

# ***Stream Table Lesson Packet***

**For Grades 4 – 6  
In Schools and Communities  
of the  
Ottauquechee Natural Resources Conservation District  
(ONRCD)**



Developed by  
Jennifer Guarino, Ecotone Education

# *Table of Contents*

	<b>Page Number</b>
A letter from the Ottawaquechee Natural Resources Conservation District	3
Teacher Evaluation Form	4
Goal and Learning Objectives	5
Important Notes	6
The Next Generation Science Standards	7
Pre-Stream Table Lesson: Streams & Watersheds	9
Lesson A. Corridors and Channels	10
Lesson A.1. Why Meanders Form	12
Lesson A.2. The Changing Channel	12
Lesson A.3. Stream Anatomy	12
<i>Student Activity Sheet: Lesson A.3. Stream Anatomy Parts</i>	13
Lesson B. Marble Races	14
Lesson B.1. Meanders and Velocity	14
<i>Student Activity Sheet: Lesson B.1. Meanders and Velocity</i>	16
Lesson B.2. Meanders, Thalweg, and Riffles	18
Lesson B.3. Meanders, Length, and Slope	18
Lesson C. Streambanks	19
Lesson C.1. Bank Protection	19
Lesson C.2. Streambanks & Habitat	20
Lesson D. Culverts	21
Lesson D.1. Culvert Types	22
<i>Student Activity Sheet: Lesson D.1. Culvert Types</i>	23
Lesson D.2. Community Culverts	25
Lesson E. Sediments & Erosion	27
Lesson E.1. Gravel Mining	29
Lesson E.2. High Banks & Low Banks	29
Lesson F. Watershed Neighbors	30
Lesson F.1. Lane's Balance	32
Lesson F.2. Upstream, Downstream	33
Lesson F.2.a. Farm to City	33
<i>Student Activity Sheet: Lesson F.2.a. Farm to City</i>	34
Lesson F.2.b. City to Farm	36
<i>Student Activity Sheet: Lesson F.2.b. City to Farm</i>	37
Glossary	39
Teaching Resources	41
Appendix 1 - Basin 10 Watershed Map: Ottawaquechee River & Black River	43
Appendix 2 - Extension Activity: Percent Slope	44
Appendix 3 - Extension Activity: Rocks & Velocity	46



## Ottawuechee Natural Resources Conservation District 28 Farmvu Drive • White River Jct., VT • 05001

### *A letter from the Ottauquechee Natural Resources Conservation District*

This lesson packet is part of the school portion of the “River Roadshow,” an educational program run by the Ottauquechee Natural Resources Conservation District (ONRCD) to bring to the community an appreciation of rivers and how they work. ONRCD is a member of the Vermont Association of Conservation Districts.

In 2012, ONRCD was fortunate to receive a grant from the Vermont Community Foundation to purchase an Emriver Em2 Geomodel from Little River Research and Design (<http://www.emriver.com/>). The Em2 is commonly called a stream table or flume. Included in the school program of the River Roadshow is this lesson packet, written by Jennifer Guarino of Ecotone Education, a division of Verdana Ventures LLC. In September 2013, ONRCD received a grant from the Wellborn Ecology Fund of the New Hampshire Charitable Foundation to expand the River Roadshow and bring it to more schools.

The lesson packet covers many aspects of river dynamics in a way that encourages observation, discussion, and experimentation. For example, students do simple activities with marbles to see the effects of meanders on speed and the relationship of speed and volume to force. They carry these activities to the stream table and easily note the relationship of river speed and volume to erosion and degradation. In short, rather than being told how streams work, they discover, on their own, the concept of Lane’s Balance, one of the primary principles of river dynamics. So while the topic of this lesson packet concerns rivers, the process is for students to learn to observe, question, form theories, test their theories, and formulate and apply their findings.

ONRCD is grateful for the advice and assistance of Staci Pomeroy and Marie Lavesque Caduto of the Vermont Department of Environmental Conservation and Chris E. Smith of the U.S. Fish & Wildlife Service for serving as scientific advisors. We are also grateful to Kathy Renfrew, Vermont Agency of Education, Jenny Hewitt, a teacher at the Pomfret School, Audrey Halpert, a teacher at the Albert Bridge School, and Jill Kurash and Karen White of Woodstock School whose years of experience insured that this packet would be valuable to classroom teachers. And finally, we thank Jennifer who has the talent to bring it all together.

There is a wealth of material on the Internet regarding stream tables/flumes, including how to build them and how to use them. One article by the Missouri Dept. of Conservation explains how to build a stream table and expresses well its value:

*An understanding of how sediment, vegetation and flowing water interact to form stream channels is essential in knowing how to restore and manage them. Because it is impractical or impossible to directly observe these processes in real streams, a portable model stream has been developed by the Missouri Department of Conservation.*

*This model stream is particularly useful because most observers, regardless of their age or background, can understand fairly complex concepts demonstrated by the model that are otherwise difficult to comprehend, e.g. illustrating a destructive practice like channelization. The model also effectively convinces audiences that protecting or restoring stream corridor vegetation is the best way to protect both property and fish and wildlife values. Within the model, fluvial processes like bank erosion and point bar formation take place rapidly, so these processes can be observed in a short period of time. Regardless of their interest in stream conservation, most people are fascinated by the model.*

We hope you find this lesson packet useful. Please use the **Teacher Evaluation Form** to give us your feedback so we may improve our work with schools.

Larry Kasden, ONRCD Supervisor Chair; Sue Greenall, District Manager; Supervisors Judy Howland, and Bill Manner; Associate Supervisors Lynn Bohi, Roy Burton, Todd Menees, and Cynthia Rankin.  
[ONRCD1@gmail.com](mailto:ONRCD1@gmail.com) or 802- 436-2266

# **STREAM TABLE LESSON PACKET** **TEACHER EVALUATION FORM**

Grade of students: \_\_\_\_\_ Number of days that you used the stream table: \_\_\_\_\_

Subject(s) taught with stream table: \_\_\_\_\_

<b>Lessons that you taught to your students (please check):</b>			
<input type="checkbox"/> Lesson A.1. <input type="checkbox"/> Lesson A.2. <input type="checkbox"/> Lesson A.3.  <input type="checkbox"/> Lesson B.1. <input type="checkbox"/> Lesson B.2. <input type="checkbox"/> Lesson B.3.	<input type="checkbox"/> Lesson C.1. <input type="checkbox"/> Lesson C.2.  <input type="checkbox"/> Lesson D.1. <input type="checkbox"/> Lesson D.2.	<input type="checkbox"/> Lesson E.1. <input type="checkbox"/> Lesson E.2.  <input type="checkbox"/> Lesson F.1. <input type="checkbox"/> Lesson F.2. <input type="checkbox"/> Lesson F.3.a. <input type="checkbox"/> Lesson F.3.b.	<input type="checkbox"/> Other; describe:

Which lessons (above) were particularly effective? Explain.

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

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 Stream Table Lesson Packet					

**Did you have an ONRCD educator join your class for any lessons?**

☐ Yes – please describe your experiences:

☐ No

**Any other comments?**

*Please return this form to Sue Greenall, ONRCD, 28 Farmvu Drive, White River Junction, VT 05001. ONRCD1@gmail.com*

## **GOAL & LEARNING OBJECTIVES**

### **The Goal of the Stream Table Lesson Packet is:**

To educate as many people as possible about how streams behave and how people can live in harmony with streams.

### **The Learning Objectives of the Stream Table Lesson Packet are:**

To understand how streams...

- move over time within a predictable corridor
- form meanders as they flow through valleys
- follow a pattern
- seek to balance energy by moving water and sediments

To demonstrate human impacts on a stream and the ways in which a stream responds.  
Human impacts include:

- straightening, berming, and armoring
- removing gravel
- installing different sizes and types of culverts
- opening and closing access to floodplains

## **IMPORTANT NOTES**

- This lesson packet was created for use with the Emriver Em2 Geomodel (stream table or flume), which can be borrowed from the Ottauquechee Natural Resources Conservation District (ONRCD). Please contact Sue Greenall at [ONRCD1@gmail.com](mailto:ONRCD1@gmail.com) or 802- 436-2266 for more information, or to request use of the stream table.
- These lessons are geared for students in grades 4, 5, and 6 and aligned with selected components of the *Next Generation Science Standards* (see NGSS below). A brief section introduces the Next Generation Science Standards and describes connections between the new standards and this lesson packet.
- 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 (Google “Living in Harmony with Streams”); and YouTube *After the Flood: Vermont’s Rivers by River Bank Media*, a series of 4 videos made by River Bank Media (<http://www.youtube.com/watch?v=Wx7EQAY8CuA&list=PLX5V6zW7pAiYEC3bIrK3ymOegGrPwg0xT>)
  - ♦ A **Materials** box that lists items that come with the stream table and items that you supply 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 used to assess student learning.
- A **Glossary** of terms used in this packet is included after the lessons.
- An annotated list of **Teaching Resources** is provided for more information.
- **Appendices** contain a watershed map of the Ottauquechee River and Black River (the region served by ONRCD) and two Extension Activities.
- A **Teacher Evaluation Form** is included to gather feedback on the lesson packet for future improvement. *Please complete this form and send it to Sue Greenall at ONRCD (see above).*

## **THE NEXT GENERATION SCIENCE STANDARDS**

In the spring of 2013, Vermont and 25 other states adopted the *Next Generation Science Standards* (NGSS), which are built on the *Framework for K-12 Science Education* developed by the National Research Academy in 2011.

NGSS introduces a new approach to teaching standards. Three dimensions – *Science and Engineering Practices*, *Disciplinary Core Ideas*, and *Cross-Cutting Concepts* – are intertwined to help students learn science content and gain important process skills. For more information about the Next Generation Science Standards, please visit <http://www.nextgenscience.org/>.

Starting in the fall of 2013, the Vermont Agency of Education will launch a plan that leads to the implementation of NGSS in 2016-2017. The first phase, during the 2013-2014 school year, will focus on raising teachers' awareness of NGSS, with emphasis on Science and Engineering Practices. The Vermont Agency of Education has created a website called *Vermont Education Exchange* that includes a section on NGSS ([http://ve2.vermont.gov/vt\\_science/n\\_g\\_s\\_s](http://ve2.vermont.gov/vt_science/n_g_s_s)).

The Stream Table Lesson Packet represents a powerful way to address many parts of NGSS and offers a taste of NGSS before teachers are asked to align their curricula to these new standards. This lesson packet strongly emphasizes the following components (Figure 1) of the three NGSS dimensions. Please note that many other NGSS components can also be addressed by this lesson packet, but we chose a subset that we believe fits especially well.

**Figure 1.**

<b>NGSS Dimensions &amp; Stream Table Education</b>		
<b>Science and Engineering Practices</b>	<b>Disciplinary Core Ideas (DCI)</b>	<b>Cross-Cutting Concepts</b>
<ul style="list-style-type: none"><li>• Asking questions and defining problems</li><li>• Developing and using models</li><li>• Planning and carrying out investigations</li><li>• Analyzing and interpreting data</li><li>• Constructing explanations and designing solutions</li></ul>	<ul style="list-style-type: none"><li>• ESS2.A. Earth Materials and Systems</li><li>• ESS2.C. The Roles of Water in Earth's Surface Processes</li><li>• ESS3.C. Human Impacts on Earth Systems</li><li>• ETS1.B. Developing Possible Solutions</li></ul>	<ul style="list-style-type: none"><li>• Patterns</li><li>• Cause and Effect</li><li>• Stability and Change</li><li>• Systems and System Models</li><li>• Influence of Engineering, Technology, and Science on Society and the Natural World</li></ul>

Figure 2 below includes two Disciplinary Core Ideas (ESS2.A and ESS3.C.) and examples of Performance Expectations for grades 4, 5, and grades 6-8 (middle school) connected to each of these DCIs.

For more information about the *Next Generation Science Standards*, the *Framework for K-12 Science Education*, and the work of the Vermont Agency of Education, please contact:

Kathy Renfrew, Grade K-5 science and math assessment coordinator  
Vermont Agency of Education  
[kathy.renfrew@state.vt.us](mailto:kathy.renfrew@state.vt.us); (802) 828-6561

Gail Hall, Grade 6-12 science and math assessment coordinator  
Vermont Agency of Education  
[gail.hall@state.vt.us](mailto:gail.hall@state.vt.us); (802) 828-0156

**Figure 2.** Please note: The sections in the table that are highlighted pertain directly to the stream table.

<b>Performance Expectations Addressed by Stream Table Education</b>		
<b>Grade-Level Performance Expectations (examples)</b>	<b>Disciplinary Core Ideas</b>	
	<b>ESS2.A. Earth Materials and Systems</b>	<b>ESS3.C. Human Impacts on Earth Systems</b>
4 <sup>th</sup> Grade	<b>4-ESS2-1.</b> <b>Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.</b> [Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.] [Assessment Boundary: Assessment is limited to a single form of weathering or erosion.]	<b>4-ESS3-2.</b> <b>Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.*</b> [Clarification Statement: Examples of solutions could include designing an earthquake resistant building and improving monitoring of volcanic activity.] [Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.]
5 <sup>th</sup> Grade	<b>5-ESS2-1</b> <b>Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.</b> [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]	<b>5-ESS3-1.</b> <b>Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment.</b>
Middle School (6 <sup>th</sup> – 8 <sup>th</sup> Grades)	<b>MS-ESS2-2.</b> <b>Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales.</b> [Clarification Statement: Emphasis is on how processes change Earth’s surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]	<b>MS-ESS3-2.</b> <b>Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.</b> [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]



## **PRE-STREAM TABLE LESSON: STREAMS & WATERSHEDS**

Please use this lesson **before** your students start working with the stream table.

### **OVERVIEW**

Every stream is the product of water being pulled downhill by gravity 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 the ocean. At every step in this process, water evaporates back into rain clouds, powering a continuous water cycle.

The brooks and streams that form at high elevations comprise the *headwaters* of a 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.*

#### ***More Info:***

Living in Harmony with Streams booklet, page 8.

<b>MATERIALS</b>	<b>SET-UP</b>
<ul style="list-style-type: none"><li>• Basin 10 Map of the Ottauquechee River and Black River (in APPENDICES)</li><li>• An atlas or road map that includes the students’ town and school</li><li>• an illustration of the hydrologic (water) cycle</li></ul>	<ul style="list-style-type: none"><li>• none</li></ul>

### **INSTRUCTIONS**

Introduce students to the definition of a watershed (see GLOSSARY). Show them the Ottauquechee River and Black River watersheds on the Basin 10 map (in APPENDICES). If you are in a different watershed, find a map of your watershed or river system.

Explain that every *river system* drains a basin 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 cycle, which continuously circulates water through our atmosphere and our earth’s crust.

## LESSON A. CORRIDORS AND 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, making them more pronounced over time. This process adds length to 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.

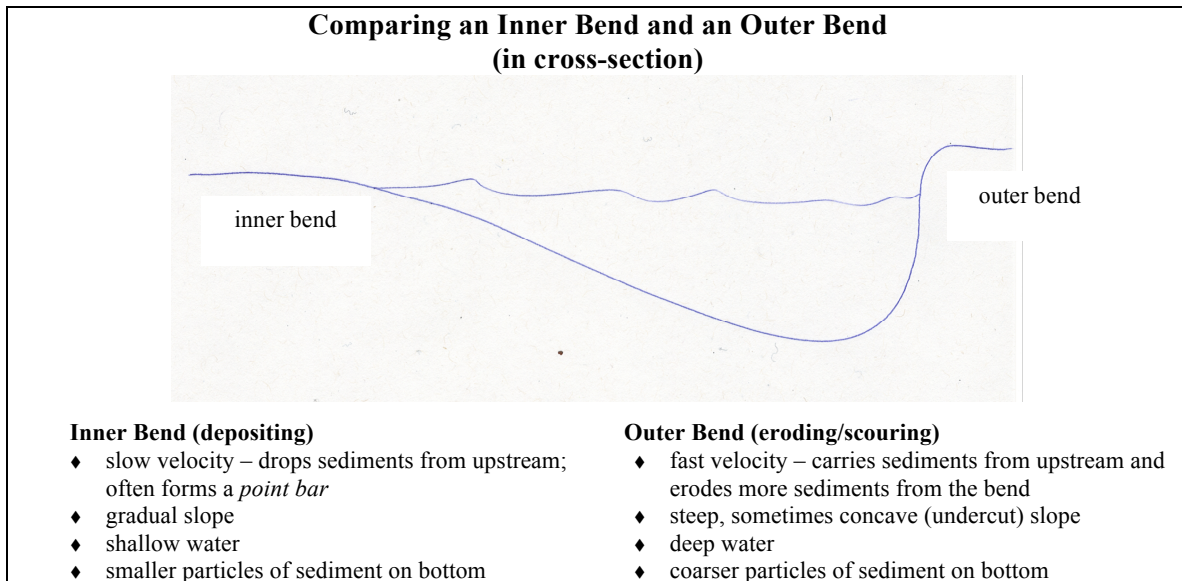
A stream's meanders can change over time, depending on many factors. A big storm can cause significant movement, as seen in the aftermath of Tropical Storm Irene in August 2011. A stream channel meanders within a broader *corridor*, which is defined as follows by the Vermont Agency of Natural Resources:

River corridors consist of lands adjacent to and including the present channel of a river. River corridor delineations are based primarily on the lateral [side to side] extent of stable meanders . . . and a wooded *riparian buffer* to provide streambank stability. (From The Vermont River Corridor Protection Guide).

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 3 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 3 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.

Figure 3.



**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](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

<p><b>MATERIALS</b></p> <p><b>Items with stream table</b></p> <ul style="list-style-type: none"> <li>• stream table</li> <li>• toy houses</li> </ul> <p><b>Items you supply</b></p> <ul style="list-style-type: none"> <li>• student science notebooks, or sheets of paper on clipboards</li> <li>• pencils</li> <li>• camera</li> <li>• clock</li> <li>• small sticks or popsicle sticks</li> <li>• STREAM ANATOMY PARTS STUDENT ACTIVITY SHEET (below)</li> </ul>	<p><b>SET-UP</b></p> <ul style="list-style-type: none"> <li>• Get the stream table ready to run.</li> <li>• Make Stream Anatomy Part signs (Student Activity Sheet)</li> </ul>
	<p><b>TIMEFRAME</b></p> <p>60 minutes</p>

## **INSTRUCTIONS**

### **Lesson A.1. -- Why Meanders Form**

Give each student a science notebook or a sheet of paper on a clipboard, and a pencil. Create a straight channel from top to bottom on the stream table. 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. 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.

### **Lesson A.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 students 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 students take a photo every 5 minutes for about 30 minutes. Occasionally, turn up the volume of water to model a heavy rainstorm.

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.

### **Lesson A.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 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.

## LESSON A.3. – STREAM ANATOMY PARTS

## Student Activity Sheet

Emriver Em2 Geomodel (stream table)

**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.

<b>Bank</b> The land along a stream, between the water and the upland areas.	<b>Point Bar</b> A low, curved bank of sediment along the <i>inner bend</i> of a meander. (It points to the <i>outer bend</i> .)
<b>Cut bank</b> An eroded, concave bank formed on the <i>outer bend</i> of a stream by the flow of water around the bend.	<b>Riparian Area</b> The vegetated areas along a stream.
<b>Stream Channel</b> An area between streambanks that contains or used to contain flowing water, and the floodplain along the stream.	<b>Streambed</b> The bottom of a stream channel that is covered by water.
<b>Headwaters</b> The high-elevation places from which the water in a stream originates.	<b>Mouth</b> The place where a stream empties into another body of water.
<b>Groundwater</b> Water that collects underground and sometimes flows beneath the surface.	<b>Surface Water</b> Water that is visible on the Earth’s surface (lakes, streams, oceans, etc.)
<b>Meander</b> A winding curve or bend of a stream.	<b>Flood Plain</b> A strip of flat land along a stream that receives the overflow of floodwaters.

## **LESSON B. MARBLE RACES**

### **OVERVIEW**

*See Lesson A OVERVIEW above.*

<b>MATERIALS</b>  <b>Items with stream table</b> <ul style="list-style-type: none"><li>• stream table</li><li>• Channel Board-A, with Straight Channel-1, (48" long) and Meandering Channel-2 (60" long)</li><li>• Channel Board-B, with Straight Channel-3 (60" long)</li><li>• Riser Board</li><li>• jar of assorted glass marbles</li></ul> <b>Items you supply</b> <ul style="list-style-type: none"><li>• student science notebooks, or sheet of paper on clipboards</li><li>• pencils</li><li>• timer</li><li>• long piece of string</li><li>• tape measure</li><li>• MEANDERS &amp; VELOCITY STUDENT ACTIVITY SHEET (in Lesson Packet)</li></ul>	<b>SET-UP</b> <ul style="list-style-type: none"><li>• Get the stream table ready to run.</li><li>• Sketch the inner bend-outer bend diagram (see above) on the board.</li></ul>
	<b>TIMEFRAME</b> 60 – 75 minutes

### **Lesson B.1. – Meanders and Velocity**

Show students Channel Board-A, with one straight channel and one meandering channel. Explain that the class will have a marble race to see which channel delivers its marble faster. Choose students to perform these 5 roles:

- a. starter (one student)
- b. marble releasers (two students)
- c. marble catchers (two students)

Choose two marbles of the same size. The marble releasers hold their marbles at the top of their channels. The marble catchers get ready at the bottom of the channels. When the starter says "Go!," both releasers release at the same time. Catchers catch the marbles at the bottom.

Which marble won the race? (the marble in the straight channel) Why? (because the meandering marble had to go around all the bends and travel a longer distance).

Have students complete the MEANDERS & VELOCITY STUDENT ACTIVITY SHEET (below Lesson B).

#### *Extension Activity:*

To complete the MEANDERS & VELOCITY sheet, students must draw conclusions to explain their results. They may be left with questions that they could not answer through this experiment.

Ask students to choose one of these questions that they could "test" through further experimentation. Then ask them to brainstorm some hypotheses (proposed

explanations) that could answer their question.

As a class, choose one hypothesis, have students design an experiment to test it, run the experiment, gather results, and analyze the results. Then ask students to review their hypothesis and draw conclusions. Was their hypothesis supported? If not, do they have a new hypothesis that might explain it? What can they conclude about what happened during their experiment, and how this “model” can help them to understand the real world?

This process – which starts with a question that is investigated and leads to more questions that are investigated in turn – reflects the process of scientific inquiry. As researchers spiral through the process, they gain more understanding and build more knowledge about the world. This is how scientific information is generated and refined over time.

Name: \_\_\_\_\_

Date: \_\_\_\_\_

**Predictions, Investigation, Results**
**1. What would happen if you raced**

- a small marble in the straight channel, and
- a large marble in the meandering channel?

**Prediction**

I predict: \_\_\_\_\_

I think this because: \_\_\_\_\_

**Investigation**

Run the race

<b>Data Collection</b>	small marble straight channel	large marble meandering channel
Time (in seconds)		

**Results:** \_\_\_\_\_

**2. What would happen if you raced ...**

- a small marble in the straight channel, and
- a medium marble in the meandering channel?

I predict: \_\_\_\_\_

I think this because: \_\_\_\_\_

**Investigation**

Run the race



<b>Data Collection</b>	small marble straight channel	large marble meandering channel
Time (in seconds)		

**Results:** \_\_\_\_\_  
 \_\_\_\_\_

## 2. What would happen if you raced ...

- a large marble in the straight channel, and
- a small marble in the meandering channel?

### Prediction

I predict: \_\_\_\_\_

I think this because: \_\_\_\_\_

### Investigation

Run the race

<b>Data Collection</b>	small marble straight channel	large marble meandering channel
Time (in seconds)		

**Results:** \_\_\_\_\_  
 \_\_\_\_\_

### Conclusions

Review your predictions and data for each race. What can you conclude about different sizes of marbles in straight and meandering channels?

---



---



---



---

## Lesson B.2. – Meanders, Thalweg, and Riffles

When a marble travels down the meandering channel, where within the channel does it travel? Does it move down the middle of the channel, or does its course vary?

Choose a small marble and ask students to carefully watch its course as it travels down the meandering channel. Have them write their observations in their notebooks. Then discuss. Students should notice two things:

1. The marble hits the outer bend of each meander. (The same thing happens with real water in a channel. The force of the water hitting the bank digs into the bank, making the outer bend sharper and deeper.) The marble traces the *thalweg*, which is the deepest part of the channel. (Every meandering stream has a thalweg.)
2. The marble travels across the channel as it moves from meander to meander. Remember our skier carving turns down the hill. (In a stream, shallow *riffles* tend to form between meanders, where the erosive force of the water is reduced and less eroding of the streambed occurs.)

Students may notice that the marble hits the downstream part of the outer bend. The stream acts similarly, eroding the downstream end of the outer bank, causing the whole meander pattern to move downstream over time.

## Lesson B.3. – Meanders, Length, & Slope

If you straightened out Meandering Channel-2, how long would it be? Have students lay a piece of string along Meandering Channel-2, then measure the length of this string (60"). Have them also measure the length of Straight Channel-1 (48"). Even though both channels occupy the same landscape, the meandering channel is actually longer.

Show students Straight Channel-3 on Channel Board-B, which represents Meandering Channel-2 straightened out (60"). Lay Channel Board-B next to Channel Board-A and prop both of them on the Riser Board so that they are at the same elevation.

Have students compare the slope (the amount of drop in elevation) of the two straight channels from the highest ends to the lowest ends. Which one is steeper? How might slope affect water velocity and its erosive force?

(Straight Channel-1 is steeper than Straight Channel-3. Meanders lengthen a stream, which makes it flatter. This slows down the water, reducing its erosive force. The water's force is further reduced when it hits each bend in the meandering channel. The same thing happens when you turn while skiing: each turn you take slows you down and reduces the force that you carry downhill by lengthening your route and making your descent less steep.)

*Extension Math Activity:* Percent Slope (see APPENDICES)

## **LESSON C. 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=PLX5V6zW7pAiYEC3blrK3ymOegGrPwg0xT>

- 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

<b>MATERIALS</b>  <b>Items with stream table</b> <ul style="list-style-type: none"><li>• rocks</li><li>• washcloths</li></ul> <b>Items you supply</b> <ul style="list-style-type: none"><li>• cheesecloth, cut into long strips</li><li>• scissors</li></ul>	<b>SET-UP</b> <ul style="list-style-type: none"><li>• Get the stream table ready to run. Allow water to flow and meanders to form.</li></ul>
	<b>TIMEFRAME</b> 45 minutes

### **INSTRUCTIONS**

#### **Lesson C.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 C.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	<ul style="list-style-type: none"> <li>• plant foods (seeds, berries, leaves, etc.) for terrestrial animals</li> <li>• cover from predators</li> <li>• easy access to water</li> <li>• aquatic prey species (e.g., crayfish) for terrestrial predators (e.g., raccoon)</li> <li>• homes like holes in trees and nests that are close to food and water resources</li> <li>• enriched soil from nutrient cycling of plants and animals</li> </ul>	<ul style="list-style-type: none"> <li>• plant parts drop into the water to provide food and habitat structures for aquatic animals</li> <li>• shade cools the water (which increases dissolved oxygen in water) which benefits fish and other aquatic animals</li> <li>• shade and overhanging vegetation provides cover for fish and other aquatic animals</li> <li>• plant roots hold soil along the banks, preventing excess erosion of soil into the stream.</li> </ul>
riprap (rocks that line the bank)	<ul style="list-style-type: none"> <li>• cover for small animals (if they can hide among or under the rocks)</li> <li>• others?</li> </ul>	<ul style="list-style-type: none"> <li>• 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)</li> <li>• others?</li> </ul>
cement walls	<ul style="list-style-type: none"> <li>• attachment location for some plants, which may serve as food and shelter</li> </ul>	<ul style="list-style-type: none"> <li>• any plants that attach and grow drop plant parts into the water, which provides some food.</li> <li>• any plants that attach and grow provide some shade (see above)</li> <li>• 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)</li> </ul>

## **LESSON D. CULVERTS**

### **OVERVIEW**

Since many of our human activities occur in stream valleys, we have to find ways to cross the paths of various flowing waters. Culverts are metal or plastic pipes that are often installed to convey water under a “travelway” such as a road or a path.

During a big storm, streams collect more water than usual and can rise dramatically. When a large volume of water is squeezed through a small culvert, the water speeds up and carries more force, creating a “fire hose” effect downstream. The culvert often acts as a bottleneck, backing up water behind it. If the culvert becomes clogged with debris, it passes even less water or completely dams the stream. 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 culverts which can accommodate increased water volumes are often more effective at managing stream waters than small ones.

Culverts can become “perched” when the outflow from the culvert erodes the streambed downward. (This is often the result of the fire-hose effect described above.) Now the downstream end of the culvert is higher than the streambed and 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 finding food.

“Bottomless” (open bottom) culverts, similar to bridges, are now being installed in some areas in Vermont. They allow water to flow more smoothly and do not become perched, which allows fish to move easily through the culvert. Natural sediment patterns develop beneath the culverts that reflect the streambed upstream and downstream, creating conditions that add tremendous value to maintaining river stability and aquatic habitats.

#### ***More Info:***

Living in Harmony with Streams booklet, page 2

Vermont Stream Crossing Handbook:

Google “Vermont Stream Crossing Handbook.”

After the Flood Videos

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

<b>MATERIALS</b>  <b>Items with stream table</b> <ul style="list-style-type: none"><li>• small culvert (metal can)</li><li>• large culvert (metal can)</li><li>• bottomless culvert (half a PVC pipe)</li></ul> <b>Items you supply</b> <ul style="list-style-type: none"><li>• CULVERT TYPES STUDENT ACTIVITY SHEET (below)</li></ul>	<b>SET-UP</b> <ul style="list-style-type: none"><li>• Get the stream table running</li><li>• Prepare a chart on the board or large sheet of paper for the class brainstorm in Lesson D.2.</li></ul>
	<b>TIMEFRAME</b> 60 minutes

## INSTRUCTIONS

### Lesson D.1. -- Culvert Types.

Show students the 3 kinds of culverts in the stream table supplies – small, large, and bottomless. Give each student a copy of CULVERT TYPES STUDENT ACTIVITY SHEET and ask them to predict which culvert type will allow the stream to flow most smoothly. (Steps 1 and 2 on the sheet.)

Run experiments with the class – on the small culvert, on the large culvert, and on the bottomless culvert - to test students' predictions (Step 3 on the sheet).

First, install the small culvert in flowing water on the stream table. Run the water at low volume and observe it flowing through the culvert. Now turn the volume up a bit (heavy rain) and observe again. Finally, turn the volume up high to simulate a storm surge and observe again. What happens? (see OVERVIEW above)

Next, rebuild the channel to its original width and install the large culvert. Repeat the steps above (low flow, medium flow, high flow) and observe after each increase in volume.

Finally, rebuild the channel to its original width and install the bottomless culvert. Does the culvert affect water flow and sediment transport?

Have students revisit their CULVERTS TYPES sheet and complete Steps 4 and 5.




**LESSON D.1. CULVERT TYPES****Student Activity Sheet**  
Emriver Em2 Geomodel (stream table)

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Look at the 3 kinds of culverts that come with the stream table: small round, large round, and bottomless half-circle.

1. **Question:** *Which culvert will allow the stream to flow most smoothly?*
2. **Prediction** (hypothesis): Check one box below, and explain why you chose it:

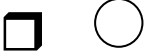


small culvert	large culvert	bottomless culvert
<input type="checkbox"/> 	<input type="checkbox"/> 	<input type="checkbox"/> 

3. **Experiment.** Install each type of culvert, one at a time, and run the stream table. Write 3 observations for each culvert below.

Culvert Type	Observations of flowing water and culvert
small culvert	1.
	2.
	3.
large culvert	1.

	2.
	3.
bottomless culvert	1.
	2.
	3.

4. **Results:** Which culvert type allowed the stream to flow most smoothly? Check one.

<p>small culvert</p> 	<p>large culvert</p> 	<p>bottomless culvert</p> 
----------------------------------------------------------------------------------------------------------	----------------------------------------------------------------------------------------------------------	----------------------------------------------------------------------------------------------------------------

5. **Conclusions:** Review your predictions and observations. What can you conclude about these 3 culvert types and their affects on flowing water?

---



---



---



## LESSON D.2. - COMMUNITY CULVERTS

Different members of a community have different perspectives on installing culverts. 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 *Getting More Information* in the VERMONT STREAM CROSSING HANDBOOK).

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

Types of Culverts	Pros (+)	Cons (-)
small culvert	<ul style="list-style-type: none"><li>• minimal cost</li><li>• adequate for moving typical water volumes</li><li>• minimal movement of earth required to install it</li><li>• takes up a small “footprint”</li></ul>	<ul style="list-style-type: none"><li>• may not be able to handle storm waters, causing them to flood the land around it</li><li>• may get blocked with debris or “blown out” during a storms, causing flooding around it</li><li>• often becomes “perched,” interfering with fish passage</li></ul>
large culvert	<ul style="list-style-type: none"><li>• relatively inexpensive</li><li>• adequate for moving typical and greater water volumes</li></ul>	<ul style="list-style-type: none"><li>• higher cost than small culvert</li><li>• requires more movement of earth to install than small culvert</li><li>• larger “footprint” than small culvert</li><li>• often becomes “perched,” interfering with fish passage and causing more erosion.</li></ul>
bottomless culvert	<ul style="list-style-type: none"><li>• lasts longer than small or large culverts</li><li>• much less likely to wash out than small or large culverts.</li><li>• mimics natural streambed; does not become “perched”</li><li>• provides benthic habitat for fish, waterbugs, and other aquatic organisms</li></ul>	<ul style="list-style-type: none"><li>• higher cost than either small or large culvert</li></ul>

Explain that a bottomless culvert costs 20% to 40% more than a traditional pipe culvert, but lasts more than twice as long.

- If a small pipe culvert costs \$1,000, what would a bottomless culvert cost? (Answer:

\$1,200 to \$1,400)

- If a traditional pipe culvert can be expected to last for 20 years, how long would you expect a bottomless culvert to last? (40 years or longer)

Ask students to play the roles of the following individuals. Which type(s) of culvert 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

## **LESSON E. SEDIMENTS & EROSION**

### **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 (see *Figure 4 below*)**

1. A landowner removes gravel from the streambed and sells it to a construction company. This creates a hole in the streambed. The slopes around the hole are steeper than the slope of the adjacent 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 below 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 will 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.

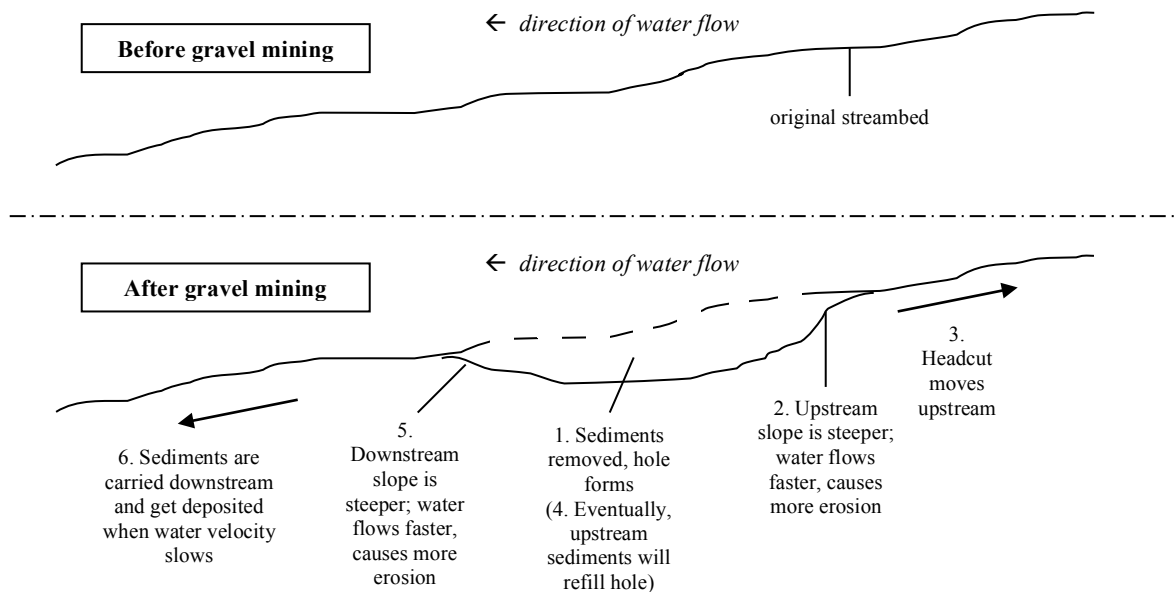
Recognizing the negative impacts that often result when stream sediments are removed, the state of Vermont banned commercial gravel mining and in-stream gravel dredging in

1987. Gravel removal is sometimes allowed where excess sediments pose a problem for human activities. For instance, the state of Vermont temporarily lifted the ban on gravel removal after Tropical Storm Irene occurred to allow people to deal with erosion and sediment damage. But sediment removal after Irene caused serious damage to some streams, so the state passed new rules to minimize future impacts.

Figure 4.

### Cross-section of a streambed before and after 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?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](http://www.emriver.com/?page_id=1521)

MATERIALS	SET-UP
<b>Items with stream table</b> <ul style="list-style-type: none"> <li>• none</li> </ul>	<ul style="list-style-type: none"> <li>• View this video: <i>Inchannel gravel mining and bar pit capture</i> (<a href="http://www.emriver.com/?page_id=1521">http://www.emriver.com/?page_id=1521</a>, bottom of page); shows <i>headcut</i> and other erosion conditions.</li> <li>• Practice using your hand as a backhoe and scoop out some sediment in the stream table's channel, watching the result. Look for a <i>headcut</i> to form. This is the effect that you want for this activity.</li> </ul>
<b>Items you supply</b> <ul style="list-style-type: none"> <li>• none</li> </ul>	<b>TIMEFRAME</b> 60 minutes

## **INSTRUCTIONS**

### **Lesson E.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 E.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.

## LESSON F. WATERSHED NEIGHBORS

### 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 changes in stream conditions, especially downstream, as the stream responds. 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. *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 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. (page 12)

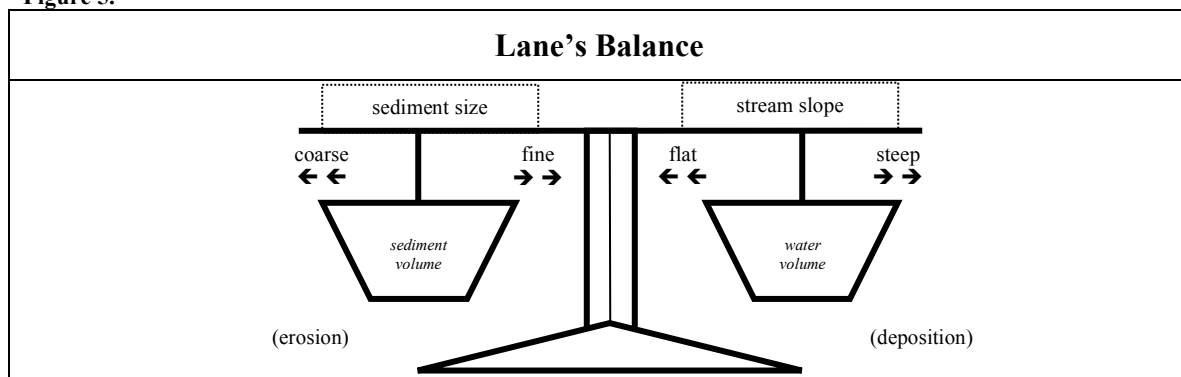
These movements and adjustments cause the erosion of soil particles in some places and the deposition of soil particles in other places. In between, the soil particles become suspended and carried in the water. Therefore, streams move both water and sediments.

*Lane's Balance* is a model that shows how a stream balances the relationship between water flow and sediment transport to maintain or regain equilibrium. It can help us to understand cause and effect in a stream. This model incorporates 4 variables in a typical old-fashioned 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 5.**



We suggest that you play with the Lane's Balance included with the stream table before introducing it to your students to understand the relationships between these 4 variables. Below are some questions (and answers) that can help you and your students understand the stream dynamics that can be modeled by Lane's Balance.

### **Stream Dynamics Questions:**

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

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

How do you re-balance the scale?

Add more sediment or coarser 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.

**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 size arm* down and causes the *stream slope arm* to rise.

How do you re-balance the scale?

Add more water: during the next flood, the increased volume of water will scour out sediments, rebalancing the system.

**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* swings 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.

**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* swings 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.

How can we, as watershed residents, make decisions that protect our real estate, minimize conflicts with our neighbors, and foster a healthy watershed? The Vermont Rivers Program is encouraging Vermonters to allow our unstable streams to re-balance themselves, which may mean allowing a straightened stream to meander, or an eroding stream to deposit sediments downstream of the disturbance. We can also remove a berm along a stream (or punch a hole in it) to allow floodwaters to spread out over floodplains, which dissipates the water's energy and absorbs excess water volumes. And replanting riparian zones with trees or other kinds of vegetation has numerous benefits. (See the OVERVIEW in Lesson C. – Streambanks). These restoration actions help the stream to regain its *dynamic equilibrium*, which makes it more stable and less susceptible to flood damage and erosion in the long run.

**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>)

<p><b>MATERIALS</b></p> <p><b>Items with stream table</b></p> <ul style="list-style-type: none"> <li>• Lane's Balance</li> <li>• items that represent farms and cities: houses, roads, farm fences, livestock, etc.</li> </ul> <p><b>Items you supply</b></p> <ul style="list-style-type: none"> <li>• FARM TO CITY STUDENT ACTIVITY SHEET, or CITY TO FARM STUDENT ACTIVITY SHEET (below)</li> </ul>	<p><b>SET-UP</b></p> <ul style="list-style-type: none"> <li>• Watch this video: Steve Nelle explaining Lane's Balance (<a href="http://www.youtube.com/watch?v=Js7wDZE4I7o">http://www.youtube.com/watch?v=Js7wDZE4I7o</a>)</li> <li>• Refer to Figure 5 above for an illustration of a simple Lane's Balance.</li> <li>• Put together the Lane's Balance from stream table supplies; place the buckets in the same position along each arm and make sure that the arms are balanced.</li> </ul> <p><b>TIMEFRAME</b></p> <p>60 minutes</p>
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

**Lesson F.1. – Lane's Balance** (*best with older students; it may be too challenging for 4<sup>th</sup> graders*)

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

With students, play with the Lane's Balance that comes with the stream table. Use the **Stream Dynamics Questions** in the OVERVIEW above to guide your explorations. Ask the question, play with the balance together as a class, and observe what happens. Have students describe what happens in their science notebooks. Now ask each successive question in turn and have students write a prediction in their science notebooks, or discuss it as a class. Then manipulate the Lane's Balance to find the answer to each question.



## **Lesson F.2. – Upstream, Downstream**

*Please note: Lesson F.2.a. and Lesson F.2.b. teach the same basic concepts. You can choose to do either one, depending on which better represents your students' experiences. Or you can do both to encourage your students to adopt different perspectives on watershed resource use and cause and effect.*

### **Lesson F.2.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 farm fields. 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.

**LESSON F.2.A. FARM TO CITY****Student Activity Sheet**  
Emriver Em2 Geomodel (stream table)

Name: \_\_\_\_\_

Date: \_\_\_\_\_

*Use a copy of this sheet for each Scenario that you run.***Check the Scenario 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

**Prediction:** 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 did you learn from 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 out one of your recommendations and observe the results. Did it accomplish your goals?

## **Lesson F.2.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.

**LESSON F.2.B. CITY TO FARM****Student Activity Sheet**  
Emriver Em2 Geomodel (stream table)

Name: \_\_\_\_\_

Date: \_\_\_\_\_

*Use a copy of this sheet for each Scenario that you run.***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

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

<b>Analysis:</b> Summarize the important findings of your experiment.	
<b>Conclusions:</b> Review your Predictions. What did you learn from this experiment?	
<b>Recommendations for improvement (designing possible solutions):</b> 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 out one of your recommendations and observe the results. Did it accomplish your goals?

## GLOSSARY

*Definitions adapted from the glossary in Living in Harmony with Streams, the dictionary tool in Microsoft Word, and other sources of definitions.*

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

**bankful 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.

**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.

**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.

**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.

**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.

**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.

**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**

*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. Google "Living in Harmony with Streams."

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

*Vermont Stream Crossing Handbook*, Vermont Fish and Wildlife Department, Vermont Agency of Natural Resources. Google "Vermont Stream Crossing Handbook"

A great reference, full of color photographs, that describes the issues concerning culverts. Includes two case studies that show how old culverts were reconstructed to enhance aquatic habitats.

*Basin 10 Water Quality Management Plan: Ottauquechee River & Black River*, Vermont Agency of Natural Resources, May 2012. Google "Basin 10 Water Quality Management Plan: Ottauquechee River & Black River."

Comprehensive plan that describes these two river systems and lays out a plan for improving and maintaining their watershed conditions over time.

*Next Generation Science Standards*. <http://www.nextgenscience.org/>.

Adopted by Vermont in spring 2013, these new science standards integrate *Science and Engineering Practices*, *Disciplinary Core Ideas*, and *Cross-Cutting Concepts*.

#### **Internet Videos**

Emriver Em2 Geomodel Educational Videos, Little River Research and Design:  
[http://www.emriver.com/?page\\_id=1521](http://www.emriver.com/?page_id=1521).

A series of short videos that show the process of meandering, a straightened river re-meandering, sediment movement, and the effects of gravel mining in a stream (shows a head cut).

*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](http://www.youtube.com/watch?v=E_a-nYl9Ak4)

**Ottawaquechee Natural Resources Conservation District (ONRCD) Resource People**

Bill Manner: [103res2010@comcast.net](mailto:103res2010@comcast.net)

Larry Kasden: [larrykasden@hotmail.com](mailto:larrykasden@hotmail.com)

Sue Greenall: [ONRCD1@gmail.com](mailto:ONRCD1@gmail.com)

**State of Vermont Resource People**

Watershed Management Division, Vermont Agency of Natural Resources

Marie Caduto, Watershed Planner, Basin10 (Ottawaquechee River and Black River): [marie.caduto@state.vt.us](mailto:marie.caduto@state.vt.us), 802-490-6142.

Jim Ryan, Watershed Planner, White River Basin: [jim.ryan@state.vt.us](mailto:jim.ryan@state.vt.us), 802-490-6140.

Staci Pomeroy, Vermont River Scientist: [staci.pomeroy@state.vt.us](mailto:staci.pomeroy@state.vt.us), 802- 490-6191.

Agency of Education

Kathy Renfrew, Grade K-5 science and math assessment coordinator: [kathy.renfrew@state.vt.us](mailto:kathy.renfrew@state.vt.us), 802-828-6561.

Gail Hall, Grade 6-12 science and math assessment coordinator: [gail.hall@state.vt.us](mailto:gail.hall@state.vt.us), 802-828-0156.

**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.

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.

## *APPENDIX 1*

### **BASIN 10 WATERSHED MAP**

From the  
***Basin 10 Water Quality Management Plan***  
Ottauquechee River & Black River  
Vermont Agency of Natural Resources  
May 2012

# Basin 10



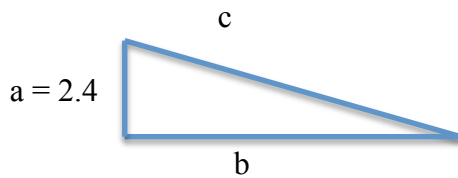
## APPENDIX 2

### EXTENSION ACTIVITY: PERCENT SLOPE

MATERIALS	SET-UP
<p><b>Items that come with the stream table</b></p> <ul style="list-style-type: none"> <li>• Channel Board A, with Straight Channel 1 and Meandering Channel 2</li> <li>• Channel Board B, with Straight Channel 3</li> <li>• Riser Board</li> <li>• Run-Out Channel Board</li> <li>• jar of assorted marbles</li> </ul> <p><b>Items that you supply</b></p> <ul style="list-style-type: none"> <li>• flexible tape measure</li> </ul>	<ul style="list-style-type: none"> <li>•</li> </ul> <p><b>TIMEFRAME</b> 60 minutes</p>

### INSTRUCTIONS

1. Set up one end of the “channel board” on the riser. Let similar sized marbles run down the straight channel and the meander channel and make observations.
2. Using a flexible tape, measure the length of the straight channel (48”) and the meander channel (60”).
3. Determine the slope of the channels. To do this, divide the rise (a) by the run (b).



For the straight channel,  $b = 47.94''$ , which can be rounded off to 48.”

For the meandering channel,  $b = 59.95''$ , which can be rounded off to 60.”

#### *Arithmetic Formulas*

$$a^2 + b^2 = c^2 \text{ or, put another way, } c^2 - a^2 = b^2$$

*for the straight channel:*

$$48^2 = 2.4^2 + b^2, \text{ or } 2,304 = 5.76 + b^2$$

$$\text{Therefore, } b^2 = 2,304 - 5.76 = 2,298$$

$$\text{And } b = 47.94$$

*for the meandering channel:*

$$\text{again } c^2 = a^2 + b^2 \text{ or } 3600 = 5.76 + b^2$$

$$\text{And } b^2 = 3594, \text{ so } b = 59.95''$$

---

So, you can get the % of angle (not degree) for the straight channel with this formula:

$$2.4'' / 48'' = 5\%$$

And you can get the % of angle (not degree) for the meander channel with this formula:

$$2.4'' / 60'' = 4\%$$

4. Set the Run-Out Board at the bottom of Channel Board 1 and place a small, stationary marble where each channel meets the Run-Out Board.
  - a. Let a small marble run down the straight channel and bump into the stationary marble and measure how far the stationary marble is pushed. Repeat by letting the same small marble run down the meander channel and measure how far the stationary marble is pushed.
  - b. Replace the small marble with a medium marble, and repeat the experiment.
  - c. Replace the medium marble with a large marble, and repeat the experiment.
  - d. Weigh the small, medium, and large marbles and consider how the size of the marble affects how far the stationary marbles are pushed.

How does this relate to the power of a river that is running deep versus the power of a river when it is running shallow?

5. Set the end of Channel Board B on the riser board so it is next to Channel Board A. Note that the straight 60'' channel represents the meander channel straightened out (which is also 60''). Note that Channel Board B has a gentler slope than Channel Board A: 4% vs. 5%.

### ***APPENDIX 3***

#### **EXTENSION ACTIVITY: ROCKS & VELOCITY**

On the stream table with the water moving, release a float down the channel along a given distance (say, 10 inches) and time it. Place some rocks in this section of the channel, release and time the float again, and see how the rocks affect the speed of the float. Have students complete the table below.

<b>Channel Condition</b>	<b>Velocity Formula</b>	
no rocks	_____ inches distance ÷ _____ seconds =	inches/sec
rocks	_____ inches distance ÷ _____ seconds =	inches/sec