Stream Morphology

Investigation Manual

CAROLINA DISTANCE LEARNING

STREAM MORPHOLOGY

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Overview

Students will construct a physical scale model of a stream system to help understand how streams and rivers shape the solid earth (i.e., the landscape). Students will perform several experiments to determine streamflow properties under different conditions. They will apply the scientific method, testing their own scenarios regarding human impacts to river systems.

Outcomes

- Design a stream table model to analyze the different characteristics of streamflow.
- Explain the effects of watersheds on the surrounding environment in terms of the biology, water quality, and economic importance of streams.
- Identify different stream features based on their geological formation due to erosion and deposition.
- Develop an experiment to test how human actions can modify stream morphology in ways that may, in turn, impact riparian ecosystems.

Time Requirements

Preparation .... 5 minutes, then let sit overnight

Activity 1: Creating a Stream Table .... 60 minutes

Activity 2: Scientific Method: Modeling Human Impacts on Stream Ecosystems................................ 45 minutes

Key

Personal protective equipment (PPE)

goggles gloves apron

follow link to video

photograph results and submit

stopwatch required

warning corrosion flammable toxic environment health hazard

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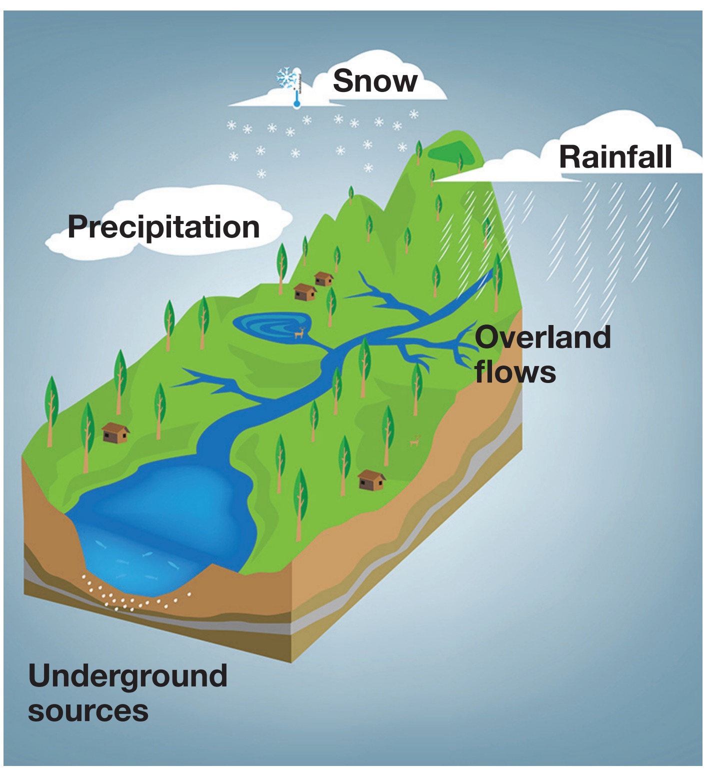
Background

A **watershed** is an area of land that drains any form of precipitation into the earth's water bodies (see Figure 1). The entire land area that forms this connection of atmospheric water to the water on Earth, whether it is rain flowing into a lake or snow soaking into the groundwater, is considered a watershed.

Water covers approximately 70% of the earth's surface. However, about two-thirds of all water is impaired to some degree, with less than 1% being accessible, consumable freshwater. Keeping watersheds pristine is the leading method for providing clean drinking water to communities, and it is a high priority worldwide. However, with increased development and people flocking toward waterfront regions to live, downstream communities are becoming increasingly polluted every day.

Figure 1.



From small streams to large rivers (hereafter considered "streams"), **streamflow** is a vital part of understanding the formation of water and landmasses within a watershed. Understanding the flow of a stream can help to determine when and how much water reaches other areas of a watershed. For example, one of the leading causes of pollution in most waterways across the United States is excessive nutrient and sediment overloading from runoff from the landmasses surrounding these waterways. Nutrients such as phosphorus and nitrogen are prevalent in fertilizers that wash off lawns and farms into surrounding sewer and water systems. This process can cause the overproduction of algae, which are further degraded by bacteria. These bacteria then take up the surrounding oxygen for respiration and kill multiple plants and organisms. A comprehensive understanding of the interaction between streams and the land as they move downstream to other areas of a watershed can help prevent pollution. One example is to build a **riparian buffer**—a group of plants grown along parts of a stream bank that are able to trap pollutants and absorb excessive nutrients; this lessens the effects of nutrient overloading in the streambed. (A **riparian ecosystem** is one that includes a stream and the life along its banks.)

Sediment, which is easily moved by bodies of water, has a negative effect on water quality. It can clog fish gills and cause suffocation, and the water quality can be impaired by becoming very cloudy because of high sediment flow. This can create problems for natural vegetation growth by obstructing light and can prevent animals

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Background continued

from visibly finding their prey. **Erosion** also has considerable effects on stream health. Erosion, or the moving of material (soil, rock, or sand) from the earth to another location, is caused by actions such as physical and chemical weathering (see Figure 2). These processes loosen rocks and other materials and can move these sediments to other locations through bodies of water. Once these particles reach their final destination, they are considered to be deposited. **Deposition** is also an important process because where the sediment particles end up can greatly impact the shape of the land and how water is distributed throughout the system (see Figure 2). Erosion and deposition can occur multiple times along the length of a stream and can vary because of extreme weather, such as flooding or high wind. Over time, these two processes can completely reshape an area, causing the topography, or physical features, of an entire watershed to be altered. Depending on weather conditions, a streambed can be altered quite quickly. Faster moving water tends to erode more sediment than it deposits. Deposition usually occurs in slower moving water. With less force acting on the sediment, it falls out of suspension and builds up on the bottom or sides of the streambed.

Sediments are deposited throughout the length of a stream as **bars**, generally in the middle of a channel, or as **floodplains**, which are more ridgelike areas of land along the edges of the stream. Bars generally consist of gravel or sand-size particles, whereas floodplains are made of more fine-grained material. **Deltas** (see Figure 3) and **alluvial fans** (see Figure 4) are sediment deposits that occur because of flowing water

Figure 2.

Figure 3.

continued on next page

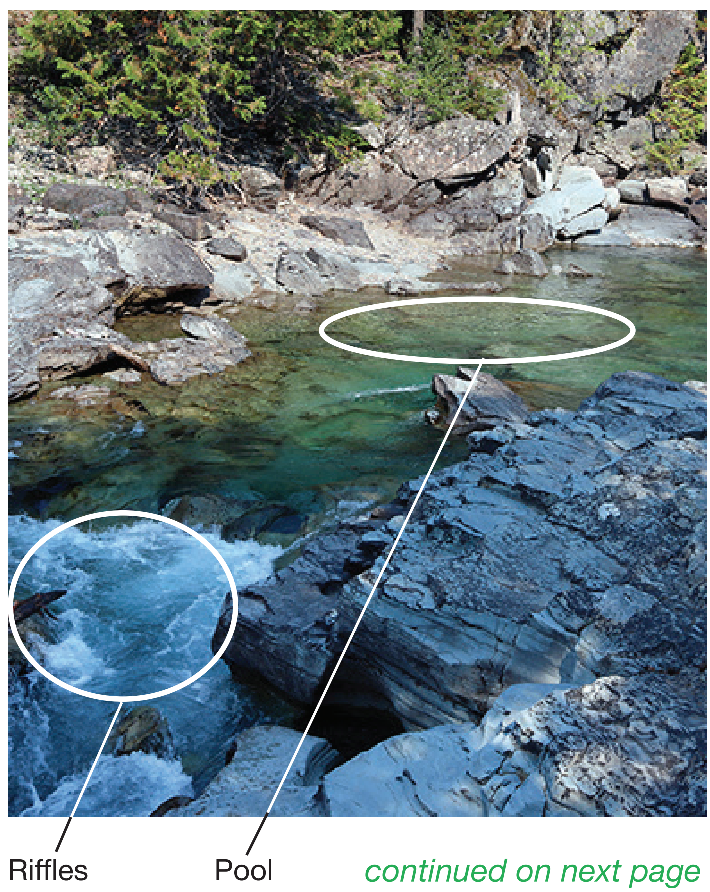
Figure 4.

and are considered more permanent structures because of their longevity. They are both fan-shaped accumulations of sediment that form when the stream shape changes. Deltas form in continuous, flowing water at the mouth of streams, whereas alluvial fans only form in streams that flow intermittently (when it rains or when snow melts). Alluvial fans are usually composed of larger particles and will form in canyons and valleys as water accumulates in these regions. The fan shape of both deposits is easy to spot from a distance, because they are formed due to the sand settling out on the bottom of the streams.

Streamflow Characteristics

Discharge, or the amount of water that flows past a given location of a stream (per second), is a very important characteristic of streamflow. Discharge and **velocity** (the speed of the water moving in the stream) are both vital to the shaping of streambeds. Within stream ecosystems, there are microhabitats (smaller habitats making up larger habitats) that have different discharges and velocities. The type of microhabitat depends on the width of that part of the stream, the shape of the streambed, and many other physical factors. In areas that contain riffles, water quickly splashes over shallow, rocky areas, which are easily observed in sunny areas (see Figure 5). Deeper pools of slower moving water also form on the outside of the bends of the streams, as shown in Figure 5. Runs, which are deeper than riffles but have a moderate current, connect riffles and pools throughout the stream. The source of a stream

Figure 5.



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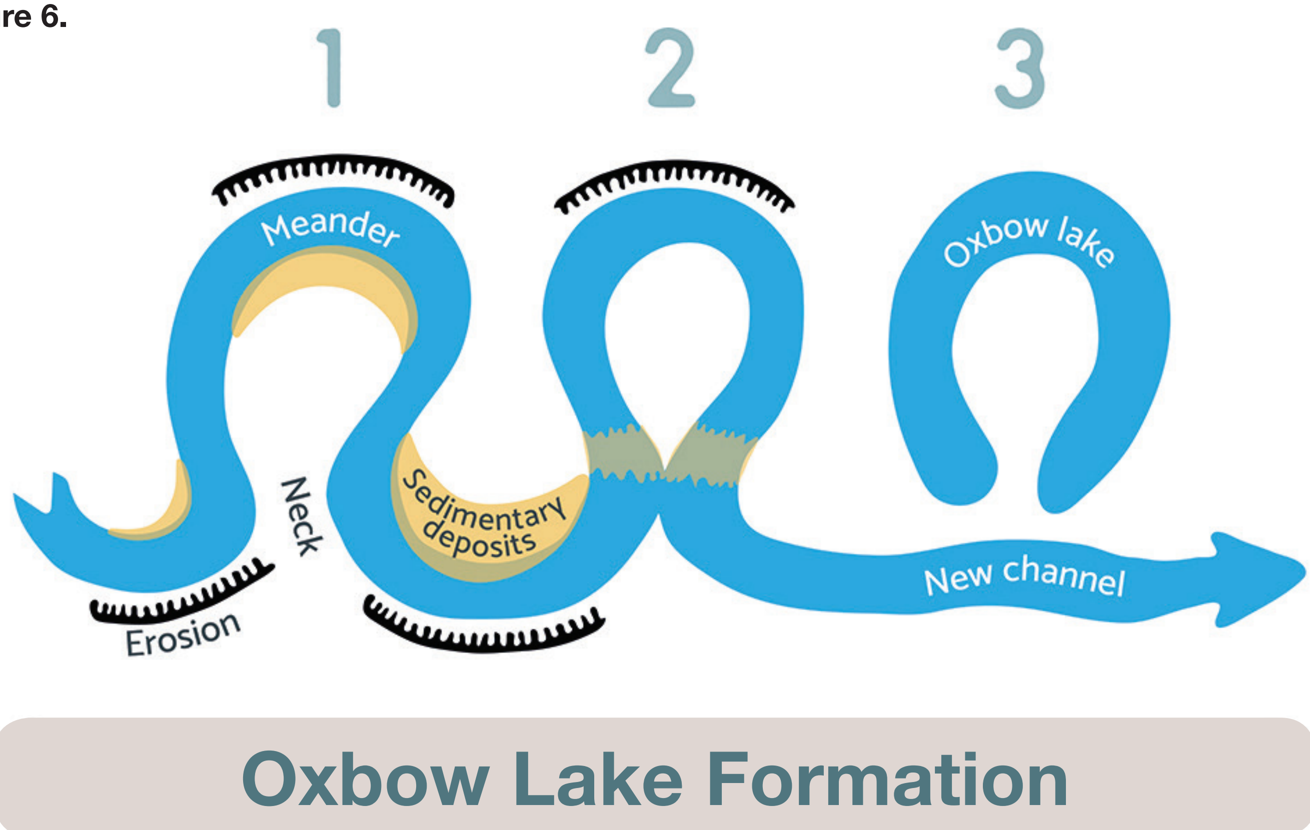
is where it begins, while the mouth of a stream is where it discharges into a lake or an ocean.

Flow rate is very helpful for engineers and scientists who study the impacts of a stream on organisms, surrounding land, and even recreational uses such as boating and fishing. The speed of the water in specific areas helps to determine the composition of the substrate in that area of the streambed, i.e., whether the material is more clay, sand, mud, or gravel. Particle sizes of different sediments are shaped and deposited throughout various areas of a stream, depending on these factors.

Most streams have specific physical features that show periodicity or consistency in regular intervals. **Meanders** can occur in a streambed because of gravity. Water erodes sediment to the outside of a stream and deposits sediment along the opposite bank, forming a natural weaving or "snaking" pattern. This pattern can form in any depth of water and along any type of terrain. **Sinuosity** is the measure of how curvy a stream is. This is a helpful measurement when determining the flow rates of streams because it can show how the curves affect the water velocity. In major rivers and very broad valleys, meanders can be separated from the main body of a river, leaving a *U*-shaped water body known as an **oxbow lake** (see Figure 6). These lake formations can become an entirely new ecosystem with food and shelter for some organisms, such as amphibians, to thrive in.

Figure 6.



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Another feature important for streamflow is the difference in elevation, or the **relief** of a stream as it flows downstream. Streams start at a higher elevation than where they end up; this causes the discharge and velocity at the source versus that at the mouth of the stream to be quite different, depending on the meandering of the stream and the type of deposition and erosion that occurs. The **gradient** is another important factor of stream morphology. This is a measure of the slope of the stream over a particular distance (the relief over the total distance of the stream). For a kayaker who wants to know how fast he/she can paddle down a particular stream, knowing the difference in elevation (relief) is important over a particular area; however, knowing the slope of this particular area will give the kayaker a more accurate prediction. With erosion and deposition occurring at different rates and at different parts of the stream, knowing the gradient is a very important part of determining streamflow for the kayaker.

Groundwater is also affected by changes in the stream shape and flow. Water infiltrates the ground in recharge zones. If streams are continuously flowing over these areas, the ground is able to stay saturated. Most streams are perennial, meaning they flow all year. However, a drought or an extreme weather event may lower the stream level. This can lower the groundwater level, which then allows the stream to only sustain flow when it rises to a level above the water table. With the small amount of available freshwater on Earth, it is vital that our groundwater sources stay pristine.

Biotic and Economic Impacts of Streams

Not only are streams a major source of clean freshwater for humans, but they are also a hotspot for diversity and life. There is great biotic variability between the different microhabitats (e.g., riffles, pools, and runs) of a stream. Riffles, in particular, have a high biodiversity because of the constant movement of water and replenishment of oxygen throughout. Pools usually have fewer and more hardy organisms in their slower, deeper moving waters where less oxygen is available. There are also a multitude of plant and animal species living around streams. From a stream in a backyard to the 1,500-mile-long Colorado River, streams have thousands of types of birds, insects, and plants that live near them because they are nutrient-rich with clean freshwater. Sometimes nutrient spiraling can occur in these streams. Nutrient spiraling is the periodic chemical cycling of nutrients throughout different depths of the streams. This process recycles nutrients and allows life to thrive at all depths and regions of different-size streams.

Streams can also have significant economic impacts on a region. Streams are a channel for fishing and transportation, two of the largest industries in the world. Because of all the commercial boating operations that occur worldwide in these channels, it is vital to understand the formation and flow patterns of streams so that they are clear and navigable. Fishing for human consumption is another large, worldwide industry that depends on stream health; keeping streams pristine and understanding how they form are of utmost importance in sustaining this top food industry. Recreational activities such as kayaking, sportfishing, and boating all shape areas where streams and rivers are prevalent as well.

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Background continued

All acts that happen on land affect the water quality downstream. Through creating a model stream table in this lab, one can predict large, system-wide effects. Many land features and physical parts of a streambed can affect the flow of water within a watershed. Houses along a streambed or numerous large rocks can cause the streamflow to change directions. If any of these factors cause erosion or deposition in an area of the stream, microhabitats can be created. These factors can affect the stream on a larger scale, creating changes in flow speeds and widths of the streambeds.

The Importance of Scaling and the Use of the Scientific Method

When a stream table model is created, a large-scale depiction of a streambed is being reduced to a smaller scale so that the effects of different stream properties on the surrounding environment can be demonstrated. While the stream table made in this lab is not a to-size stream and landscape, the same processes can be more easily observed at a scaled-down size. Scientists frequently create models to simplify complex processes for easier understanding. For example, to physically observe something that is too big, such as the distance between each planet in the solar system, the spatial distance can be scaled to create a solar system model. By changing the distance between each planet from kilometers to centimeters, this large system is now more feasibly observed. Similarly, the stream model allows us to physically view different scenarios of a streambed and analyze different stream properties. Mathematical equations are also used frequently to observe data to predict future conditions, such as in meteorological models. Ultimately, models can be very important tools for predicting future events and analyzing processes that occur in a system.

When one creates a model, many different outcomes for the same type of setup can be possible. In this case, multiple variations of similar-size streambeds will be designed to evaluate different stream features and their impacts on the surrounding ecosystem. When performing any type of scientific evaluation, the **scientific method** is very useful in obtaining accurate results. This method involves performing experiments and recording observations to answer a question of interest.

Although the exact step names and sequences sometimes vary a bit from source to source, in general, the scientific method begins with a scientist making observations about some phenomenon and then asking a question. Next, a scientist proposes a **hypothesis**—a "best guess" based upon available information as to what the answer to the question will be. The scientist then designs an experiment to test the hypothesis. Based on the experimental results, the scientist then either accepts the hypothesis (if it matches what happened) or rejects it (if it doesn't). A rejected hypothesis is not a failure; it is helpful information that can point the way to a new hypothesis and experiment. Finally, the scientist communicates the findings to the world through presenting at a peer-reviewed academic conference and/or publishing in a scholarly journal like *Science* or *Nature*, for example.

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When creating stream table models, we are trying to understand how different factors can affect streamflow. A few very important steps from the scientific method are required. The first is forming a testable hypothesis, or an educated prediction, of what you expect to observe based on what you have learned about stream morphology thus far. In Activity 1, the steps are already listed, so the main goal is to compare the two differences in stream reliefs. However, in Activity 2, the goal is to alter a different variable and predict what will happen to several stream features in this new situation. In general, when recording these observations to test a hypothesis, it is important to repeat the tests. To obtain valid results, you need to have similar results over multiple attempts to ensure consistency in the findings and to show that what you are discovering is not by chance but is instead replicated each time the experiment is run. While multiple trials are not required in this lab experiment, if you feel particularly less than confident with your results from doing only one trial run in Activity 1 or 2, feel free to do multiple trials to test for validity.

Materials

Needed but not supplied:

- Tray or cookie sheet (or something similar)
- 2–3 lb bag of **play sand** (not construction sand or any other type of sand or soil) or, if that is unavailable, substitute with 1 lb bag (or more) of **plain cornmeal** (not self-rising)
- Single-use cup that can have a hole poked in it (e.g., plastic yogurt cup, foam cup)
- Small piece of foam (such as from a foam cup), about the size of a grain of rice
- Cup, such as a glass, mug, or plastic cup
- Paper clip, skewer, or thumbtack (to poke a hole in the single-use cup)
- 2 books, one approximately twice as thick as the other
- Ruler (There is a ruler in the Equipment Kit if you have already received it, or you can print one at a website such as printable-ruler.net.)
- Tap water
- 2 Plastic bags (to cover the books or objects you don't want to get wet)
- Stopwatch (or cell phone with a timer)
- Digital camera or mobile device capable of taking photos
- Piece of string
- Marker

Safety

Wear your safety goggles, gloves, and lab apron for the duration of this investigation.

Read all the instructions for these laboratory activities before beginning. Follow the instructions closely, and observe established laboratory safety practices, including the use of appropriate personal protective equipment (PPE).

Do not eat, drink, or chew gum while performing these activities. Wash your hands with soap and water before and after performing the activities. Clean the work area with soap and water after completing the investigation. Keep pets and children away from lab materials and equipment.

Preparation

Note: This investigation is best performed outdoors or in an area in which it is easy to clean up wet sand/cornmeal and water. **Do not** dump any of the sand/cornmeal and water mixture down the sink, because it can cause clogging.

1. Read through the activities.
2. Obtain all materials.
3. Pour the sand or cornmeal in one, even layer on the tray or cookie sheet.
4. Pour water slowly over the sand/cornmeal until it is completely saturated. Pour off any excess water outside.
5. With your hands, rub the sand/cornmeal so it is flat, and let it dry overnight in the tray/cookie sheet.
6. Using the paper clip, skewer, or thumbtack, poke a hole in the side of the single-use cup, 1 cm up from the bottom of the cup.

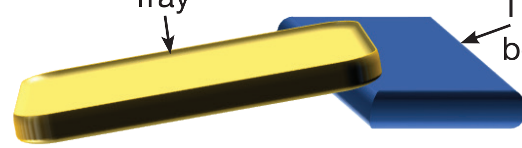
ACTIVITY 1

A Creating a Stream Table

In this activity, you will be measuring different factors (see Step 5) for two different stream models: one where the streambed is tilted at a steeper angle and another where the streambed is tilted at a shallower one. Propose four separate hypotheses for which of the two streambed angles (steeper or shallower) will have the highest values for sinuosity, velocity, relief, and gradient. Briefly state why you feel that way. Complete this information in the “Hypotheses” section of the **Lab Worksheet**.

1. Bring the tray outside. Place the thicker book in a plastic bag. Place the tray on one end of the book so it is tilted (see Figure 7).

Figure 7.



2. Fill the cup *without* a hole in it with tap water and slowly pour the water into the single-use cup. Ensure that the single-use cup is right above the higher end of the tray.
   Note: Store extra tap water on-site if more water is needed to form a stream.
3. Let the water trickle out of the hole in the single-use cup down the sand/cornmeal. Observe how the water forms a “stream” in the table. Stop pouring after a small streamflow has formed down the table.

   Poking a Hole in a Cup to Create a Stream
   https://players.brightcove.net/17907428001/HJ2y9UNi_default/index.html?videoId=5973740372001

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4. On a blank sheet of paper, carefully sketch what the formed stream looks like. Clearly label where erosion and deposition have occurred along the streambed. Take a photograph of your completed drawing and another photograph of your actual stream table. In the stream table photograph, include a strip of paper with your name and the date written on it. You will be uploading both photographs to your lab report.

5. Use the instructions below to calculate the values for the different physical stream features in the "Calculations" section of the **Lab Worksheet**. Record these values in Data Table 1 of the "Observations/Data Tables" section of the **Lab Worksheet**.

   a. **Sinuosity** = curvy distance (cm)/straight distance (cm) *(no units)*

      i. Use a piece of string to measure the distance from the mouth to the source of the stream along the curve (curvy distance). Once you have used the string to trace the stream, hold each end of the string, straighten it, lay it flat, and mark where the two ends of the stream were. Use a ruler to measure this distance between the marks (the curvy distance).

      ii. Use a ruler to measure the distance straight down the stream from the mouth to the source of the stream (no curve—straight distance).

      iii. Now, divide the curvy distance by the straight distance. **Note:** If there is no curvy distance (if the stream forms straight down the table), then the sinuosity is 1.

      How to Measure the Sinuosity of a Stream
      https://players.brightcove.net/17907428001/HJ2y9UNi_default/index.html?videoId=5973736251001

   b. **Velocity** = distance traveled (cm)/time to travel (s) *(recorded in cm/s)*

      Obtain the small piece of foam (about the size of a grain of rice). Hold the single-use cup over the raised edge of the stream table, allow water to flow out of the hole, and drop the piece of foam into the top of the stream. Time how long it takes (in seconds) for the piece of foam to float downstream. Divide the curvy distance by this time.

      How to Measure the Velocity of a Stream
      https://players.brightcove.net/17907428001/HJ2y9UNi_default/index.html?videoId=5973739032001

   c. **Relief** = highest elevation (cm) – lowest elevation (cm) *(recorded in cm)*

      Measure the elevation change from the beginning to the end of the stream. Use the ruler to measure the highest point of the incline to the ground for the highest elevation and measure the bottom part of the tray to the ground for the lowest elevation.

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ACTIVITY 1 continued

[How to Measure the Relief of a Stream]
https://players.brightcove.net/17907428001/HJ2y9UNi_default/index.html?videoId=5973740399001

d. **Gradient** = relief (cm)/total distance (cm) (rise/run) *(no units)*

Measure the slope of the stream; divide the relief by the total distance (calculated in Steps c and a). **Note:** If the stream is curvy, this distance is the curvy distance; if it is not, then this distance is the straight distance.

[How to Measure the Gradient of a Stream]
https://players.brightcove.net/17907428001/HJ2y9UNi_default/index.html?videoId=5973742678001

6. Gently pour the excess water from the stream table into the grass, and flatten the sand/cornmeal out where the stream formed, making a uniform layer.
7. Repeat Steps 1–6 with the thinner book to obtain a more gradual stream formation.
8. While not required, if you feel particularly less than confident with your results from doing only one trial run, feel free to do multiple trials to test for validity.

ACTIVITY 2

A Scientific Method: Modeling Human Impacts on Stream Ecosystems

Note: In Activity 1, the heights of the source of the streams were altered to observe how streamflow and streambed formation were affected. In Activity 2, use your streamflow knowledge to design an experiment by altering a different characteristic. You will record the same calculations for your new experimental setup.

1. Design a procedure similar to Activity 1. Choose one height to test the trials and change a different variable to analyze the same calculations for stream movement and formation throughout the streambed. Choose a variable to change that models how humans might modify a stream channel for good or for ill. Activities such as pre-digging a stream, adding a dam or other features along the streambed, or adding plants along these areas are all common factors that can be altered within a streambed. Feel free to implement additional materials from your surroundings, such as using a rock to represent a dam, for example.
2. Hypothesize whether each of the four calculations (sinuosity, velocity, relief, and gradient) will increase, decrease, or stay the same, and include your reasoning in your choices. Record this in the “Hypotheses” section in your **Lab Worksheet**.

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3. Test your new experimental design by using the same procedure as in Activity 1. On a blank sheet of paper, carefully sketch what the formed stream looks like. Clearly label where erosion and deposition have occurred along the streambed. Take a photograph of your completed drawing and another photograph of your actual stream table. In the stream table photograph, include a strip of paper with your name and the date written on it. You will be uploading both photographs to your lab report.
4. Calculate the values of the four different stream features in the "Calculations" section of the **Lab Worksheet**. Record your findings in Data Table 2 of the "Observations/Data Tables" section of the **Lab Worksheet**.
5. While not required, if you feel particularly less than confident with your results from doing only one trial run, feel free to do multiple trials to test for validity.

Submission

Using the **Lab Report Template** provided, submit your completed report to Waypoint for grading. It is not necessary to turn in the Lab Worksheet.

Disposal and Cleanup

1. Dispose of the sand/cornmeal mixture either in the environment or in the household trash. Dispose of any other materials in the household trash, or clean them for reuse.
2. Sanitize the work space, and wash your hands thoroughly. The single use cup may be recyclable.

ACTIVITY

Lab Worksheet

Hypotheses

Activity 1.

Sinuosity hypothesis:

Velocity hypothesis:

Relief hypothesis:

Gradient hypothesis:

Activity 2.

Sinuosity hypothesis:

Velocity hypothesis:

Relief hypothesis:

Gradient hypothesis:

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Observations/Data Tables

Data Table 1.

	Trial	Sinuosity	Velocity (cm/s)	Relief (cm)	Gradient
Thicker Book	1				
	2				
	3				
Thinner Book	1				
	2				
	3				

Data Table 2.

Variable changed: ______________________________

Book thickness used: ______________________________

Trial	Sinuosity	Velocity (cm/s)	Relief (cm)	Gradient
1				
2				
3				

continued on next page

ACTIVITY

Lab Worksheet continued

Calculations

Activity 1.

Sinuosity:

Curvy distance (cm)/Straight distance (cm) = Sinuosity *(no units)*

__________ / ___________ =

Both the curvy and straight distances are measurements taken from the stream formation in the stream table. Please refer to Activity 1 for more details.

Velocity:

Distance traveled (cm)/Time it takes to travel (s) = Velocity (cm/s)

__________ / ___________ =

The distance it takes a small piece of paper to travel downstream divided by how long it takes to get downstream is the velocity. Refer to Activity 1 for more details.

Relief:

Highest elevation (cm) – Lowest elevation (cm) = Relief (cm)

__________ – ___________ =

By subtracting the highest elevation of the stream and the lowest elevation of the stream from each other, the relief can be calculated. Please refer to Activity 1 for more details.

Gradient:

Relief (cm)/Total distance (cm) = Gradient *(no units)*

__________ / ___________ =

By dividing the relief by the total distance of the stream, the gradient can be calculated. Please refer to Activity 1 for more details.

Activity 2.

Sinuosity:

Curvy distance (cm)/Straight distance (cm) = Sinuosity *(no units)*

__________ / ___________ =

Both the curvy and straight distances are measurements taken from the stream formation in the stream table. Please refer to Activity 1 for more details.

Velocity:

Distance traveled (cm)/Time it takes to travel (s) = Velocity (cm/s)

__________ / ___________ =

The distance it takes a small piece of paper to travel downstream divided by how long it takes to get downstream is the velocity. Refer to Activity 1 for more details.

Relief:

Highest elevation (cm) – Lowest elevation (cm) = Relief (cm)

__________ – ___________ =

By subtracting the highest elevation of the stream and the lowest elevation of the stream from each other, the relief can be calculated. Please refer to Activity 1 for more details.

Gradient:

Relief (cm)/Total distance (cm) = Gradient *(no units)*

__________ / ___________ =

Divide the relief by the total distance of the stream to calculate the gradient. Please refer to Activity 1 for more details.

NOTES

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