New Hampshire Stream Table Unit

Companion Curriculum Guide

for the

Emriver Em2 Geomodel ("The Flume")

For Teachers and Students in Grades 3 to 6

Developed by

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May 6, 2015

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History & Gratitudes

In the summer of 2012, The Ottauquechee Natural Resources Conservation District (ONRCD), based in White River Junction, Vermont, purchased a stream table to foster understanding of stream dynamics in Vermont communities. Called the Emriver Em2 Geomodel by its creator, Little River Research and Design (www.emriver.com), this tool is used for river and hydroscience research and education all over the world.

At that time, Vermont was recovering from Tropical Storm Irene, which hit the region in August 2011 with severe flooding that devastated numerous communities. ONRCD believed that allowing people to observe actual stream dynamics in a scaled-down model would help them understand how to work with streams to minimize future flood damage.

Jenny Hewitt, a teacher at the Pomfret School in Vermont, saw the stream table's potential for enhancing her watershed curriculum. She borrowed it from ONRCD in the fall of 2012 for her third/fourth grade class. Jenny's unit, developed in collaboration with Larry Kasden of ONRCD and Jennifer Guarino, Watershed Education Specialist with Ecotone Education, formed the basis of the *Vermont Stream Table Lesson Packet*, now in its third year in Vermont schools.

Stream table fever hit New Hampshire in 2014, when the Maple Avenue School in Claremont, NH, borrowed it from ONRCD. Lionel Chute, District Manager of the Sullivan County (NH) Conservation District, purchased a stream table for New Hampshire schools in the fall of 2014 with funding from the Wellborn Ecology Fund of the New Hampshire Charitable Foundation.

Another grant from the Wellborn Ecology Fund was made to the Grantham (NH) Village School to allow Jennifer Guarino and Kevin Gianini, Grantham's fifth grade teacher, to adapt the Vermont lesson packet for New Hampshire's schools and geographic setting. Shane Csiki, Flood Hazards Administrator at the New Hampshire Department of Environmental Services, generously offered his expertise and resources to this development process.

The ***New Hampshire Stream Table Unit*** is the result of these efforts. We are grateful to all the pioneers who saw the enormous educational opportunity that the Emriver Em2 Geomodel offers to New Hampshire's students, their teachers, and, by extension, their communities. As you use this curriculum guide with your own students, please consider ways you can help to improve and further develop it.

A *Teacher Evaluation Form* is included on the last page to gather your feedback, or you can email us your comments. Please send to: Lionel Chute, Sullivan County Conservation District, 95 County Farm Road, Unity, NH 03743. Voice (603) 542-4891, Fax (603) 542-2829. E-mail: lchute@sullivancountynh.gov.

Through continuing collaboration across the Connecticut River and among educators and stream scientists, we can help people learn how to live in balance with the vital flowing waters in our communities.

UNIT GOAL & LEARNING OBJECTIVES

Goal of the *Stream Table Unit*:

To educate school children and their communities about the ways streams behave and how people can live in harmony with streams.

Learning Objectives of the *Stream Table Unit*:

1. To understand how streams…
    - move over time within a predictable corridor
    - form meanders as they flow through valleys
    - create and follow a pattern
    - seek to balance energy by moving water and sediments
2. To demonstrate human impacts on a stream and the ways a stream responds. Human impacts include:
    - straightening, berming, and armoring
    - removing gravel
    - installing different sizes and types of stream crossings
    - opening and closing access to floodplains

How To Use The Stream Table Unit

The Stream Table Unit was created for use with the Emriver Em2 Geomodel (stream table or "flume"), which can be borrowed from the Sullivan County Conservation District (SCCD) in Unity, NH. Please see How Schools Can Reserve the Stream Table below for more information, or to request the use of the stream table.

- These lessons are geared for students in **grades 4, 5, and 6**.
- **Each lesson** has the following parts:
  - An **Overview** section that provides context for the lesson. ***More Info*** boxes are included that direct you to resources that pertain to that lesson. Two such resources are used extensively in this lesson packet: Living in Harmony with Streams: A Citizen's Handbook to How Streams Work, prepared by the Friends of the Winooski River and partners; and *After the Flood: Vermont's Rivers,* a Youtube series of 4 videos made by River Bank Media.
  - A **Materials** box that lists items needed for that lesson.
  - A **Set-Up** box with information on how to prepare for the lesson.
  - A **Timeframe** box with a rough estimation of the time needed to teach the lesson.
  - **Instructions** for teaching the lesson.
- Some lessons have ***Student Activity Sheets****,* which can be copied for student work and used to assess student learning.
- A **Glossary** of terms used in this unit is included after the lessons.
- An annotated list of **Teaching Resources** is provided for more information.
- An **Additional Student Activity, Lane's Balance,** is offered at the end for older students or those who need a challenge.
- A **Teacher Evaluation Form** is included to gather feedback on the unit for future improvement. *Please complete this form and send it to* Lionel Chute, Sullivan County Conservation District, 95 County Farm Road, Unity, NH 03743. Voice (603) 542-4891, Fax (603) 542-2829. E-mail: lchute@sullivancountynh.gov.
- For more information on stream table education, please contact Jennifer Guarino, Ecotone Education, 214 Sugar Plum Court, Randolph, VT 05060. Voice (802) 728-9135 or (802) 431-3714. E-Mail: jguarino556@gmail.com.

Curriculum Planning

Teachers borrow SCCD's stream table for 1 to 2 weeks at a time. We recommend that you hold a Parent / Community Night toward the end of your time with the stream table. During this event, students can teach what they've learned to adults and other children, extending the learning into the community and providing a powerful opportunity for student self-assessment.

Below are sample units based on the use of the table for 5 days and 10 days. We would love to hear from you as you adapt this unit to your own teaching goals and environment. Please send us your ideas!

Figure 1. Sample 5-Day and 10-Day Units

Most teachers borrow the stream table for 5 or 10 school days. Here are suggested unit formats for these two timeframes.

Before the stream table arrives:

- *Consider your goals and student learning outcomes for the unit; decide which lessons to teach*
- *Do the Streams & Watersheds Lesson*
- *Discuss guidelines and expectations with your students for using the stream table and associated materials*

Once the stream table is in your school:

- *Teach students how to run it and maintain it properly and safely.*
- *Discuss a system for organizing all the pieces*
- *Decide how you will pack up the stream table, and whether you will involve students in this process.*

A Sample 5-Day Unit

Lessons are in italics; those with student assessment sheets are underlined

Mon	**Tues**	**Wed**	**Thurs**	**Fri**
Lesson 1: Corridors and Channels	*Lesson 2: Water & Sediments*	*Lesson 3: Streambanks*	*Lesson 4: Stream Crossings* Parent / Community Night	*Lesson 5: Upstream, Downstream*

A Sample 10-Day Unit

Lessons are in italics; those with student assessment sheets are underlined

Mon	**Tues**	**Wed**	**Thurs**	**Fri**
Allow students to visit the stream table in pairs or small groups. Ask them to record Observations, Thoughts, and Questions as they explore in an unstructured way.	*Lesson 1: Corridors and Channels*	*Lesson 2: Water & Sediments*	Introduce students to the scientific method, and explain that each experiment begins with a question that can be tested using this method. Discuss the Questions generated on	*Lesson 3: Streambanks*

			Monday during unstructured explorations. Choose one Class Question that is *testable* and ask pairs of students to design an experiment to test it.	
Allow each student pair to take turns implementing their experiment on the stream table and gathering data. Have each pair present its work to the class. Discuss their exper. design and results. As a class, formulate a set of conclusions that capture student learning.	Lesson 4: Stream Crossings	Lesson 5: Upstream, Downstream	Lesson 6: Stream Table Performance Task Parent / Community Night	Lesson 6: Stream Table Performance Task, concluded

HOW SCHOOLS CAN RESERVE THE STREAM TABLE

The STREAM TABLE UNIT was designed to accompany the Emriver Em2 geomodel (often called the stream table or "flume"), an educational tool that models stream dynamics and human impacts on streams through demonstrations and hands-on activities. Thanks to a generous grant from the Wellborn Ecology Fund of the New Hampshire Charitable Foundation, the Sullivan County Conservation District has purchased a stream table to loan to Upper Valley schools in New Hampshire. Schools can borrow the stream table for 1 to 2 weeks.

Stream Table Location, Set-Up, and Management

The stream table's dimensions are roughly 3 feet by 6 feet and its footprint is about 8 feet by 10 feet (this allows students to surround the table comfortably). It comes with all needed equipment for operation as well as a floor tarp that is laid down before the table is set up.

Experienced stream table assemblers can set it up in about 45 minutes (including time to bring all equipment into the building). A person new to its set-up should allow up to 2 hours. For more information and a set-up guide with photos, please view the manual, ***Use and Care of the Emriver Em2 Geomodel*** on the website of Little River Research and Design, the company that manufactures it:

http://www.emriver.com/wp-content/uploads/2011/09/Emriver_Em2x_manual_2012_05-02_AQ.pdf

Recommendations for choosing a location and managing the stream table:

- Many schools put the stream table in a classroom, but some put it in a common space in the school, like an extra classroom or a lobby. *Please note: If the stream table is in a common space, student access to it should be controlled. See below.*
- The stream table combines "sediments" (small plastic particles), running water, electrical equipment, and an electrical cord. Students should always be supervised around the stream table.
- The stream table requires 25 gallons of water. You need easy access to a sink to fill up its reservoir.
- Because it contains sediments and water, the stream table tends to be messy. Please consider this when deciding on its location.
- When the stream table is not being used, please cover it with a tarp or tablecloth. Some teachers also place a sign on it that reads "Stream Table Closed". This prevents students from playing with it when they are not supervised.

To reserve the stream table in New Hampshire, please contact:

Phylicia Schwartz, Environmental Education and Outreach Specialist
Sullivan County Conservation District (SCCD)
95 County Farm Road
Unity, NH 03743

E-mail: pschwartz@sullivancountynh.gov
Voice: (603) 504-1004
Fax: (603) 542-2829

Before the Stream Table Arrives: Streams & Watersheds Lesson

Overview

Every stream is the result of gravity pulling water downhill over a particular landscape. Raindrops that fall on high points of land course down the slope and join other drops of water, forming a small brook that continues to flow downward. A brook eventually joins other brooks, creating a stream. Streams join other streams to form a river, and so on down the slope until the gathering waters collect in the lowest valley. Eventually, this collected water flows out its "mouth" into another water body: a larger river, a pond, a lake, a wetland, or the ocean. At every step in this process, water evaporates back into rain clouds, powering a continuous water cycle.

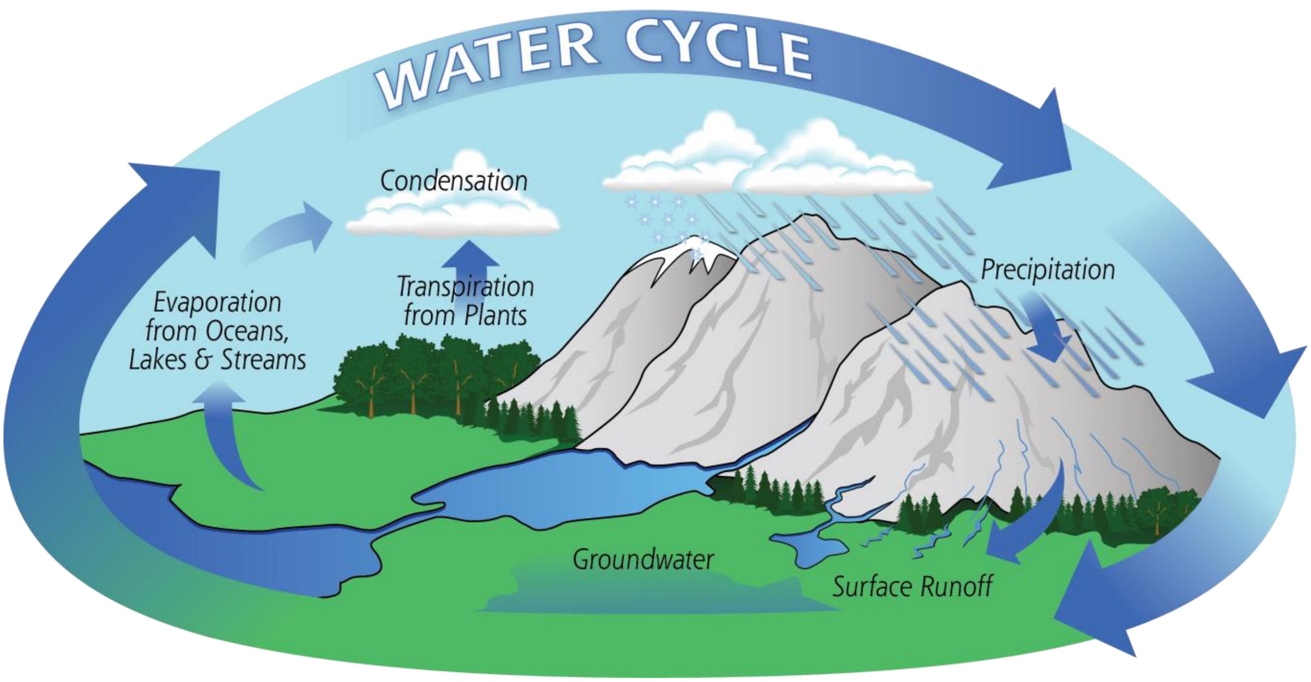


Figure 2. The Water (Hydrologic) Cycle.
(From the National Aeronautics and Space Administration's (NOAA) Precipitation Education Program:
http://pmm.nasa.gov/education/water-cycle)

All connected flowing waters create a *river system*, which occupies a basin of land called a *watershed* (see Glossary). The brooks and streams that form at high elevations comprise the *headwaters* of the watershed. They come together to create *tributaries*, which flow into the *mainstem* (the largest river at the lowest elevation in the watershed).

Please note: The stream table represents one slice of a watershed and one section of a mainstem; it does not include the whole imaginary basin in which this model stream flows, or any tributaries flowing into the mainstem on the table.

Mascoma River Watershed Base Map

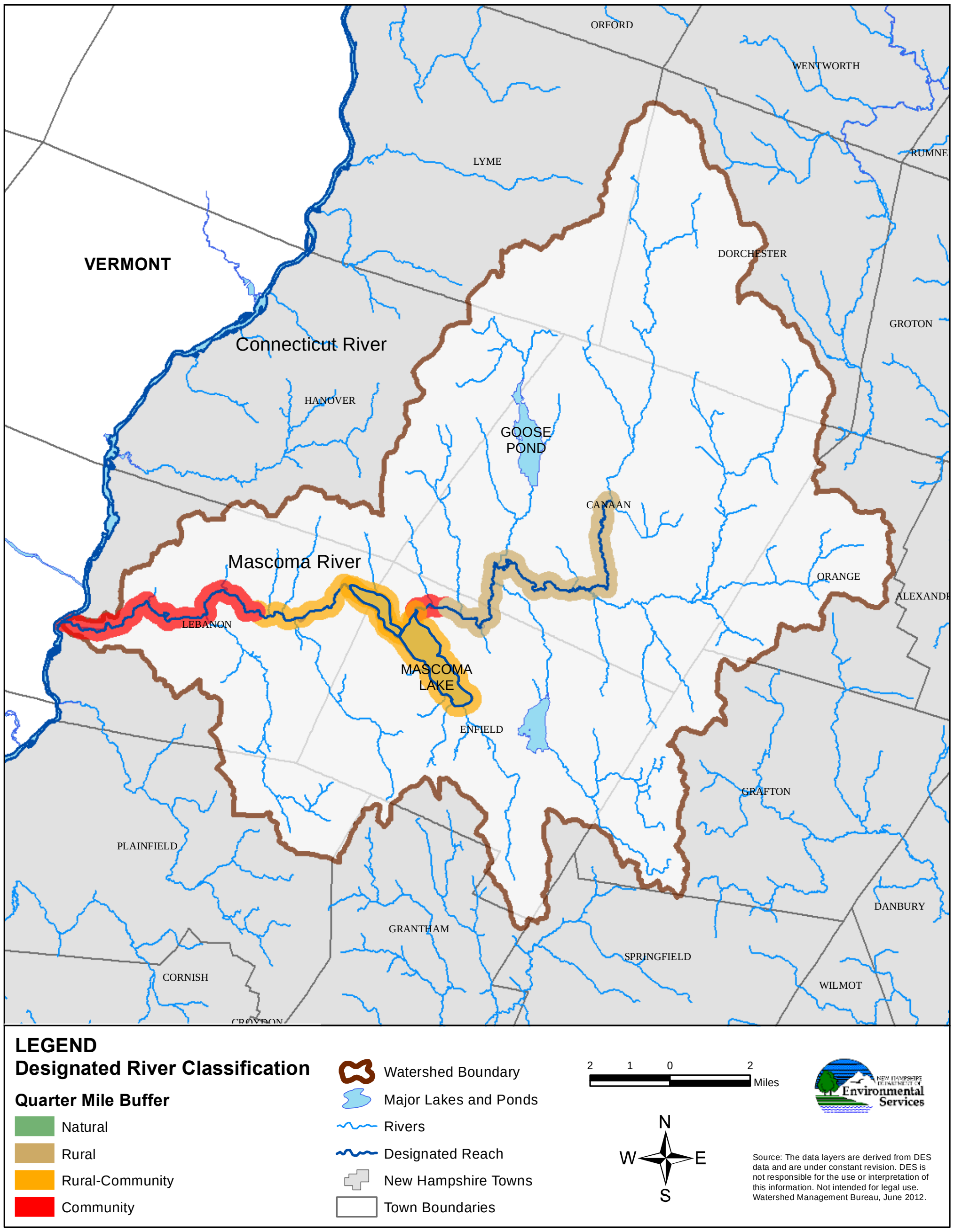


Figure 3. The Mascoma River System, which includes all flowing waters that exit the watershed at one point (its "mount") on the Connecticut River. (From NH Department of Environmental

Services.)

MORE INFO:

Living in Harmony With Streams booklet, page 8:

http://www.winooskiriver.org/images/userfiles/files/Stream%20Guide%201-25-2012%20FINAL.pdf

MATERIALS	SET-UP
• Mascoma River Watershed Base Map (see above or TEACHING RESOURCES), or an appropriate map of your river's watershed • An atlas or road map that includes the students' town and school • NASA diagram of the water cycle (below) and at http://pmm.nasa.gov/education/water-cycle	• none

INSTRUCTIONS – STREAMS & WATERSHEDS LESSON

Introduce students to the definition of *watershed* (see GLOSSARY). Show them the Mascoma River Watershed Basin Map (above) or a watershed or river system map of their area.

Explain that every *river system* drains a basin (watershed) of land, from the highest elevations (the "rim" of the basin) to the lowest valley. A river system flows out its "mouth" into another river, a pond, a lake, a wetland, or the ocean.

Have students find the location of their town on the watershed map, their school, and their homes (if, in fact, their homes are within this watershed). When water leaves their river system, where does it go? (into the Connecticut River). Where does the water go after that? (into Long Island Sound in the Atlantic Ocean).

Explain that water in any watershed is part of the hydrologic (water) cycle, which continuously circulates water through our atmosphere and our earth's crust. Show students the NASA water cycle diagram above (or another one) and have them trace the flow of water through this cycle.

Lesson 1. Corridors & Channels

Overview

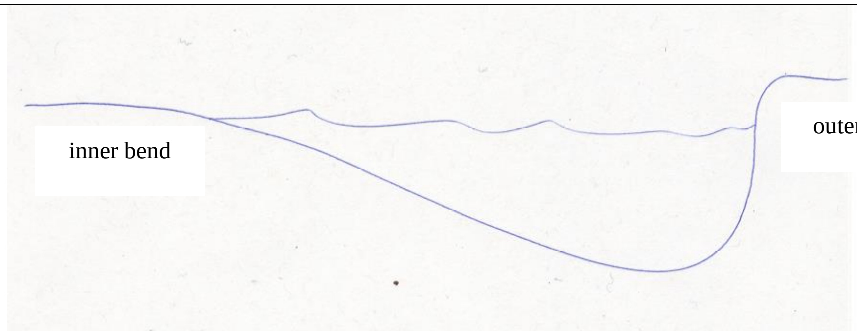
Flowing water carries energy as it courses across a landscape. This energy, and the water's natural "corkscrew" motion, erode a *channel* through the landscape and often create bends called *meanders*. (You can see the same meandering motion as you watch a water drop move down your car's windshield: it twists from side to side rather than running straight down.) The stream continually carves into the bends, eroding the soil and making the bends more pronounced over time. This process lengthens the stream and makes the stream's slope more gradual, which slows down the water. As flowing water hits the bends, it loses some of its energy and is further slowed. In this way, meanders help to absorb the force of the stream moving through the landscape.

A skier making turns down a snowy slope models a stream's meander pattern. As the skier turns to the left, her outer (right) ski travels a bit further and moves faster, pushing forcefully against the snow and carving into the outside of the curve. The inner (left) ski moves slower and carries less force. As the skier moves from one turn to the next, her skis move at equal speeds, producing less overall pressure on the snow. As she turns from side to side, she slows down, transfers some of her energy into the slope, and lengthens her route down the mountain. Both the skier's turns, and the stream's carving action, create a *meander belt*, the side-to-side (lateral) extent of a series of meanders (see GLOSSARY). A stream's meanders can change over time, depending on many factors. A big storm can cause significant movement, as seen in the aftermath of recent large flooding events.

A stream channel meanders within a broader *corridor*, which is defined as the land that includes the active channel of a stream, its meander belt, the *riparian buffer* along the stream, and the stream's *floodplain* (see GLOSSARY).

Each meander in a stream has a similar profile in cross-section. The inner bend has slower water and a gradual slope, while the outer bend has faster water and a steeper slope (see Figure 4 below). Sometimes a *point bar* of deposits forms within the inner bend. The erosive force of the water gouging the outer bend often forms a steep or concave *cut bank.* The table in Figure 4 summarizes the physical conditions found in each location.

The stream table models an *alluvial* stream, which erodes and deposits sediments, forming meanders in the process. Please note that not all streams form meanders. For example, mountain (non-alluvial) streams tend to drop straight down steep gradients. They dissipate their energy as they flow across rough, rocky beds and over cascades and falls. There is little soil to erode along the banks and streambed, and therefore little sediment to move downstream.



Inner Bend (depositing)

- slow velocity – drops sediments from upstream; often forms a *point bar*
- gradual slope
- shallow water
- smaller particles of sediment on bottom

Outer Bend (eroding/scouring)

- fast velocity – carries sediments from upstream and erodes more sediments from the bend
- steep, sometimes concave (undercut) slope
- deep water
- coarser particles of sediment on bottom

Figure 4. Comparing Inner Bend and Outer Bend (in cross-section)

MORE INFO:

Living in Harmony with Streams booklet, page 10 - 11

Little River Research and Design Educational Videos: http://www.emriver.com/?page_id=1521

- Emriver straight channel simulation
- Grand River remeandering, 1939-1996
- Grand River remeandering comparison

After the Flood videos: http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

- Video 1: Staci Pomeroy using stream table; starting at 4:08 minutes
- Video 1: straightening a stream; starting at 8:13 minutes
- Video 2: river corridor; starting at 5:50 minutes
- Video 2: urban areas, mitigating flood damage, and berms; starting at 9:09 minutes
- Video 3: straightening a river; starting at 6:38 minutes

MATERIALS

- stream table
- toy houses
- student science notebooks, or sheets of paper on clipboards
- pencils
- camera
- clock
- small sticks or popsicle sticks
- STREAM ANATOMY PARTS STUDENT ACTIVITY SHEET (below)

SET-UP

- Make Stream Anatomy Part signs (Student Activity Sheet)
- Get the stream table ready to run.

TIMEFRAME

60 minutes

INSTRUCTIONS

Lesson 1.1. -- Why Meanders Form

Give each student a science notebook, or a sheet of paper on a clipboard, and a pencil. On the stream table, create a straight channel from top to bottom. Ask students to observe what happens as you turn on the water and let it flow for a few minutes. Ask them to write down 3 of their observations. (Another option is to have students draw a before and after picture of the channel.)

They will see bends (meanders) form along the channel. Why does this happen?

> (Flowing water moves in a corkscrew pattern, which eats into the channel and begins to form bends. As the flowing water scours the outer bend, it further erodes it, causing the bend to become more pronounced.)

Discuss student observations and explain that most (but not all) streams and rivers naturally form meanders as they flow over the landscape. Introduce the term *meander belt* (see GLOSSARY) and ask them to observe any changes to the shape and size of the meander belt as the water continues to flow.

Lesson 1.2. – The Changing Channel

Turn off the water on the stream table. Create a straight channel down the stream table, and have students place sticks along the channel on both sides to define the width and path of the channel. Have a student stand at the "mouth" end of the table and take a photo of the channel. Ask them to predict where it is safe to build houses along the stream, and have them place some toy houses on those spots.

Run the water and have a student take a photo from the same spot every 5 minutes for about 30 minutes (see Figure 4 below). Occasionally, turn up the volume of water to model a heavy rainstorm. (For younger students or a large class, use a shorter period of time.)

After 30 minutes, discuss what happened. Did the stream behave as they predicted it would? Did any houses get dangerously close to the stream, or even fall into the stream? Ask them to explain what happened and why.

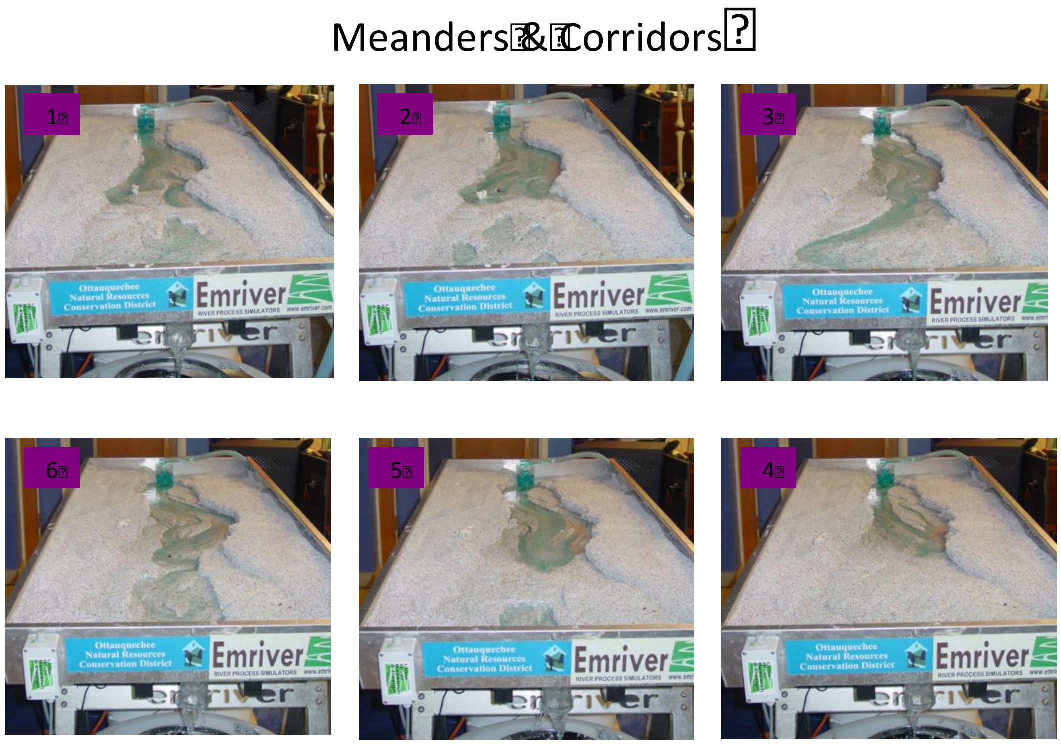
> (Since water corkscrews through the landscape, flowing water carves meanders, which tend to get wider over time until a stable meander belt is formed.)

Lesson 1.3. – Stream Anatomy

After the stream table has run for a little while and nice meanders have formed, tell students that they will learn about the "anatomy" of a stream. Hand out a STREAM ANATOMY PART sign (see below) to each student. Taking turns, have each student read his/her sign and place the sign in an appropriate spot on the stream table. Clarify any confusion over terms and definitions.

Ask students to write some new observations in their science notebooks using the vocabulary they just learned. This gives them a chance to practice the new vocabulary and sharpens their observation skills.

Figure 5. *Patti Collins' 5th graders at Reading School in Vermont took 21 photos at*



regular intervals to record changes in their flowing stream. The photos above are a subset.

Directions: Laminate this sheet (so it can get wet on the stream table). Cut out the cards and tape each one to a stick. Discuss each term with the students and have them post each "sign" in an appropriate place in the stream table.

Bank The land along a stream, between the water and the upland areas away from the stream.	**Point Bar** A low, curved bank of sediment along the *inner bend* of a meander. (It points to the *outer bend*.)
Cut bank An eroded bank carved by the flow of water around a bend.	**Riparian Area** The area along the banks with growing plants.
Stream Channel An area between the banks that contains flowing water, or used to contain flowing water, and the floodplain.	**Streambed** The bottom of a stream channel that is covered by water.
Headwaters The places at high elevation where the stream starts.	**Mouth** The place where a stream empties into another body of water.
Groundwater Water that collects underground and sometimes flows beneath the surface.	**Surface Water** Water that is visible on the Earth's surface (lakes, streams, oceans, etc.)
Meander A winding curve or bend of a stream.	**Flood Plain** A strip of flat land along a stream that is flooded when a stream flows over its banks.

LESSON 2. WATER & SEDIMENTS

OVERVIEW

People have been removing *sediments* from streams for a long time. This is done to straighten a channel, to collect gravel for construction, or to deepen a channel to "make room" for floodwaters. Ironically, removing sediments from a stream can create unstable conditions and increase flood damage, which can lead to further change in the stream channel as the stream seeks to reestablish balance. Here are two hypothetical examples of gravel removal (cause) and the stream's response (effect):

Example 1: Deepening the Channel to Make More Room

1. A community dredges a stream channel, lowering the streambed, so it can hold more water during a flood.
2. A huge rainstorm occurs, during which a slug of water enters the channel.
3. The water in the stream rises rapidly, but is contained within the banks because the streambed is now lower. The stream cannot overflow its banks and spill out over its floodplain, which would have absorbed both the larger volume of water and the increased energy created by rapidly moving water.
4. The energy of the high, fast water eats away at the banks, making them unstable and susceptible to collapse.
5. The swollen stream (which includes both water and eroded soil particles) barrels downstream at high velocity, hits a bend in the stream, bites into the bank, and takes out the road at that bend.

Example 2: Mining Gravel for Construction Material *(numbered steps below correspond to numbered steps in Figure 6 below)*

1. A landowner removes gravel from the streambed and sells it to a construction company. This creates a "hole" (depression) in the streambed. The slopes around the hole are steeper than the slope of the original streambed.
2. When flowing water tips into the hole at the upstream end, it falls down the steep slope, picks up speed (becoming "hungry" for sediment), and erodes the streambed along that steep slope.
3. Sediments continue to erode off the upstream slope, causing a *headcut* to work its way upstream (see MORE INFO: Little River video on in-channel gravel mining). This causes high, steep, unstable banks to form downstream of the headcut.
4. The sediments that are scoured off the upstream slope of the hole flow over the hole, where the water slows down and drops its load. (Eventually, these sediments fill the hole.)
5. The flowing water is then forced up the slope at the downstream end of the hole, where it picks up speed again (becoming "hungry") and erodes the sediment on that downstream slope.
6. Once beyond the hole, the water tends to slow down again and drop its load of sediments, causing deposition downstream of the hole.
7. Another flood occurs, which bites into the unstable banks, causing them to collapse.

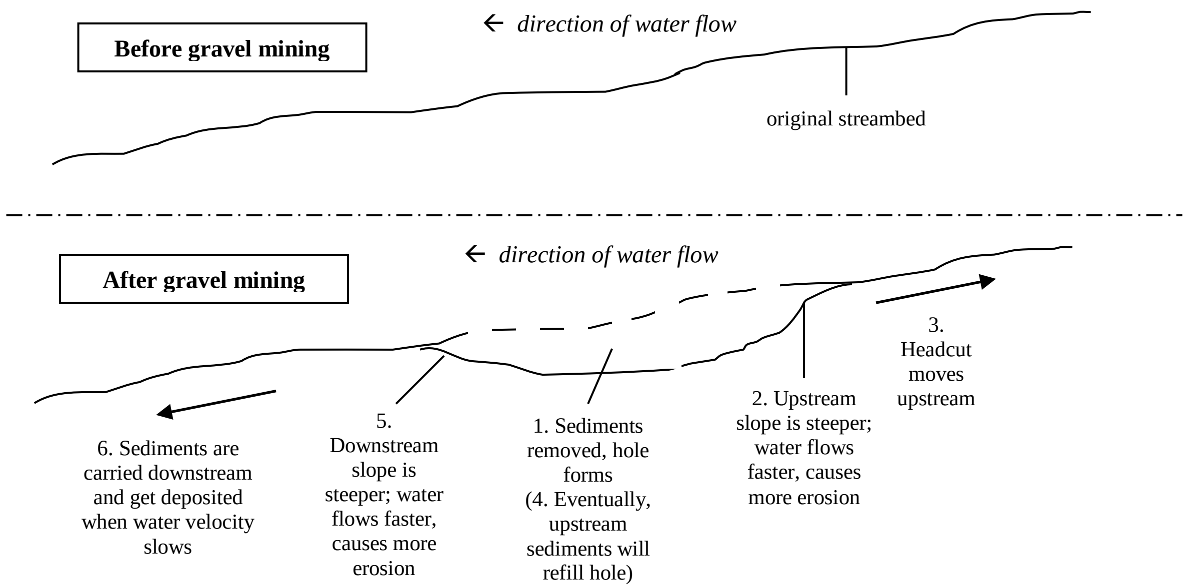


Figure 6. Cross-section of a streambed ***<u>before</u>*** ***and*** ***<u>after</u>*** ***gravel mining.***
(Note: Numbers in the "After gravel mining" section refer to the steps in Example 2 above.)

MORE INFO:
Living in Harmony with Streams booklet, page 14 and page 19
After the Flood Videos
http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

- Video 1: floodplain, headcut; starting at 5:53
- Video 1: high banks; starting at 8:53
- Video 3: recovering from flood damage; starting at 6:38
- Video 3: traditional river management and dredging; starting at 10:15

Little River Research and Design, Educational Videos, Inchannel gravel mining
http://www.emriver.com/?page_id=1521

MATERIALS	SET-UP
• Lane's Balance Student Activity Sheet	• View this video: *Inchannel gravel mining and bar pit capture* (http://www.emriver.com/?page_id=1521, bottom of page); shows *headcut* and other erosion conditions. • Practice using your hand as a backhoe and scoop out some sediment in the stream table's channel, watching the result. Look for a *headcut* to form. This is the effect that you want for this activity.
	TIMEFRAME 60 minutes

INSTRUCTIONS

Lesson 2.1. - Gravel Mining

Run the water in the stream table and allow meanders to form. Discuss gravel mining with students and ask them to imagine that your hand is a backhoe. When you scoop out some sediment, what will happen to:

- the water velocity?
- the streambed?
- the banks of the stream?
- the area downstream of the dredged area?

Ask them to write their predictions in their science notebooks.

- Now use your “backhoe” (hand) to scoop out sediments and have students observe the effects. Discuss the reasons why the stream adjusts as it does. (see OVERVIEW above).

Lesson 2.2. - High Banks & Low Banks

On the stream table, build a channel section with very high vertical banks and another channel section with low banks. Place a house on each, the same distance from the channel. Run a “storm event” (high water volume) and see what happens to each bank, and the house on each bank.

Here are some probable scenarios:

- The steep bank erodes and becomes unstable. It eventually collapses, taking the house with it.
- Water along the low bank surges up the bank and spreads out over the floodplain around the house, where it loses its velocity and force.
- The low house floods, but the land around it doesn’t erode as much as the land under the high bank house. And the house remains intact (if wet).

LESSON 3. STREAMBANKS

Overview

Vegetation growing along streams – the *riparian buffer* - helps to hold streambanks, filters pollutants from water that runs off the land, and absorbs the energy of floodwaters. Riparian plants directly benefit the stream ecosystem in several ways. They shade the water, keeping it cool and providing cover for aquatic organisms. Leaves, branches, and logs that fall into the water contribute resources to the stream's food web. On land, the riparian buffer provides cover for terrestrial animals that come to the stream for water and food, and offers them a safe travel corridor. In general, riparian trees are more ecologically valuable than riparian herbs and grasses; their bigger roots systems hold the banks more securely, and they often harbor a diverse plant community beneath their canopies that supports a diverse wildlife community.

Humans often remove riparian vegetation to establish buildings, roads, industrial developments, and agricultural areas along streams. In so doing, we tend to destabilize their banks and increase the risk of erosion. To protect the banks, we implement streambank stabilization programs that call for building various structures along streams, including "riprap" (rocks that line the bank) and cement walls. While these artificial materials armor the banks and prevent erosion at that site, they can transfer the force of flowing water downstream, where it can cause significant erosion.

MORE INFO:
Living in Harmony with Streams booklet, page 11
After the Flood videos
http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

- Video 3: armoring banks; starting at 7:54 minutes
- Video 4: VT's fisheries; starting at 4:24 minutes
- Video 4: aquatic habitat; starting at 10:04 minutes

MATERIALS

- rocks
- washcloths
- cheesecloth, cut into long strips
- scissors

SET-UP

- Get the stream table ready to run. Allow water to flow and meanders to form.

TIMEFRAME

45 minutes

INSTRUCTIONS

Lesson 3.1. – Bank Protection.

Define the term *riparian buffer* (see OVERVIEW and GLOSSARY). Explain that people often remove the plants along a streambank and then armor it with artificial materials. Ask students to think about the kinds of artificial materials they see along streams. (The list should include rocks and cement walls).

Allow the water to run and meanders to form on the stream table. Give students various materials – rocks, solid surfaces that model cement walls, and washcloths and cheesecloth strips to represent vegetation. Have students use each material in turn to line the streambanks and make observations to answer the following questions:

1. Which material holds the bank the best?
2. Which one absorbs more water? (Talk about the holding capacity of roots, which can absorb and hold large amounts of water during flooding. *Please note: washcloths and cheesecloth are used here to model vegetation, but they lack the root structure that serves to hold stream banks so effectively in nature. Discuss this limitation as you model riparian vegetation with these materials.)*
3. Does erosion occur upstream and/or downstream with each kind of material?

Lesson 3.2. -- Streambanks & Habitat

Explain that streams and their riparian vegetation provide resources for wildlife and fish. Have students brainstorm some important habitat benefits provided by vegetation, riprap, and cement walls. A table with possible answers is provided below.

Bank Materials	**Habitat Benefits**	
	For terrestrial organisms on land	**For aquatic organisms in the water**
riparian vegetation	• plant foods (seeds, berries, leaves, etc.) for terrestrial animals • cover from predators • easy access to water • aquatic prey species (e.g., crayfish) for terrestrial predators (e.g., raccoon) • homes like holes in trees and nests that are close to food and water resources • enriched soil from nutrient cycling of plants and animals	• plant parts drop into the water to provide food and habitat structures for aquatic animals • shade cools the water (which increases dissolved oxygen in water) which benefits fish and other aquatic animals • shade and overhanging vegetation provides cover for fish and other aquatic animals • plant roots hold soil along the banks, preventing excess erosion of soil into the stream.
riprap (rocks that line the bank)	• cover for small animals (if they can hide among or under the rocks) • others?	• rocks hold soil along the banks, preventing excess erosion of soil into the stream (but may divert the water's force downstream and lead to erosion there) • others?
cement walls	• attachment location for some plants, which may serve as food and shelter	• any plants that attach and grow drop plant parts into the water, which provides some food. • any plants that attach and grow provide some shade (see above) • walls hold soil along the banks, preventing excess erosion of soil into the stream (but diverts the water's force downstream and can lead to flooding and erosion there)

LESSON 4. STREAM CROSSINGS

OVERVIEW

Since many of our human activities occur in stream valleys, we often need to cross various flowing waters. *Stream crossings* are **culverts (pipes), open-bottom arches**, and **bridges** that are installed to convey water under a "travelway" such as a road or a path. The size, shape, material, and placement of the stream crossing should be carefully considered to accommodate high flows and to allow for the migration of aquatic organisms such as fish and salamanders.

An undersized crossing, such as a pipe culvert that is not sized to handle large volumes of water, can create lots of problems. During a big storm, streams collect more water than usual and can rise dramatically. A small culvert pinches the flow, causing a backup of water upstream of the culvert, where its swirl can erode the banks and streambed. When a large volume of water is squeezed through the small pipe, the water speeds up and carries more force, creating a "fire hose" effect downstream, often causing severe erosion. If the culvert becomes clogged with debris, it passes even less water or completely dams the stream. In this situation, water flows around and/or over the culvert, often gouging the land and destroying roads. Eventually, the culvert can get washed out, causing the backed up water to surge downstream where it can do significant damage. Because of this, large crossings (pipes, arches, and bridges) that can accommodate increased water volumes are more effective at managing floodwaters than small ones. And the reality is that even small streams will flood on occasion.

Small pipe culverts can also become "perched" when the outflow from the culvert erodes the streambed downward. (This is often the result of the fire-hose effect described above.) If a culvert becomes perched, the downstream end of the culvert is higher than the streambed. A small waterfall forms, causing additional erosion and creating a barrier to fish movements. This can interfere with spawning and prevent fish from escaping predators, moving away from pollution events, and/or finding food.

The New Hampshire Crossing Guidelines, developed by the University of New Hampshire in 2009 (see TEACHING RESOURCES) recommends that a stream crossing structure (culvert, arch, or bridge) should be designed to:

- be wide enough to allow for high flows without constriction
- contain natural streambed sediments
- maintain water depths within or under the structure that are similar to the water depths of the stream itself
- have a slope that is similar to the slope of the streambed

These measures generally prevent severe flooding and erosion. They also allow aquatic organisms to migrate upstream and downstream to access critical parts of their habitats and mix up breeding populations, which increases their genetic diversity and contributes to stable populations.

To design a stream crossing that achieves these objectives, we must consider bankfull width. *Bankfull width* is the typical high water mark that is reached about every other year and can generally be seen as a line along the bank where vegetation changes. It is the area where rising water tips onto its floodplain.

The New Hampshire Crossing Guidelines recognize that every stream is unique, so its authors say that it is unrealistic to follow one standard approach for designing crossings. The general recommendation given by the NH Guidelines is that a stream crossing should be 1.2 times bankfull width plus 2 feet. (See Figure 7 on the right.)

Figure 7. Recommended Width of a Stream Crossing:

1.2 x bankfull width + 2 feet

Example 1:

A stream is 3 feet wide at bankfull width.

Therefore, its crossing should be

(3 feet x 1.2) + 2 feet

= 6 feet wide at the streambed

Example 2:

More Info:

Living in Harmony with Streams booklet, page 2

New Hampshire Stream Crossing Guidelines, University of New Hampshire:

http://www.streamcontinuity.org/pdf_files/nh_stream_crossing_guidelines_unh_web_rev_2.pdf

Vermont Stream Crossing Handbook:

http://www.vtfishandwildlife.com/library/Reports_and_Documents/Aquatic%20Organism%20Passage%20at%20Stream%20Crossings/__AOP_%20Handbook.pdf

After the Flood Videos

- Video 2: culverts; starting at 11:36 minutes
- Video 3: culverts; starting at 00:00 minute (beginning)

Materials

- small culvert (like tomato paste can)
- large culvert (like large soup can)
- "bridge" span (long, flat piece of wood)
- bridge supports (wooden blocks or something similar)
- Stream Crossings Student Activity Sheet (below)

Set-Up

- Get the stream table running
- Prepare a chart on the board or large sheet of paper for the class brainstorm in Lesson 4.2.

Timeframe

60 minutes

INSTRUCTIONS

MATERIALS	SET-UP
• small culvert (small metal can, like a tomato paste can) • large culvert (large metal can, like a large soup can) • bottomless arch (half a wide PVC pipe) • bridge (a long, straight piece of wood with supports) • STREAM CROSSING EXPERIMENT STUDENT ACTIVITY SHEET (either Grades 3/4 or Grades 5/6; see below) • Clipboards, one per student	• Get the stream table running • Prepare a chart on the board or large sheet of paper for the class brainstorm in Lesson 5.2. **TIMEFRAME** 60 minutes or more; ideally carried out over 2 such time periods

Lesson 4.1. – Stream Crossing Experiment

(See appropriate section below -– Grades 3/4 or Grades 5/6 -- for your students' grade or ability level)

Grades 3/4

Show students 2 sizes of stream crossings: the small pipe and the large pipe. Give each student the Grades 3/4 STREAM CROSSING EXPERIMENT STUDENT ACTIVITY SHEET. Read the *Question* to students, clarifying as needed. Ask them to *hypothesize* which crossing size will minimize erosion by checking one of the boxes next to their crossing of choice, then have them explain their reasoning on the line below (their "because" statement). (**Step 1** and **Step 2** on the sheet.)

Step 3 asks students to run an *Experiment* that compares the 2 stream crossing structures to test students' hypotheses. Follow the procedure below to set up a comparable scenario with each type of crossing.

Part 1 – Small Pipe Culvert

1. Create a straight channel in the stream table that is the same width as your small pipe.
2. Install the small pipe in the flowing water on the stream table. Pack sediment against it on either side. (If you have a "road" that you can put across it and some toy cars to drive the road, all the better.)
3. Run the water at low volume and watch it flow through the culvert for a few minutes. Have students write an observation in the first box of the **Observation** table on the student activity sheet. (You may choose to have students draw their observation instead of writing it.) Encourage students to observe water movements, sediment movements, and the changing stream channel.
4. Now turn the volume up a bit (heavy rain) and have students write (or draw) their second **Observation**.
5. Finally, turn the volume up high to simulate a storm surge and have students write (or draw) their third **Observation**.

Part 2 – Large Pipe Culvert

1. Turn off the water flow and rebuild the channel to its original width (small pipe width).
2. Install the large pipe. Note: *The large pipe will be wider than the channel of flowing water. Pack sediment on either side of it.*

Repeat Steps 3, 4, and 5 in Part 1 above (low flow and Observation, medium flow and Observation, high flow and Observation).

<u>Grades 5/6</u>

Show students 3 stream crossings: the small pipe, the bottomless arch, and the bridge. Give each student the Grades 5/6 STREAM CROSSING EXPERIMENT STUDENT ACTIVITY SHEET. Read the *Question* to students, clarifying as needed. Ask them to *hypothesize* which crossing structure will minimize erosion by checking one of the boxes next to their crossing of choice, then have them explain their reasoning on the line below (their "because" statement). (**Step 1** and **Step 2** on the sheet.)

Step 3 asks students to run an *Experiment* that compares the 3 stream crossing structures to test students' hypotheses. Follow the procedure below to set up a comparable scenario with each type of crossing.

A Note to teachers of older and/or more accomplished students: See the box below entitled "Designing a More Rigorous Experiment"

Part 1 – Small Pipe Culvert

1. Create a straight channel in the stream table that is the same width as your small pipe.
2. Install the pipe in flowing water on the stream table. Pack sediment against it on either side. (If you have a "road" that you can put across it and some toy cars to drive the road, all the better.)
3. Run the water at low volume and watch it flow through the culvert for a few minutes. Have students write an observation in the first box of the **Observation** table on the student activity sheet. Encourage students to observe water movements, sediment movements, and the changing stream channel.
4. Now turn the volume up a bit (heavy rain) and have students write their second **Observation**.
5. Finally, turn the volume up high to simulate a storm surge and have students write their third **Observation**.

Part 2 – Bottomless Arch

1. Turn off the water flow and rebuild the channel to its original width (small pipe width).
2. Install the bottomless arch. Note: *The arch will be wider than the channel of flowing water. Pack sediment on either side of it.*

Repeat Steps 3, 4, and 5 in Part 1 above (low flow and Observation, medium flow and Observation, high flow and Observation).

Part 3 - Bridge

1. Turn off the water flow and rebuild the channel to its original width (small pipe width).
2. Install the bridge (long span with bridge supports). *Note: The bridge span will be wider than the channel of flowing water. Pack sediment around the supports.*

Repeat Steps 3, 4, and 5 in Part 2 above (low flow and Observation, medium flow and Observation, high flow and Observation).

Discussion – Gear it for your students' grade and ability level

1. Ask for volunteers to read their Observations to the class – what happened with each of the stream crossing structures? At each flow level (low, medium, high)?
2. Ask students if they see any patterns and/or relationships in their Observations. For instance, did the water behave in a particular way with any of the crossings? Did the water's flow change in a predictable way from one flow level to the next?
3. Have students review the *Question* that started this experiment, then their *Hypothesis* and their "because" statement. Remind them that a scientist's hypothesis is often proven wrong because the world is a complex place and sometimes things happen that you can't predict. But even disproving a hypothesis leads to tremendous learning, and scientific knowledge is often advanced when we get unexpected results.
4. Have students record their *Results* by checking the box next to the structure that they believe created minimal erosion. *Please note that a viable choice is "Not enough data*" (see below).
5. Ask students for a show of hands as follows:
    a. Grades 3/4: Who chose the small pipe? Large pipe? Not enough data? Record the number of votes that each choice received on a flipchart sheet. Have them explain their choices and encourage student discussion.
    b. Grades 5/6: Who chose the small pipe? Bottomless arch? Bridge? Not enough data? Record the number of votes that each choice received on a flipchart sheet. Have them explain their choices and encourage student discussion.

    Explain that professional scientists often work with lots of colleagues, some of whom may disagree about experimental results. By discussing their observations, questions, and understandings, they help to inform each other and produce more accurate, useful results overall.

6. Now that students have reviewed and discussed their *Observations* and *Results*, they are ready to draw *Conclusions*. What do they know now, after doing their experiment, that they didn't know beforehand? As students provide ideas, list them on flipchart paper. As a class, summarize students' ideas into 3 concluding statements. Or have each student summarize his/her own conclusions as an independent exercise. Then have them write their Conclusions on their STUDENT ACTIVITY SHEET.

7. Explain that, in the event that a scientist determines he/she doesn't have enough data for analysis, he/she should review the experiment's design, improve it if needed, and run the experiment again.

   If students chose "Not enough data," ask them to follow this process (above) and describe how they might work to produce more clearcut data. Older students may want to review Figure 8 for some suggestions of ways to improve the rigor of this experiment.

Figure 8. Improving the Rigor of the Stream Crossing Experiment

- *For each crossing structure, dig the exact same channel (location and width) before installing the structure.*
- *Mark the flow dial to standardize your flow settings. (Please do note leave permanent marks on the stream table.)*
- *For each Observation, run the*

LESSON 4.1. STREAM CROSSING EXPERIMENT

Student Activity Sheet (Grades 3/4)
Emriver Em2 Geomodel (stream table)

Name: ____Date: ___________

Look at 2 sizes of pipe culverts:

1. **Question**: *Which size will cause the <u>least</u> erosion?*

2. **Hypothesis**: Check one box below:

small culvert	large culvert
❒	❒

   I chose this size culvert because

   ____

3. **Experiment (A and B)**.

   A. Install the small culvert. Watch the stream flow through it. Write or draw 3 observations.

Small Culvert Observations
1.
2.
3.

B. Install the large culvert. Watch the stream flow through it. Write or draw 3 observations.

Large Culvert Observations
1.
2.
3.

4. **Results**: Which size culvert caused the <u>least</u> erosion? Check one.

small culvert	large culvert	Not enough data
❒ ○	❒ ◯	❒

5. **Conclusions**: Review your *Observations* and *Results*. What do you know now that you didn't know before the experiment? Write 3 conclusions.

____

____

____

LESSON 4.1. STREAM CROSSING EXPERIMENT

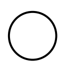
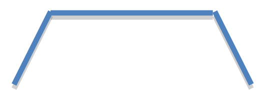
Student Activity Sheet (Grades 5/6)
Emriver Em2 Geomodel (stream table)

Name: ______________________________________ Date: ____________

Look at 3 kinds of stream crossing structures: small pipe culvert, bottomless arch, and bridge.

1. **Question**: *Which crossing structure will minimize erosion along the stream?*

2. **Hypothesis**: Check one box below

Small culvert	Bottomless arch	Bridge
❐ 	❐ 	❐ 

I chose this crossing structure because:

____

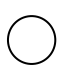
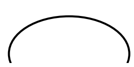
____

3. **Experiment**. Install each crossing structure, one at a time, and run the stream table. Write 3 observations for each structure below, one observation for each flow level.

Crossing Structure	**Observations**
small pipe culvert	1. low flow
	2. medium flow
	3. high flow

bottomless arch	1. low flow
	2. medium flow
	3. high flow
bridge	1. low flow
	2. medium flow
	3. high flow

4. **Results**: Which structure minimized erosion? Check one. *Please check "Not enough data" if your results are not clear.*

Small culvert	Bottomless arch	Bridge	Not enough data
☐ 	☐ 	☐ 	☐

5. **Conclusions**: Review your original *Question*, your *Hypothesis*, your *Observations*, and your *Results*. What do you know now (after your experiment) that you didn't know before? That is, what can you conclude? What new questions do you have about crossing structures?

Conclusions: ____

____

New questions: ____

____

LESSON 4.2. - COMMUNITY CROSSINGS

Different members of a community have different perspectives on installing stream crossings. Things to consider include:

- cost
- life-span (how long it will last, which affects the replacement cost)
- affects on fish and wildlife habitats
- affects on water quality
- affects on local roads, landowners, settlements, farms, etc.
- local, state, and federal requirements that need to be met to receive a permit for the culvert (see *NH Stream Crossing Guidelines* in TEACHING RESOURCES).

Imagine that a town has to replace a culvert or bridge on Trout Brook, a popular fishing location. Have students brainstorm the pros and cons of each type of crossing using a table format such as the one below. (Possible answers are provided for the teacher.)

Types of Crossing	Pros (+)	Cons (-)
small culvert	• minimal cost • adequate for moving typical water volumes • minimal movement of earth required to install it • takes up a small "footprint"	• may not be able to handle storm waters, causing them to flood the land around it • may get blocked with debris or "blown out" during a storms, causing flooding around it • often becomes "perched," interfering with fish passage • water often speeds up as it enters culvert, causing "firehose" effect downstream
large culvert	• relatively inexpensive • adequate for moving typical and greater water volumes	• higher cost than small culvert • requires more movement of earth to install than small culvert • larger "footprint" than small culvert • often becomes "perched," interfering with fish passage and causing more erosion.
bridge	• lasts longer than culverts • much less likely to wash out than culverts. • does not change the velocity of water • has natural streambed, which provides aquatic habitat • does not become "perched" • provides benthic habitat for fish, waterbugs, and other aquatic organisms.	• higher cost than either small or large culvert • longer construction process

Ask students to play the roles of the following individuals. Which type(s) of crossing would they choose and why?

- town manager, who's in charge of balancing the town's budget and dealing with flooding
- owner of Joe's Fishing Store
- owner of the Riverview Motel, which is on the floodplain next to the stream
- school principal, whose athletic fields are on the floodplain next to the stream

Lesson 5. Upstream, Downstream

Overview

Watershed neighbors are the people, settlements, and businesses that share the land and water resources within the landscape drained by a particular river system. Human activities in and along our streams often lead to changing sediment and water flow conditions as the stream responds, especially downstream. Some activities are felt more broadly throughout the watershed. Therefore, our activities can affect our watershed neighbors.

Often, a stream's response to human activities presents problems for watershed residents. For example, a straightened stream may develop meanders that cut into a farmfield, or an eroding channel may deliver its load of sediments onto a road. By responding in these ways, the stream is trying to stabilize its forces and adopt a pattern that it can generally maintain over time (see LANE'S BALANCE above).

Dynamic equilibrium describes the process by which streams constantly change in the process of creating or maintaining balance over time. Living in Harmony with Streams (see TEACHING RESOURCES) explains it this way:

> Dynamic equilibrium means that the stream moves and adjusts toward the most efficient distribution of the energy of the system. Change is what makes the equilibrium dynamic.

Instructions

Please note:

Two options (Option A – Farm to City, and Option B – City to Farm) are provided for this activity. Both options teach the same basic concepts. Please choose the one that better represents your students' experiences. Or do both to encourage your students to adopt different perspectives on watershed resource use and cause and effect.

Option A - Farm to City

On the stream table, have students create a farm along the stream and build a city downstream of the farm along the stream. The farm and/or city can be built on both sides of the stream with a bridge connecting the two halves.

Hand out the FARM TO CITY STUDENT ACTIVITY SHEET. Ask students to set up one or more of the scenarios on the sheet, each of which reflects some ways in which the farm might change the flow of surface and/or groundwater and affect the city downstream.

As students run these scenarios, have them complete the activity sheet.

Class Discussion Ideas

After the scenario(s) is/are run, ask students to discuss the following questions:

- Do activities that occur upstream affect downstream people and activities? Explain.
- Do activities that occur downstream affect upstream people and activities? Explain.
- We share our watershed with many people, human settlements, and businesses. Do

we have a responsibility to each other when it comes to land and water resources? That is, should we try to minimize negative impacts and maximize positive impacts for our watershed neighbors?

If we reduce the area in which the stream can move, flood, and/or store sediments in our farming areas, how can we reduce negative impacts downstream? Discuss student recommendations from their activity sheets. Here are some possible options:

- The farmer can establish a forested buffer between his/her farmland and the stream to absorb the volume and force of floodwaters, and reduce erosion of the farmfields. The restored riparian buffer will also lessen flood damage downstream in the city.
- The farmer can allow the stream to meander, which flattens the streambed's slope and slows down floodwaters.

Option B - City to Farm

On the stream table, have students build a city along the stream and create a farm downstream of the city along the stream. The city and/or farm can be built on both sides of the stream with a bridge connecting the two halves.

Hand out the CITY TO FARM STUDENT ACTIVITY SHEET. Ask students to set up one or more of the scenarios on the sheet, each of which reflects some ways in which the city might change the flow of surface and/or groundwater and affect the farm downstream.

As students run these scenarios, have them complete the activity sheet.

Class Discussion Ideas

After the scenario(s) is/are run, ask students to discuss the following questions:

- Do activities that occur upstream affect downstream people and activities? Explain.
- Do activities that occur downstream affect upstream people and activities? Explain.
- We share our watershed with many people, human settlements, and businesses. Do we have a responsibility to each other when it comes to land and water resources? That is, should we try to minimize negative impacts and maximize positive impacts for our watershed neighbors?

If we reduce the area in which the stream can move, flood, and/or store sediments in our urban centers, how can we reduce negative impacts downstream? Here are some possible options:

- The city can buy floodplain land between the city and the farm to absorb floodwater volume and force.
- The city can establish parks and other green spaces along the stream that can absorb floodwater forces to reduce flood damage downstream.
- The city can reimburse the farmer for lost crops whenever the land floods.

OPTION A - FARM TO CITY	**Student Activity Sheet** **Emriver Em2 Geomodel (stream table)**

Name: ______________________________ Date: __________

Check one or more of the following Scenario(s) you are running:

- ❒ farm narrows the stream and ripraps the banks
- ❒ farm builds a berm along the stream to prevent flooding onto its fields
- ❒ farm straightens the channel to deliver high water downstream, past the farm
- ❒ your own Scenario – describe: ______________________________

Predictions: What do you think will happen:
to surface water at the <u>farm</u>?
to groundwater at the <u>farm</u>?
to surface water at the <u>city</u>?
to groundwater at the <u>city</u>?
Experiment: Run the scenario and write your observations. Make sketches if you would like.

Analysis: Summarize the important findings of your experiment.
Conclusions: Review your Predictions. What do you know now that you didn’t know before this experiment?
Recommendations for improvement (designing possible solutions): Make 3 recommendations of actions that the farm can take to protect its land and water resources and minimize impacts on the city.
1.   2.   3.

If there is time, try one of your recommendations on the stream table and observe the results. Did it accomplish your goals?

OPTION B - CITY TO FARM	**Student Activity Sheet** **Emriver Em2 Geomodel (stream table)**

Name: ____ Date: ____________

Check the Scenario you are running:

- ❐ city narrows the stream and ripraps the banks
- ❐ city builds concrete walls along both sides of the stream.
- ❐ city straightens the channel, from just upstream to just downstream of the city
- ❐ your own Scenario – describe: ____

Predictions: What do you think will happen:
to surface water at the farm?
to groundwater at the farm?
to surface water at the city?
to groundwater at the city?
Experiment: Run the scenario and write your observations. Make sketches if you would like.

Analysis: Summarize the important findings of your experiment.
Conclusions: Review your Predictions. What do you know now that you didn't know before this experiment?
Recommendations for improvement (designing possible solutions): Make 3 recommendations of actions that the farm can take to protect its land and water resources and minimize impacts on the city.
1. 2. 3.

If there is time, try one of your recommendations on the stream table and observe the results. Did it accomplish your goals?

LESSON 6. STREAM EROSION PREVENTION

This lesson was originally developed by Jenny Hewitt, 4th grade teacher at Pomfret School in Pomfret, VT. It was adapted by Kevin Gianini, 5th grade teacher at Grantham Village School in Grantham, NH, to culminate his stream table unit.

Scenario presented to students:

You have been asked by the town of Grantham to create a plan to perform erosion control work along Sawyer Brook, which runs through the center of town. The select-board is looking for your expertise to help prevent damage to existing roads, houses, and to the brook. It was discovered that there is significant runoff from the pastures of a family farm located along the banks of the brook. This causes pollutants to enter the brook during heavy rains. They also want your recommendations as to areas best suited for future development.

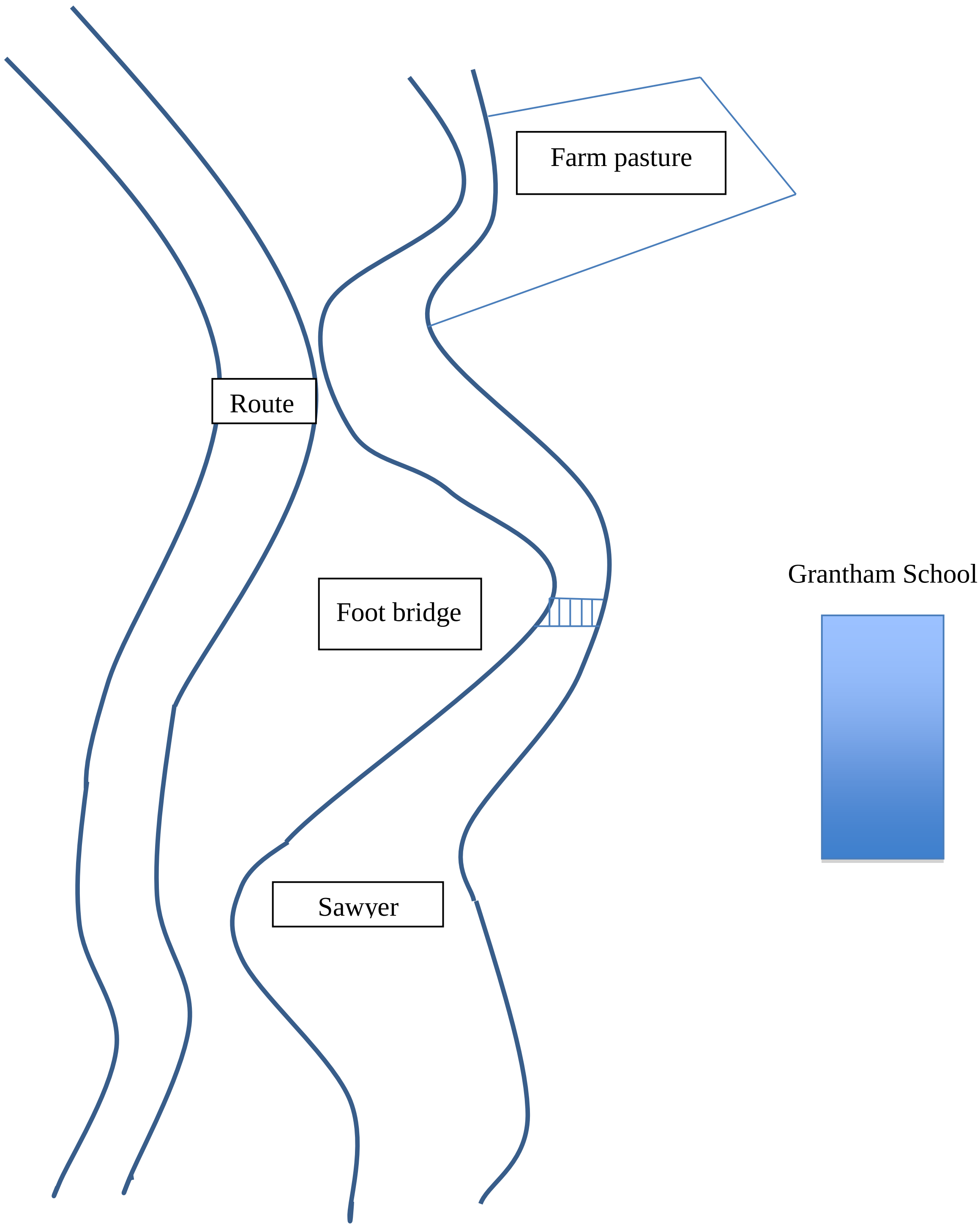
The select-board will choose **the plan that provides the clearest explanations as to how each method you choose will best prevent erosion and decrease runoff.** As the select-board members are not experts on stream dynamics or erosion control, they will be looking for the **most complete diagrams, explanations, and recommendations.**

Your plan must include:

- ❒ Road access to Grantham Village School from Route 10
- ❒ Ways to keep Sawyer Brook from damaging Route 10
- ❒ Ways to reduce runoff at the family farm
- ❒ Areas that can be sold as building sites for new river view houses
- ❒ A way to fix the crumbling supports of the foot bridge that leads to Grantham Village School

See the map below for a view of the landscape under consideration.

Diagram of Sawyer Brook & Surrounding Landscape



Stream Erosion Prevention Rubric

Name___________________________ Date _________________

Category	**3**	**2**	**1**	**Comments**
Erosion Control Methods	The plan addresses all 5 areas indicated by the Select-board as needing attention.	The plan addresses 3-4 areas indicated by the Select-board as needing attention.	The plan addresses 0-2 areas indicated by the Select-board as needing attention.	
Diagrams	Accurate, easy to follow diagrams with labels.	Some parts of the diagram were easy to follow and contained labels.	The diagrams were incomplete, hard to follow, and missing labels.	
Vocabulary	6 or more vocabulary words relating to streams and erosion are used accurately and appropriately.	3-5 vocabulary words relating to streams and erosion are used accurately and appropriately.	0-2 vocabulary words relating to streams and erosion are used accurately and appropriately.	
Elaboration	It is clear what methods of erosion control are being recommended and why they are suited to each area.	Some parts of the explanation of erosion control methods are clear.	Erosion control methods are not recommended, or are not at all clear.	
Points Earned				

Adapted by K. Gianini from J. Hewitt

GLOSSARY

Definitions adapted from Living in Harmony with Streams, the Vermont Stream Geomorphic Assessment, Appendix Q, the dictionary tool in Microsoft Word, and other sources of definitions.

aggradation (see Lane's Balance) -- a progressive buildup, or raising, of the channel bed and floodplain due to sediment deposition; opposite of degradation.

alluvial – refers to a stream or river that flows through sedimentary deposits, which it sorts, carries downstream, and deposits.

bankfull channel depth -- the maximum depth of a channel within a riffle segment when flowing at a bank-full discharge.

bankfull channel width – the typical high water mark along a stream that is reached about every other year and can generally be seen along the bank where vegetation changes.

bankfull discharge -- the stream discharge corresponding to the water stage that first overtops the natural banks. This flow occurs, on average, about once every 1 to 2 years.

benthic – refers to the streambed and other underwater surfaces in a stream, such as a submerged log, and the bottom-dwelling organisms that live there.

berm – a mound of soil or other materials, constructed along a stream, a road, or other area, to protect against flooding and/or erosion.

channel -- an area confined by the banks and streambed that contains continuously or periodically flowing water.

channelization -- the process of changing (usually straightening) the natural path of a waterway.

culvert -- a buried pipe that allows flowing water to pass under a road.

degradation (of a streambed) **--** a progressive lowering of the stream's channel bed due to scour. Degradation is an indicator that the stream's discharge and/or sediment load is changing. The opposite of aggradation.

dredging -- removing material (usually sediments) from wetlands or waterways to make them deeper or wider.

dynamic equilibrium – describes a stream system that has achieved a balance in transporting its water and sediments over time without building up sediments, cutting into its streambed, or migrating laterally (eroding its banks and changing course). A stream in dynamic equilibrium resists flood damage, resists erosion, and provides good aquatic habitat.

floodplain -- land built of sediment that is regularly covered with water as a result of the flooding of a nearby stream.

groundwater -- subsurface water and underground streams that can be collected with wells, or that flow naturally to the earth's surface through springs.

head cut – a marked change in the slope of a streambed that creates a small waterfall with increased water velocity, which causes erosion of the streambed that eats its way upstream.

headwaters – small, flowing waters that form in the upper elevations of a watershed.

Lane's Balance – a model with balance beam arms that demonstrates some of the interactions in a stream between water, slope (gradient), and sediments.

mainstem – the largest river in a watershed; it collects all flowing water within the watershed and occupies the lowest valley in that watershed.

meander – *noun:* a bend in a stream; *verb:* to wind back and forth through the landscape. A meandering stream generally exhibits a characteristic pattern of bank erosion (outer bend) and point bar deposition (inner bend).

meander belt – the side to side (lateral) extent of stable meanders in a stream.

point bar – a gradual shelf extending out from the inner bend of a stream that forms when slow water drops its load of sediments.

pool -- a reach of stream that is characterized by deep, low-velocity water and a smooth surface.

riffle – a stream feature in which water flow is shallow, rapid, and turbulent compared to adjacent areas. Riffles typically alternate with pools along the length of the stream.

riparian – the strip of land along a streambank in which vegetation directly influences stream processes.

riparian buffer – a vegetated zone along a streambank that helps to stabilize the bank and fosters a healthy terrestrial habitat on one side and a healthy aquatic habitat on the other side.

riprap -- rock or other material used to stabilize streambanks or riverbanks from erosion or to create habitat features in a stream.

river corridor – the land that includes the active channel of a stream, its meander belt, the riparian buffer along the stream, and the stream's floodplain. The corridor is the area within which the channel can meander to distribute sediments and the energy of flowing water, which leads to a balanced condition called dynamic equilibrium.

river system – the mainstem of a river and all of the waters that flow into it. It forms a branching pattern that resembles a tree, with the trunk being the mainstem, the major tributaries being the large branches, and the high-elevation streams being the twigs.

run (in stream or river) **--** a reach of stream characterized by fast-flowing, low-turbulence water.

sediments – materials eroded from soil or rocks that are carried by water, wind, or ice and deposited somewhere else.

slope (gradient) – the amount of change in elevation as a stream flows across the landscape.

thalweg – a line connecting the deepest areas of a stream channel or valley.

tributary – a stream that flows into another stream or river; it is usually smaller than the mainstem.

watershed – a basin of land in which all water flows to a common water body, such as a river, lake, pond, wetland, or the ocean.

TEACHING RESOURCES

AN ANNOTATED LIST

Internet Publications

Use and Care of the Emriver Em2 River Process Geomodel: http://www.emriver.com/wp-content/uploads/2011/09/Emriver_Em2x_manual_2012_05-02_AQ.pdf

A step-by-step guide for setting up and maintaining the stream table.

Living in Harmony with Streams: A Citizen's Handbook to How Streams Work, Friends of the Winooski River, White River Natural Resources Conservation District, Winooski Natural Resources Conservation District, 2012. http://www.winooskiriver.org/images/userfiles/files/Stream%20Guide%201-25-2012%20FINAL.pdf.

Very concise and informative handbook for laypersons. Lots of useful photos and illustrations.

New Hampshire Stream Crossing Guidelines, University of New Hampshire, May 2009. http://www.streamcontinuity.org/pdf_files/nh_stream_crossing_guidelines_unh_web_rev_2.pdf

An extensive, somewhat technical document written to assist in the design, construction, and permitting of stream crossings (culverts, arches, and bridges) in New Hampshire.

Internet Videos

River Geomorphology Videos: http://serc.carleton.edu/NAGTWorkshops/geomoph/emriver/index.html

Created by Little River Research and Design to help students better understand geomorphic processes in rivers with special attention to the effects of channelization and gravel mining. The clips are intended for use by an instructor.

After the Flood: Vermont's Rivers and the Legacy of Irene, Riverbank Media, June 2013. http://www.youtube.com/playlist?list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

A series of 4 videos that explore the condition of rivers in the Green Mountain State following the devastating flooding from Tropical Storm Irene. Topics include: river dynamics, floodplains and flood resiliency, impact of improperly sized culverts and the benefits of upgrading, consequences of river modification, and the current state of Vermont's fisheries.

Vermont Rivers Program Videos, Vermont Agency of Natural Resources, May 2012.

A somewhat technical series of videos made by the Vermont Rivers Program that shows how to minimize flood damage by better understanding river dynamics.

Segment One: Vermont Rivers Program. http://www.youtube.com/watch?v=w8BWjRM-ptI

Segment Two: River Dynamics. http://www.youtube.com/watch?v=0Va7E7KOz94

Segment Three: Meanders and Floodplains. http://www.youtube.com/watch?v=RQ6oyf9C8Lc

Segment Six: River Restoration. http://www.youtube.com/watch?v=E_a-nYl9Ak4

New Hampshire Resource People

Lionel Chute, District Manager, Sullivan County Conservation District: lchute@sullivancountynh.gov, 603-542-4891

Please contact Lionel to reserve use of the stream table for New Hampshire schools.

State of New Hampshire Resources

New Hampshire Stream Crossing Guidelines, University of New Hampshire, 2009

http://www.streamcontinuity.org/pdf_files/nh_stream_crossing_guidelines_unh_web_rev_2.pdf

Department of Education

Science Education: http://www.education.nh.gov/instruction/curriculum/science/index.htm

New Hampshire Environmental Literacy Plan: https://nhenvironmentalliteracyplan.wordpress.com

Fact Sheets, Maps, & Other Useful Documents

Mascoma River Environmental Fact Sheet:
http://des.nh.gov/organization/commissioner/pip/factsheets/rl/documents/rl-26.pdf

Mascoma River Watershed Base Map:
http://des.nh.gov/organization/divisions/water/wmb/rivers/documents/masc-map.pdf

Connecticut River Environmental Fact Sheet:
http://des.nh.gov/organization/commissioner/pip/factsheets/rl/documents/rl-4.pdf

Culvert Problem and Solution Table:
http://t2.unh.edu/sites/t2.unh.edu/files/documents/training/culvert/slides%2074%2C%2075.pdf

Rivers Management and Protection Program (25th anniversary poster):
http://des.nh.gov/organization/divisions/water/wmb/rivers/documents/rmpp25-poster.pdf

Books

Stream Ecology: Structure and Function of Running Waters, by J. David Allen, School of Natural Resources and Environment, University of Michigan. 2006. ISBN: 0-412-35530-2.

A textbook that covers the stream's chemical, physical, and biological factors, and how they interact to create the unique conditions of a particular stream. Includes a chapter on modification of running waters by humankind.

Pond and Brook: A Guide to Nature in Freshwater Environments, by Michael J. Caduto, University Press of New England, 1990.

A conversational yet thorough overview of freshwater ecology.

Streams: Their Ecology and Life, by Colbert E. Cushing and J. David Allen, Academic Press, 2001

A textbook that covers river ecology; types of rivers; biota of rivers; and management, conservation, and restoration of rivers.

Riparia: Ecology, Conservation, and Management of Streamside Communities, by Robert J. Naiman, Henri Decamps, and Michael E. CmClain. Elseveir Academic Press, 2005.

A technical textbook that covers catchments and the physical template; riparian typology; structural patterns; biotic functions of riparia; biophysical connectivity and riparian functions; disturbance and agents of change; management; conservation; and restoration. Beautiful color illustrations and photos.

The River Book, by James Grant MacBroom, Natural Resources Center, Connecticut Department of Environmental Protection. 1998. ISBN: 0-942085-06-X.

A book written for a variety of audiences that covers hydrologic, biologic, water quality, hydraulic, and geologic disciplines of stream study. Includes information on ways in which human activities affect natural stream processes.

<u>ADDITIONAL STUDENT ACTIVITY – LANE'S BALANCE</u>

(Most appropriate for older students and students who need a challenge!)

OVERVIEW

A stream is a very dynamic system. Water flows change for many reasons, including:

- more water enters the stream with precipitation
- less water enters the stream in dry conditions
- people change the stream channel by straightening or building structures within the stream
- people change the banks of the stream by cutting down vegetation or building on them.

These adjustments cause the erosion of soil particles in some places and the deposition of soil particles in other places. In between, the soil particles become suspended and carried in the water. Therefore, streams move both water and sediments.

Lane's Balance is a model that shows how a stream balances the relationship between water flow and sediment transport to maintain or regain *dynamic equilibrium* (see GLOSSARY). It can help us to understand cause and effect in a stream. This model incorporates 4 variables in a typical old-fashioned balance-beam scale:

- amount of moving water
- slope (gradient) of the streambed
- amount of sediment
- size of sediment particles

If one of these variables changes, one or more of the other variables must change to regain balance in the river system.

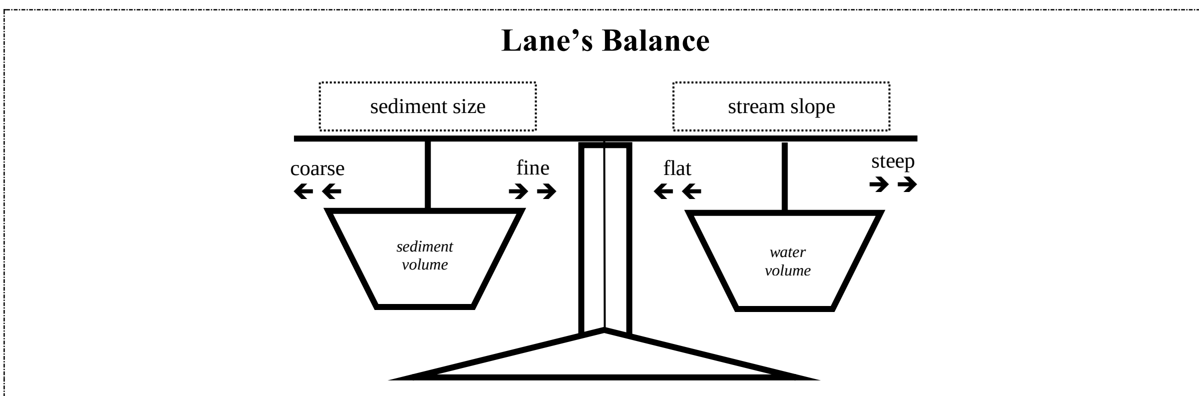


***Figure 9. Lane's Balance** (a simplified version); adapted from the American Society of Civil Engineers.*

MORE INFO:

Living in Harmony with Streams booklet

- Pages 12 – 14
- Pages 29 - 36

After the Flood Videos
http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT

- Video 1: river stability; starting at 2:14 minutes
- Video 2: water flows and floodplain functions; starting at 0:00 minute (beginning)
- Video 2: the need for river corridor maps; starting at 4:55 minutes
- Video 3: berms; starting at 8:50 minutes
- Video 4: equipment in streams, re-engineering channels; starting at 0:53 minute

Youtube video: Steve Nelle explaining Lane's Balance (http://www.youtube.com/watch?v=Js7wDZE4I7o

MATERIALS	**SET-UP**
• Lane's Balance Student Activity Sheet	• Watch this video: Steve Nelle explaining Lane's Balance (http://www.youtube.com/watch?v=Js7wDZE4I7o) • Refer to Figure 6 above for an illustration of a simple Lane's Balance.
	TIMEFRAME 60 minutes

INSTRUCTIONS

Introduce students to Lane's Balance (see Figure 8 above), which is a model that shows the relationships between water, slope, and sediments in a stream.

Hand out the LANE'S BALANCE SCENARIOS STUDENT ACTIVITY SHEET and discuss each scenario with the class, using the questions and answers below. Once students understand how the stream "rebalances" itself in each scenario, ask them to describe it in writing on the activity sheet. Then ask for volunteers to read their answers to the class, and clarify any confusing concepts.

Questions to accompany the Lane's Balance Scenarios activity

1. What happens if *more water* enters the stream channel? (for instance, during a storm)

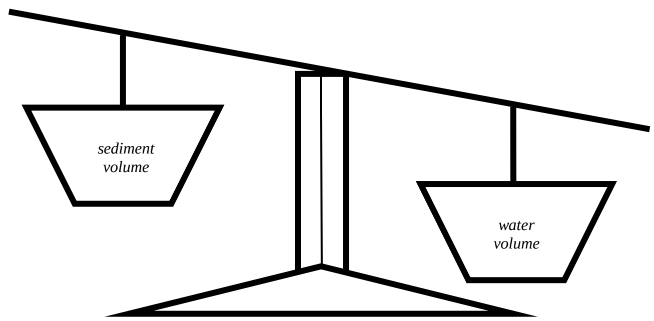
The *water bucket* becomes heavier, which tilts the water bucket arm down and raises the sediment arm.

How do you re-balance the scale?

Add more sediment. More water causes water velocity to increase, which makes the water "hungry" for more sediment; it eats into the streambed and/or banks, causing more sediment to enter the stream through erosion.

More water

- How do you regain balance?
- Add more sediment ("hungry" water erodes sediment from the banks and/or streambed)



2. What happens if *more sediment* enters the stream channel? (for instance, if upstream erosion causes downstream deposition)

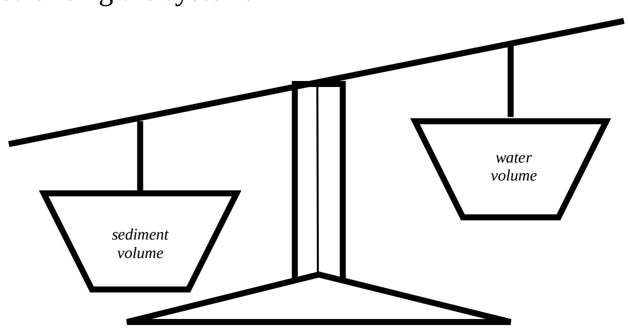
The *sediment bucket* becomes heavier, which tilts the sediment arm down and causes the water arm to rise.

How do you re-balance the scale?

Add more water. During the next flood, the increased volume of water will increase velocity, which scours out sediments, rebalancing the system.

More sediment

- How do you regain balance?
- Add more water to carry the sediment away



3. What happens if *stream slope* becomes *flatter* (for instance, through greater meandering)

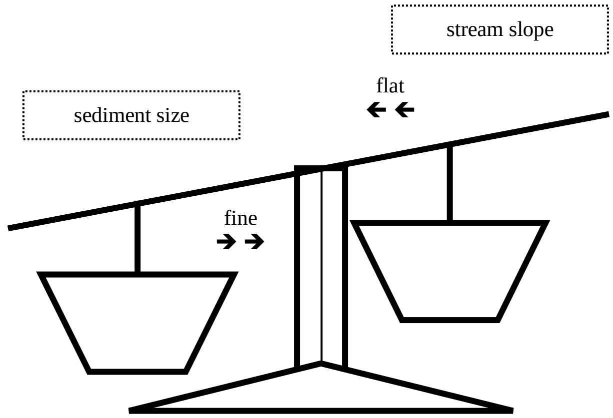
The *water bucket* moves to the left on its arm (toward "flat") and the *sediment size arm* tilts down.

How do you re-balance the scale?

Move the sediment bucket to the right toward the center post (toward "fine"). When a stream's slope becomes more gradual, the water slows down and drops the fine sediments that it has been carrying in suspension. The streambed under a flat slope with slow water is covered with fine sediment.

Flatter slope

- How do you regain balance?
- Water drops its load of ***fine sediment*** (bucket moves right to rebalance)



4. What happens if the *__stream slope__* becomes *__steeper__*? (for instance, when we cut through meanders and straighten a channel)

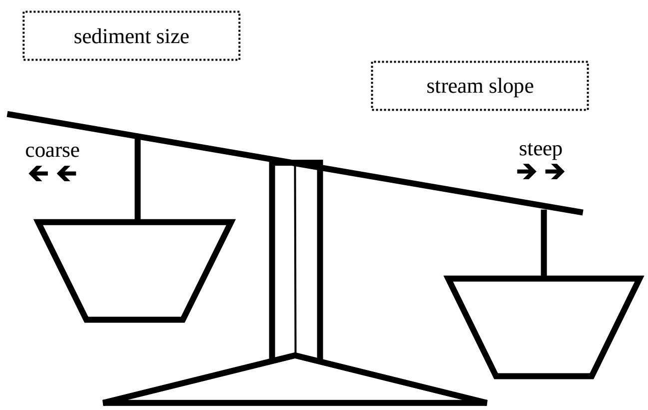
The *water bucket* moves to the right (toward "steep") and the *sediment size arm* tilts up.

How do you re-balance the scale?

Move the sediment bucket to the left (toward "coarse"). When a streambed becomes steeper, the water picks up velocity and becomes "hungrier", which means that it eats into the streambed and banks and can move coarser, larger particles.

Steeper slope

- How do you regain balance?
- Water picks up speed and gets "hungrier", eating ***coarse sediments*** from banks and streambed

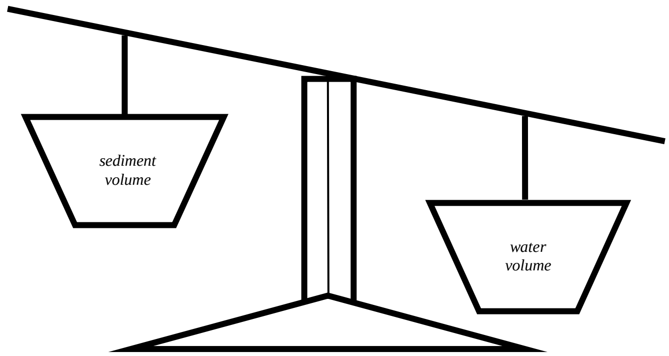


LANE'S BALANCE SCENARIOS

Student Activity Sheet
Emriver Em2 Geomodel (stream table)

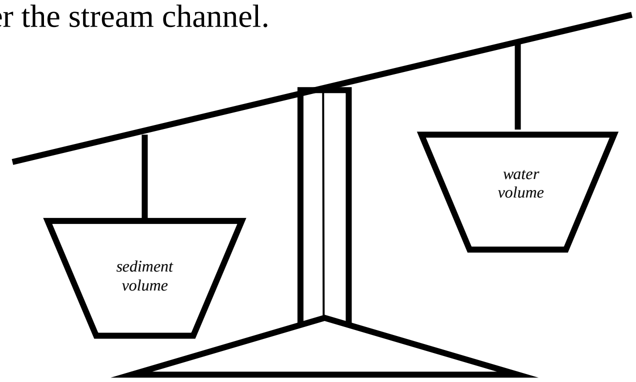
Name ____ Date ___________

1. It rains heavily all day and *more water* enters the stream channel.



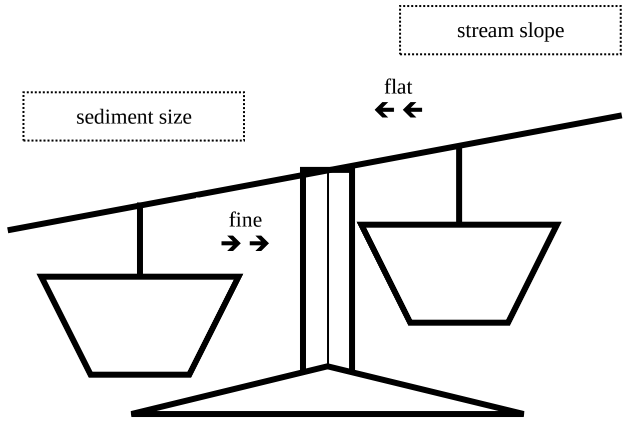
How does the stream regain balance?

2. A person upstream drives his car across the stream, creating erosion that causes *more sediment* to enter the stream channel.



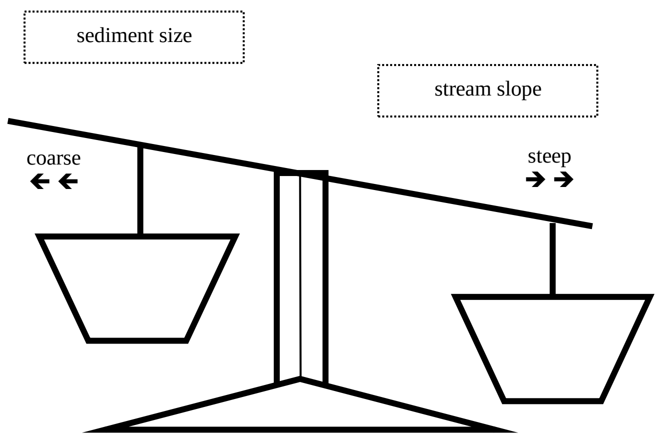
How does the stream regain balance?

3. A stream slows down and carves wider meanders, making the stream slope *flatter*.



How does the stream regain balance?

4. A town cuts through a series of meanders to straighten the stream, making the stream slope steeper.



How does the stream regain balance?

NEW HAMPSHIRE STREAM TABLE UNIT

TEACHER EVALUATION FORM

Grade of students: _____________ Number of days that you used the stream table: ___________

Subject(s) taught with stream table: ____

Stream Table Unit lessons that you taught to your students (please check):

1. Corridors & Channels	❒ 1.1. Why Meanders Form	❒ 1.2. Changing Channel	❒ 1.3. Stream Anatomy
2. Sediments & Erosion	❒ 2.1. Gravel Mining	❒ 2.2. High Banks, Low Banks	❒ 2.3. Understanding Lane's Balance
3. Streambanks	❒ 3.1 Bank Protection	❒ 3.2 Streambanks & Habitat	
4. Stream Crossings	❒ 4.1 Stream Crossing Experiments	❒ 4.2. Community Crossings	
5. Upstream, Downstream	❒ Option A: Farm to City	❒ Option B: City to Farm	

Which lessons (above) were particularly effective? Explain.

Can you recommend other lessons or sources of lessons that would complement this unit?

Please rank the following items.	1 (not useful)	2	3 (somewhat useful)	4	5 (very useful)
Usefulness of stream table as a teaching tool					
Usefulness of NH Stream Table Unit					

Suggestions for improvement:

Please check all that apply:

❒ I received training to teach with the stream table. *Please tell us about your experience:*

❒ I received a visit from a stream table educator (planning and/or teaching). *Please tell us about your experience:*

❒ I would like to receive training to teach with the stream table and Stream Table Unit.

❒ I would like to receive a visit from a stream table educator to help me teach with the stream table.

Please send form to Phylicia Schwartz: 95 County Farm Road, Unity, NH 03743; pschwartz@sullivancountynh.gov. Thanks!