

Summary: Students will investigate the velocity, sedimentation, and discharge of a stream.

Objectives: Students will produce a vertical profile of a stream, measure flow velocity differences across a stream and correlate stream flow velocity with size of substrate sediment collected.

Vocabulary: gradient, velocity, flow rate, base level, graded stream, aggradation, degradation, abrasion, hydraulic lifting, dissolution, capacity, competence, suspended load, bed load, dissolved load, alluvium, point bars, natural levees, backswamps, wetlands.

Related Module Resources:

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Materials (Included in Module):

- 2 measuring tapes
- 2 plastic golf balls
- 2 pinwheels
- 2 stop watches
- 2 meter sticks
- 2 hand shovels
- ziploc bags
- sediment comparison guides

Additional Materials (NOT Included in Module):

- graph paper

ACADEMIC STANDARDS: ENVIRONMENT & ECOLOGY

10th Grade

4.1 A Describe the changes that occur from a streams origin to its final outflow.

4.1 B Explain the relationships among landforms, vegetation, and the amount and speed of water.

- Analyze a stream's physical characteristics.
- Explain how the speed of water and vegetation cover relates to erosion.

4.1 C Describe the physical characteristics of a stream and determine the types of organisms found in aquatic environments.

- Describe and explain the physical factors that affect a stream and the organisms living there.
- Identify the types of organisms that would live in a stream based on the stream's physical characteristics.

BACKGROUND:

As streams flow over the landscape they erode, transport, and deposit sediment. The flow of a stream is determined by its **gradient**, its vertical drop in elevation over a given horizontal distance. The steeper its gradient, the faster the stream flows. The gradient is expressed in feet per mile (or m/km) and generally decreases from a stream's headwaters to the mouth of the stream. A small, headwater stream usually has a steeper gradient than a medium sized creek, which usually has a steeper gradient than a large river.

Streams also change in average depth from headwater (small stream) to mouth (larger waterway). Depth or **stage** is more shallow in small, narrower streams and deeper as you progress downstream. Stream stage is often measured by government and environmental agencies to record fluctuations in water levels throughout the year. Correlations between weather and water depth can be made. Comparisons between annual stage data can help determine the impact of drought conditions on water levels. Keeping an eye on stage levels can help determine if flooding is going to occur at the present location or a downstream location. Stage levels are also important in large waterways for transportation purposes.

As a stream changes in size, it usually changes in average velocity as well. Stream **velocity** or **flow**

rate, expressed in feet per second (or m/sec) is a measure of the distance a stream's water travels in a given amount of time. It is how fast the water is flowing. Stream water does not have a uniform velocity. Water velocity is slowest along the sides closest to the banks and on the stream bottom due to the friction between the water and the channel. Water velocity is greatest in the center of a stream in a straight segment of the channel, equidistant from the banks and just below the surface. When a stream curves, velocity is greatest at the outside of the curve and least at the inside.

The texture of a stream bed also determines velocity. At the headwaters, boulders and large rocks cause significant friction and send stream water swirling upward, downward, and sideways. Here, most of the stream's energy is expended against its bed and the actual downstream velocity is low. Downstream, velocity increases because the stream flows over a smoother bed of sand, silt, and clay, which lowers frictional resistance to flow.

Streams tend to cut downward into bedrock until they reach their **base level**, the lowest point to which a stream can erode. After some streams reach base level they enter a temporary state of equilibrium. At equilibrium, the stream transports all the sediment it receives with very little increase in erosion and deposition. A stream in this state is called a **graded stream**. If more sediment is introduced to a graded stream, it responds by increasing its gradient in a process called **aggradation**. If sediment is removed from a graded stream it responds by instantly lowering its gradient, a process called **degradation**.

A stream's erosive power increases with its velocity. During a flood a stream's erosive power and velocity increase dramatically. Streams erode their channels by **abrasion**, **hydraulic lifting**, and **dissolution**. Abrasion is the scouring of a stream bed by transported particles. Erosion by abrasion is most efficient in swift-flowing, sediment-rich floodwaters.

Hydraulic lifting, erosion by water pressure, occurs when turbulent stream waters flow through cracks in the bedrock and loosens sediment grains and large chunks of rock. Hydraulic lifting is most active during high velocity floods. When a stream flows across and dissolves soluble bedrock such as limestone, dolostones, and evaporites, dissolution also contributes to stream erosion.

A stream's velocity, the composition and texture of its sediment, and the characteristics of the bedrock through which the stream flows determine the amount and type of sediment that it transports. High velocity is required to erode and transport large boulders. High velocity is also required to transport small, flat clay particles and mica flakes, because electrical forces on their surfaces cause them to cling to the stream bed (Chernicoff, Stanley. Geology. New York: NY, 1995.). Once in the streamflow the fine clay particles remain suspended and are transported long distances.

The maximum load of sediment that a stream can transport is its **capacity**. Capacity is expressed as the volume of sediment passing a given point on the stream bank in a given amount of time. Capacity is proportionate to discharge: the more water flowing in the channel per second, the greater the volume of sediment that is transported in that time. The diameter of the largest particle that a stream can transport is the measure of a stream's **competence**. Streams transport sediment in different ways, depending on particle size. Very fine solid particles are usually distributed within stream water as a s**uspended load**. Coarse particles that move along the stream bottom form the **bed load**. Other sediment is carried invisibly as dissolved ions in the water, forming the **dissolved load**.

When stream particles are deposited the heaviest particles settle out first. Deposited stream sediments are described collectively as **alluvium**. During normal flow, a stream with large amounts of coarse bed-load sediment often deposits some of its load in its channel as mid-channel bars. As sand and gravel accumulates the stream flows around the channel bars and the stream becomes braided. The bars become more resistant to erosion as vegetation begins to grow on them. In-channel deposits may also be in the form of **point bars**, where sediments from the outside banks of meandering streams are deposited on the inner banks. Point bars are where meandering streams drop their heaviest particles; gold, platinum, and silver may be concentrated there. When a stream's channel is unable to contain the water flowing through it, the water overflows onto the surrounding floodplain. Flood plains catch large volumes of sediment from floodwaters because the velocity of the water is decreased and the sediments settle out. **Natural levees** are ridges of coarser sediment deposited on both banks of a stream during successive flooding. Natural levees grow higher from sediment accumulation from each flood and tend to be the highest points on a flood plain. **Backswamps** are the portion of the flood plain near the river where deposits of fine silts and clays settle from standing waters following a flood. If a floodplain has surface depressions water may remain at the surface as **wetlands**.

OVERVIEW: Students will measure the profile of a stream, determine its current velocity at various points and depths and examine the sediment on the stream bottom. Students will determine the relationships between stream profile and flow velocity and between sediment grain-size and flow velocity.

PROCEDURE:

Teacher Preparation:

1. This research is best done as a large group project. Everyone should get a data sheet. You will have to get volunteers for various tasks for the research. Try to include as much of the class as possible. This will be dictated sometimes on the space available, size of the waterway, and the amount of materials that you have.

Student Experiment or Activity:

****Safety Precautions**

Large waterways (very wide or deep) will not be able to be studied with this procedure. Only enter the waterway if the teacher gives permission. Do not enter the stream if it is flowing faster than normal; currents can be misleading, powerful, and cause you to lose balance. Water should not be entered in the winter (late Novembermid March), even if you are wearing hip waders, because of the threat of hypothermia. Be careful not to slip or fall on rocks in the creek.

A. Procedure - Measuring Flow Rate at the Surface

1. Three students will need to be in the stream. Other students should stay on shore to record data and one student should be the time keeper.

2. Two students will need to take the tape measure, stand in the stream, and measure out 10 meters. One student should stand upstream, one downstream, and pull the tape measure taut for the 10 meters, parallel with the stream current.

3. A third student should stand near the downstream student and be in charge of catching a floating plastic golf ball as it passes by.

4. The upstream student should have the plastic golf ball. When the time keeper is ready, this student will drop the plastic golf ball slightly upstream of where they are standing, and slightly upstream of the 0 meter mark on the tape measure. The students should also drop the plastic golf ball as far away from them as possible (stretch your arm and body far out from where you stand). This will keep your legs/body from affecting the flow of the water and affecting the golf ball's travel.

5. The time keeper should start the stopwatch as soon as the plastic golf ball hits the 0 meter mark. Stop the watch when it reaches the 10 meter mark. Catch the ball before it floats downstream.

6. Calculate the flow rate (velocity) by dividing distance (10 meters) by the recorded time (seconds). Record this value. The units are meters/second or m/sec.

7. Repeat this procedure for two more trials for the same location in the stream. Record the calculated flow rates for these trials.

B. Procedure - Calibrating the Pinwheel

1. In the same location in the stream that you found the flow rate, you will calibrate your pinwheel. This pinwheel will be used to measure the flow velocity of the stream at depths that the plastic golf ball cannot be used.

2. Place the pinwheel just below the surface of water and make sure it rotates with the flow. Do not block flow with your legs or body. You will watch the pinwheel and count the number of rotations as accurately as possible that it takes in a certain amount of time. The time keeper will let you know when to stop.

3. Regarding the certain amount of time, reset the stopwatch and be ready to run the stop watch for as close to the amount of average time that it took the plastic golf ball to travel the 10 meters. When this amount of time is reached, yell "stop".

Average time for ball to float 10 meters _____________

Number of pinwheel revolutions in this amount of time _____________

4. Now calculate the stream flow velocity (meters/second) based on the number of pinwheel revolutions.

$$\frac{\text{10 meters ball traveled}}{\text{\_\_\_\_ seconds ball traveled}} = \text{\_\_\_\_\_\_ meters/second}$$

$$\frac{\text{\_\_\_\_ pinwheel revolutions}}{\text{\_\_\_\_\_\_ seconds ball traveled}} = \text{\_\_\_\_\_\_ pinwheel revolutions/second}$$

______ pinwheel revolutions/second = ______ meters/second stream flow

C. Procedure - Measuring Width of Stream

1. Two students will need to enter the stream. One student should stay at the one edge of the waterway and hold the tape measure. The other students should take the end of the tape (0 m mark) and carefully walk across the stream to measure the width.

2. The student holding the tape measure should read the stream width in meters. Record this data on the data sheet.

3. These students should stay in place for the next procedure.

D. Procedure - Measure the Stage of the Stream

1. Have a third student enter the waterway with a meter stick. For at least 5 spots along the width of the stream (pick spots along the measure tape), the student should use the meter stick to record the stage (depth). More students can enter the stream if you have enough meter sticks for them each to use.

2. Record both the distance from shore (read the tape measure) and the stage for that spot. Repeat for other distances from shore.

E. Procedure - Determining Flow Rate Across the Stream Width

1. At the various spots along the width of the stream, use the pinwheels to determine the flow rate. Count how many pinwheel revolutions occurred in 10 seconds. Then divide this number of rotations by 10 seconds to get ___ pinwheel revolutions/sec.

Your Results: Results from Calibration Step:

______ pinwheel revolutions/sec = ______ pinwheel revolutions/sec

__X__ meters/second stream flow ______ meters/second stream flow

2. Solve for X m/sec like the follows:

$$X \text{ m/sec} = \frac{\underset{\text{Your result}}{\_\_\_\_\_\_} \text{ pinwheel revolutions/sec} \times \underset{\text{calibration result}}{\_\_\_\_\_} \text{ m/sec}}{\underset{\text{calibration result}}{\_\_\_\_\_} \text{ pinwheel revolutions / sec}}$$

F. Procedure - Collection of Sediments Across the Stream Width

1. At the same spots along the stream width that you measured flow rate with the pinwheel, you will collect samples of the substrate (stream bottom).

2. Using a hand trowel or your hands (if there may be glass in your stream - do not use your hands), fill a ziploc bag with as much of the bottom sediment/rocks from your particular spot along the width of the stream. Do not just pick up the rocks - include the fine small sediments too. Label the Ziploc bag with the location (distance from shore that you collected the sample).

3. Save the bags for further observation back in the classroom or on shore. Record the observations about the sediment/substrate on your data sheet. You can use the sediment fact sheets or the sediment comparison guides. You can also use rulers or calipers to measure sediment/rock sizes.

G. Procedure - Comparison of Flow Rate at Various Stream Depths

1. Find a deep, accessible, flowing water spot in the stream. Measure the flow rate (m/sec) using the pinwheel method just below the surface of the water. Record on your data sheet.

2. Next measure the flow rate at mid-depth in the water column. Record this flow rate (m/sec).

3. Lastly, measure the flow rate at the bottom, near the substrate. Record this flow rate (m/sec).

H. Procedure - Create a Stream Depth Profile

1. Create a stream profile on graph paper. Label the Y-axis Depth (m) of the stream and label the (X)-axis Width (m) of the stream. Mark the Data Collection Points you had on the graph. Connect the points to create a cross-section of the stream. \

2. Place a star at the point in your stream that had the highest stream flow velocity. Why is this the point of highest velocity.

DISCUSSION:

Was there a difference in flow velocity at various locations in the stream? Why? *Velocity is affected by overall stream depth, location within the width of the stream, whether the water is flowing over rocks vs. sediments, and at what depth the velocity was measured. See background section for more information.*

Why did we need to use a pinwheel to measure the velocity*? It is more convenient. You also hšMe to use the pinwheel to measure velocity at specific depths in the water because the plastic golf ball stays at the surface only. Velocity changes with depth in the water.*

Was there difference in sediments found across the width of the stream? Was there a correlation between type of sediments/rocks found and the stream velocity for that spot? What relationship is usually found? *Slow flow rate allows fine sediments to settle out to the bottom. Faster flow rate keeps the spot clear of fine sediments and you might only find gravel or larger rocks here. See background section for more information.*

EVALUATION:

- Ask students to turn in their correctly completed data sheets for evaluation.
- See discussion questions above to create a quiz or creates some stream scenarios and ask them to predict velocities and/or potential sediments found.

EXTENSIONS AND MODIFICATIONS:

- Create and space teams at different locations along the stream; this will require additional supervision. Complete the stream investigation as written but in the end have the groups share their data and create a collective stream profile that covers more length of the stream.

NOTES (PLEASE WRITE ANY SUGGESTIONS YOU HAVE FOR TEACHERS USING THIS ACTIVITY IN THE FUTURE)

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