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Emriver Em2 and Em3 Lab Manual

Chapter 1

1 Safety and Lab Manual Contents

The Emriver Lab Manual goes beyond the basic information given in the Use and Care Manual to describe methods for advanced demonstrations and experiments.

This manual is a companion to the ***Use and Care Manual***, and essential information in that manual is not repeated here. *It is vital that you read and understand the* ***Use and Care Manual*** *before using this Lab Manual.*

The Emriver model is capable of dozens of experiments and demonstrations, and new ones are constantly being developed. For the latest information on module development please contact us at info@emriver.com or visit our support page at emriver.com/supportFAQ/.

See Chapter 2 for detailed Setup procedures.

In this chapter

1.1 Safety

1.2 Emriver Lab Manual Contents

1.3 Introduction

1.3.1 Setting Up for Demonstrations

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1.1 Safety

YOU MUST READ AND UNDERSTAND THESE WARNINGS BEFORE USING THE EMRIVER MODEL

- The Emriver model is very heavy when filled with water and sediment. A collapse of the model supports could severely injure or kill a person. Be absolutely sure you understand how to use the supports.
- Use only the supports provided with the Emriver geomodel. Despite weight-bearing claims, no standard production sawhorse is strong enough to support the model. Sawhorses and folding tables can collapse under dynamic or side loading.
- Check all fittings on the aluminum supports before each use to be sure they are secure.
- When setting up the box, the supports must be laterally level and aligned. They must also be aligned with the proper support point underneath the box. Otherwise the box could warp or collapse when loaded. Make sure spreader bars are fully engaged.
- Never set the box up on a surface with a slope exceeding 8% (a 7-inch drop in 7 feet).
- Never use more than 27 gal (102 L) of water and the provided 150 lbs (68 kg) of sediment in the Em2, 40 gal (151 L) of water and 240 lbs (109 kg) of sediment in the Em3, or 60 gal (227 L) and 360 lbs (163 kg) of sediment in the Em4. Using more than the maximum amount of water and sediment could cause the box or supports to collapse.
- Do not place any heavy objects in the box and never allow people to sit or stand on or in the box. Never get underneath the loaded box.
- Use only the pump and power supply provided with the Emriver system. Be certain to connect the power supply to a properly grounded outlet. Always use the Ground Fault Circuit Interrupter (GFCI) provided with the Emriver model, and be sure to read the manual that accompanies the GFCI.
- When using a 12-volt battery to power the model, always use the Emriver battery adapter from Emriver, Inc. Never bypass the fuses.
- When powering the model with a 12-volt battery, be sure you understand the dangers associated with charging and using lead-acid batteries, and consider using safer spill-proof batteries.
- The box should only be used for its intended purpose as stated herein.
- If any part of the box or pumping system is damaged, or you have any doubts about the electrical or structural safety of the model, or if you do not understand these directions, do not use this model.

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1.2 Emriver Lab Manual Contents

1. Introduction
- 1.1 Safety
- 1.2 Lab Manual Contents
- 1.3 Introduction

2. Advanced Setup and Operation
- 2.1 Channel Slope
- 2.2 Slope Variables and Equations
- 2.3 Controlling Flow
- 2.4 Initial Conditions
- 2.5 Sediment Properties

3. Measurements
- 3.1 Thalweg and Other Horizontal Measurements
- 3.2 Vertical Measurements and Laser Levels
- 3.3 Water Discharge
- 3.4 Sediment Discharge

4. Demonstrations
- 4.1 In-channel Gravel Mining
- 4.2 Sediment Transport Measurement, Continuity, and Channel Stability

5. Exercises and Experiments
- 5.1 Channelization
- 5.2 Bank Armoring
- 5.3 Modeling Riprap

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1.3 Introduction

The first models similar to the Emriver that we know of were built in the late 1980s by river managers working for the Missouri Department of Conservation (MDC). These models were developed to meet a dire need: teaching private landowners about river geomorphology.

Static drawings and talks had proven inadequate. There is a human tendency to oversimplify the morphologic response of rivers to practices like channel straightening or bedload mining, and attempts at education were frustrating. Miners, farmers and loggers who had observed river behavior all their lives were understandably reluctant to accept new ideas. But those early models built by MDC fisheries biologists proved to be very powerful tools for conveying the complicated processes and responses of rivers. Landowners and laypeople could clearly see, for example, how headcuts and incision can damage land upstream of a gravel removal operation.

Indeed, the Emriver geomodel and its ancestors are very powerful tools for teaching and understanding river processes and morphology for all ages. On seeing the model, experienced river observers invariably recognize morphological features and processes they have seen in the field. The strong similarities between channel behavior in the Emriver model and the behavior and morphology of real rivers is very convincing, even for the most skeptical observers. Observation of these processes is made easier by a greatly compressed time scale and expanded physical scale. Things happen faster in the model, and in the 2-meter Emriver Em2 one can see the equivalent of a few hundred meters of real stream. Thus we often see people make great leaps in understanding by observing the model. The Emriver model and its ancestors used by Midwestern river conservationists have proven to be very powerful tools in teaching landowners and other stakeholders how rivers function and respond to human impacts.

The Emriver model is also a powerful tool for education of professional river managers with backgrounds in fisheries, forestry, ecology, stream biology or civil engineering who may have little or no formal training in applied fluvial geomorphology, as well as children and laypeople through environmental outreach education. And, of course, the model is very useful to academic geomorphologists for more advanced demonstrations, research, and teaching.

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1.3.1 Setting Up for Demonstrations

Teaching takes lots of practice and skill. As with any teaching tool, your success with the Emriver model will depend on your understanding of fluvial geomorphology, the model, and your audience. Preparation is important. The model is not difficult or complex to operate, but small differences in how you use it can make big differences in your teaching effectiveness. In general, you should remember these guidelines:

- For field demonstrations, allow plenty of time for setup. The model can be set up and ready for use in as little as 30 minutes, but you should allow an hour, especially in unfamiliar settings. You should allow at least 10 minutes to start a model in which the groundwater has drained – it can take this long to replenish the groundwater so you can begin demonstrations. Dry media can take up to 30 minutes to become saturated.

- Understand channel slope and flow rates and how they affect your demonstrations. It is tempting to use higher discharges for more dramatic (and faster) effect, but you will usually get better results by using lower flow rates. This chapter gives recommended starting slopes and discharges for demonstrations. Chapter 2 (*Advanced Setup*) gives detailed instructions on setting up the model. Those who use the model infrequently and only for a few demonstrations should standardize and write down their setup procedure to achieve the necessary box and channel slope with minimum hassle.

- At the start of your demonstration, tell your audience about the model and how it works. People are invariably curious about the modeling media (and almost never guess that it is plastic). For advanced groups, you may want to explain how the lower density of the plastic sediment accounts for scaling (see *Sediment Properties* in Chapter 2). If your audience is overly concerned with the mechanics of the model, they may miss parts of your demonstration.

- Limit your audience size so that observers can stand comfortably around the model and can see activity inside the box. You may have to split a large audience into smaller groups.

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Emriver Lab Manual

Chapter 2

2 Advanced Setup and Operation

For the latest information on module development please contact us at info@emriver.com or visit our support page at emriver.com/supportFAQ/.

This manual is a companion to the ***Use and Care Manual***, and essential information in that manual is not repeated here. *It is vital that you read and understand the **Use and Care Manual** before using this Lab Manual.*

In this chapter

2.1 Channel Slope

2.2 Slope Variables and Equations
- 2.2.1 Calculating Maximum Slope
- 2.2.2 Calculating Channel Slope
- 2.2.3 Slope Calculation and Adjustment Methods – Quick Setup

2.3 Controlling Flow
- 2.3.1 Using the Emriver K28 Electronic Flow Controller
- 2.3.2 Flow Measurement
- 2.3.3 Discharge Ranges
- 2.3.4 Creating Hydrographs

2.4 Initial Conditions
- 2.4.1 Floods and Feature Formation
- 2.4.2 Valley Shape

2.5 Sediment Properties
- 2.5.1 Modeling Media Sizes and Colors
- 2.5.2 Groundwater Behavior

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2.1 Channel Slope

Channel slope in the Emriver model is controlled by the slope of the box and the elevation of the standpipe. For most setups, the slope of the box is determined by the relative height of its supports.

Unless you're investigating tectonic effects on channels, it's much more practical and realistic to control channel slope with the model's standpipe than to move the entire box. The slope of the box will determine the range of slopes attainable using standpipe adjustments, but, as in real rivers, the range of realistic slopes in the model is quite narrow – from zero to around 5 percent. You can set slopes throughout this range with only two or three box adjustments and the full range of standpipe adjustments.

Figure 2.1 and the equations that follow show the relationship between the box slope, standpipe height, and the maximum channel slope. Maximum channel slope is the straight-line distance divided by the vertical drop between the Energy Dissipater Unit (EDU) and the standpipe. You'll only see this channel slope in a perfectly straight channel.

Later in this chapter, you'll find a method for quick setups and approximate slope setting.

For experimental work and detailed study of fluvial geomorphology, you should directly measure slopes in the model using a leveling device. A self-leveling visible laser level is best for this, though other means can be used. See Chapter 3 of this manual for details on direct measurement of box and channel slope in the Emriver model.

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2.2 Slope Variables and Equations

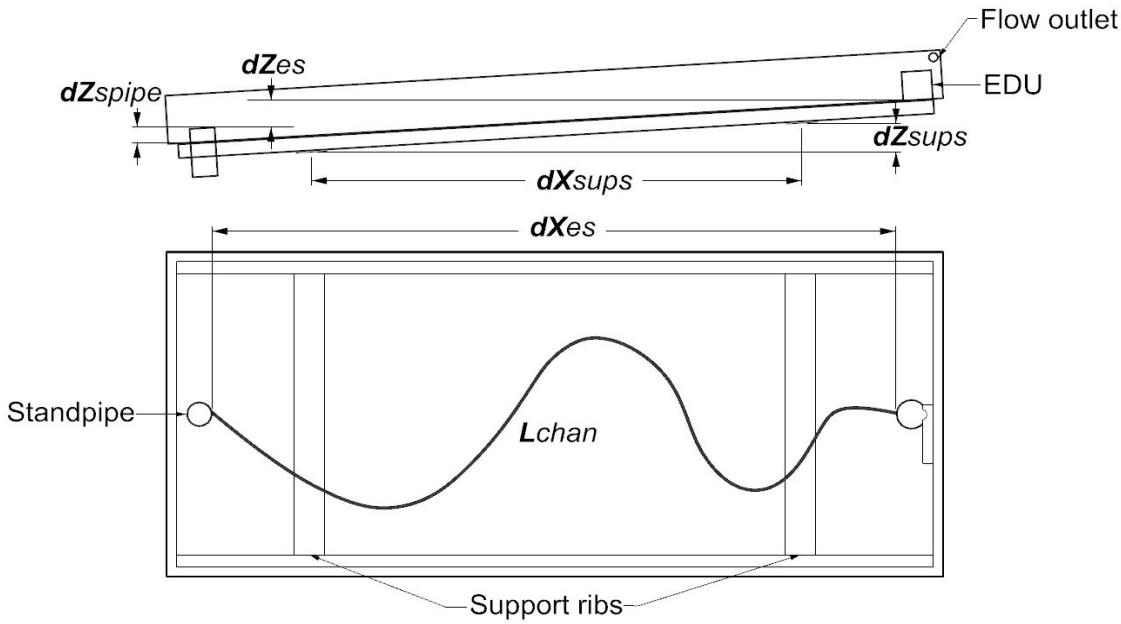

Figure 2.1 - Schematic longitudinal (top) and aerial (bottom) layout of the Emriver geomodel. Variables used in setting and calculating slope are listed in the table below.

Variable	Definition
dX_{es}	*Horizontal (X) distance (d) between the Energy Dissipator Unit (EDU)(e) and standpipe (s). In the Em2 this is 67", in the Em3 it is 108"*
dZ_{es}	*Vertical (Z) distance (d) between the EDU (e) outlet and top of standpipe (s). Changes with slope change. Maximum is 72mm in Em2 and 105mm in Em3.*
dZ_{spipe}	*Vertical (Z) distance (d) between top of standpipe and box floor (spipe).*
dX_{sups}	*Horizontal (X) distance (d) between the box support ribs (sups). In the Em2, this is 49" or 1.24 meters, in the Em3 it is 59" or 1.5 meters*
dZ_{sups}	*Vertical (Z) distance (d) between the box support ribs (sups). Can change by shims or tilt base. In Em2, through mid-2021, this was 3". After mid-2021, this is 2". In Em3, this is 3"*
L_{chan}	*Length (L) of channel (chan) measured along the thalweg, or the deepest part of the channel*
S_{max0}	*Maximum (max) possible channel slope (S) with a standpipe height (dZ_{spipe}) of zero. Can be calculated. In Em2, it is 0.039, and in Em3 it is 0.05.*
S_{max}	*Maximum possible channel slope for a given box slope and standpipe height (dZ_{spipe}). Slope of a straight channel running from the EDU to the standpipe. Can be calculated*
S_{mc}	*Slope of meandering channel. Can be calculated*
Sinuosity	*Ratio of channel length (L_{chan}) to straight-line distance from the EDU to the standpipe (dX_{es}). Can be calculated*

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2.2.1 Calculating Maximum Slope

S_{max_0} is the maximum possible channel slope in the box, given a straight channel and zero standpipe (dZ_{spipe}) elevation. If standpipe height is zero, then S_{max} = S_{max_0}, assuming leveled media. **As the standpipe is raised, S_{max} decreases**. S_{max} can be directly measured using a leveling device and equation 1 below:

$$S_{max} = {dZ_{es}}/{dX_{es}} \quad \text{(Rise over Run)} \qquad 1$$

2.2.2 Calculating Channel Slope

The slope of a meandering channel can be measured directly using a leveling device, measuring tape, and equation 2 below:

$$\text{(Slope of meandering channel)} \quad S_{mc} = {dZ_{es}}/{L_{chan}} \quad \text{(Rise over Run of Channel)} \qquad 2$$

Alternately, channel slope can be calculated by multiplying the reciprocal of the channel's sinuosity by S_{max}. Sinuosity is the channel length divided by the straight-line distance from the EDU to the standpipe:

$$Sinuosity = {L_{chan}}/{dX_{es}} \quad \text{(Ratio of channel length to linear distance)} \qquad 3$$

$$S_{mc} = \left(\frac{1}{Sinuosity}\right)(S_{max}) = \left({dX_{es}}/{L_{chan}}\right)(S_{max}) \qquad 4$$

Reciprocal of Sinuosity times Maximum Slope Rise over Run of Channel times Maximum Slope

2.2.3 Slope Calculation and Adjustment Methods – Quick Setup

For quick setups, slope can be adjusted using these steps. This method requires the model be set up on a perfectly flat surface.

1. Use equation 1 to measure slope of a straight channel, given standpipe height dZ_{spipe}:

$$S_{max} = {dZ_{es}}/{dX_{es}}$$

To determine S_{mc} you can measure it directly. If you do not have a level, you can measure L_{chan} and calculate sinuosity and then S_{mc} using equation 4:

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$$S_{mc} = \left({dX_{es}}/{L_{chan}} \right) (S_{max})$$

For example: If S_{max} is 0.04, and $Sinuosity = {L_{chan}}/{dX_{es}}$ = 2.12, then

$$S_{mc} = (1 / 2.12) * 0.04 = 0.019$$

2. Alternatively, you may make up spreadsheets and charts that show S_{max} for given values of dZ_{es} or dZ_{spipe}. Figure 2.3 shows an example of such a chart. You will still need to measure L_{chan} in order to calculate the slope of meandering channels.

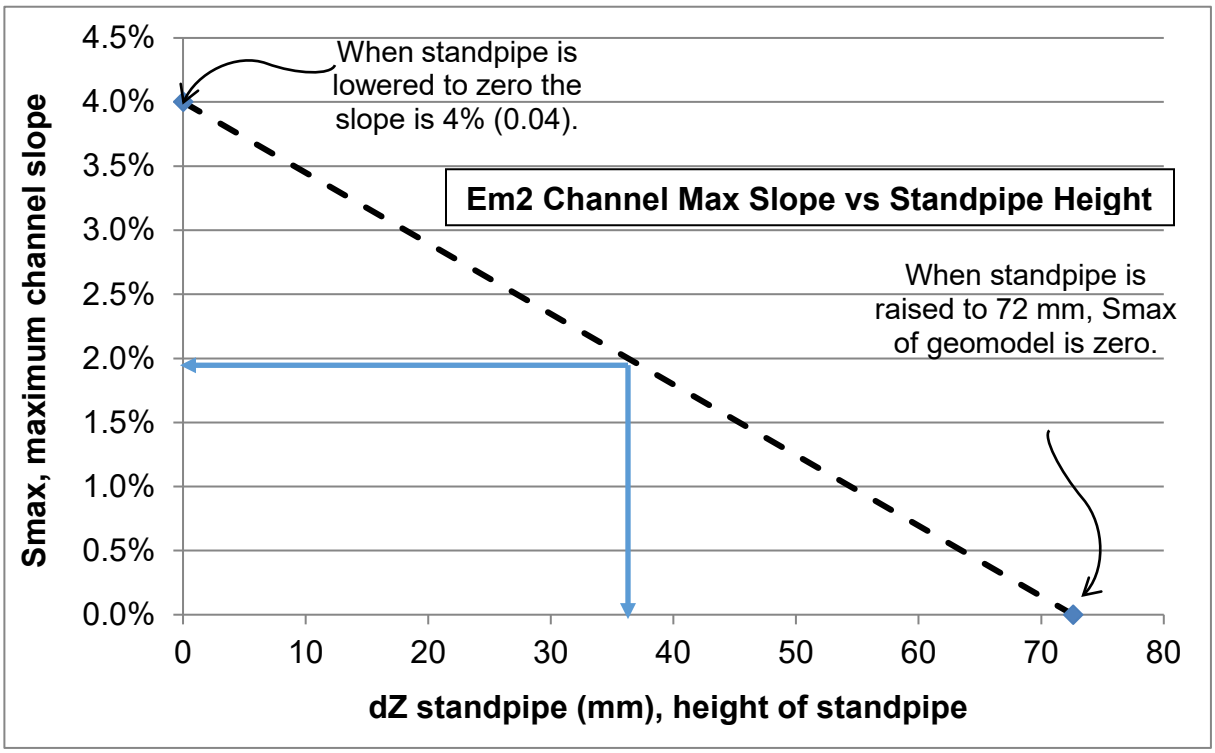

Figure 2.2 - A graph showing maximum channel slope (S_{max}) at a given standpipe height above the box bottom (dZ_{spipe}) and given known slope.

Figure 2.2 shows that

- Since the box slope of the Em2 geomodel is known to be about 0.04,
  - When dZ_{spipe} = 0 mm, it is possible for S_{max} = 0.04.
  - When dZ_{spipe} = 72 mm, then S_{max} = 0.
  - When the dZ_{spipe} maxes out at about 120 mm, S_{max} is under 0.

- At any given standpipe height (dZ_{spipe}), S_{max} can be found.

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- For example, when dZ_{spipe} = 37 mm, S_{max} = nearly 0.02.

Note that such charts can be constructed using the formulas above for various typical model setups.

Note that the chart in Figure 2.2 is an example that depends on the known slope of the Em2 with supports with a 2-inch height difference.

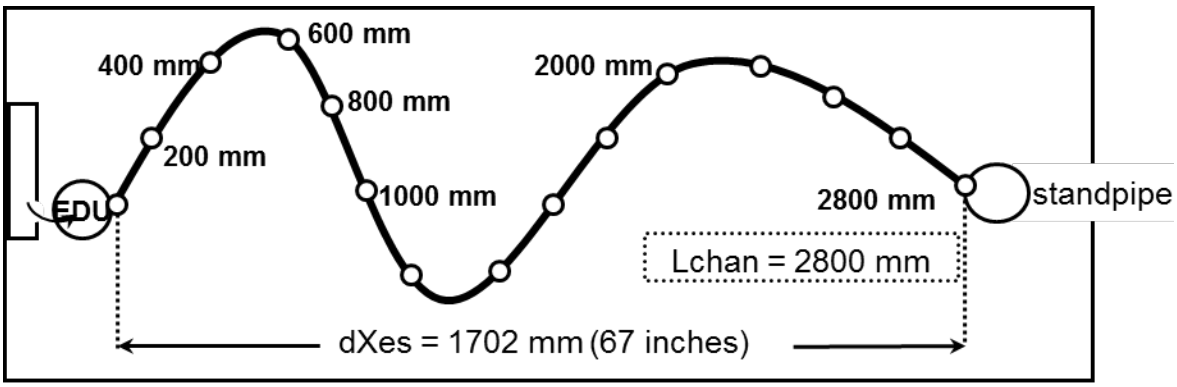

Figure 2.3 - A meandering channel in an Em2 model showing typical meander size and variables controlling sinuosity and slope. Round markers, which are 200 mm apart, represent channel length.

Figure 2.3 shows a typical meandering channel in an Emriver Em2 model. In this example we have:

L_{chan} = 2800 mm
dX_{es} = 1702 mm
Therefore, sinuosity = 2800 mm /1702 mm = 1.65

Box slope is thus:

$$S_{max_0} = {dZ_{es}}/{dXes}$$
$$= dZ_{es} \text{ (mm) /1702 mm}$$
$$= 72 \text{ mm /1702 mm}$$
$$= 0.042 \text{ or about } 4\%$$

Maximum channel slope with the dZ_{spipe} set at zero (S_{max_0}) is thus 0.042. Let's set the standpipe about 2 in. (51 mm) above the box floor and calculate S_{max}:

$$S_{max} = S_{max_0} - dZ_{spipe} \text{ (mm) / } dXes \text{ (mm)}$$
$$= S_{max_0} - (dZ_{spipe} \text{ (mm) / 1702 mm})$$
$$= 0.042 - (51 \text{ mm /1702 mm})$$
$$= 0.042 - 0.03$$
$$= 0.012, \text{ or } 1.2\%$$

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In this case, the slope of a straight channel from the EDU to the standpipe would be 0.012. Raising the standpipe 2 in. (51 mm) reduces S_{max} from 0.42 to 0.012.

Our meandering channel has a sinuosity of 1.65. We can determine its overall slope using equation 4:

$$S_{mc} = \left(dXes/_{L_{chan}}\right)(S_{max}) \text{ or}$$
$$S_{mc} = \left(\frac{1}{Sinuosity}\right)(S_{max})$$
$$= (1/1.65)\ 0.012$$
$$= 0.007, \text{ or } 0.7\%$$

2.3 Controlling Flow

A pump in the reservoir circulates water throughout the Emriver system. When the pump is first turned on, the water level in the reservoir will drop considerably before flow from the standpipe begins to replenish it. Interstitial spaces in the modeling media hold over 6.6 gal. (25 L) of water in an Em2, so water level will appear lower in the reservoir. If the standpipe is raised, several liters of water may accumulate in the lower end of the box before flow from the standpipe begins to refill the reservoir. Do not add more water to the reservoir, even if the water level appears diminished during demonstrations and exercises. Fill the reservoir with the amount of water outlined in the **Emriver Use and Care Manual** during initial setup and do not add or remove water during use.

Flow is controlled by the Emriver K28 Electronic Flow Controller or the Emriver K500 Digital Flow Controller. Assembly and use of flow controllers are covered in the **Emriver Use and Care Manual.**

2.3.1 Using the Emriver K28 Electronic Flow Controller

To initialize flow and send the pump's full output to the box, turn the dial on the electronic flow controller several turns clockwise until flow no longer increases. From this setting, incrementally turn the dial counterclockwise to reduce flow rate. To completely shut off flow without turning off the pump, turn the dial on the controller counterclockwise until flow stops.

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2.3.2 Flow Measurement

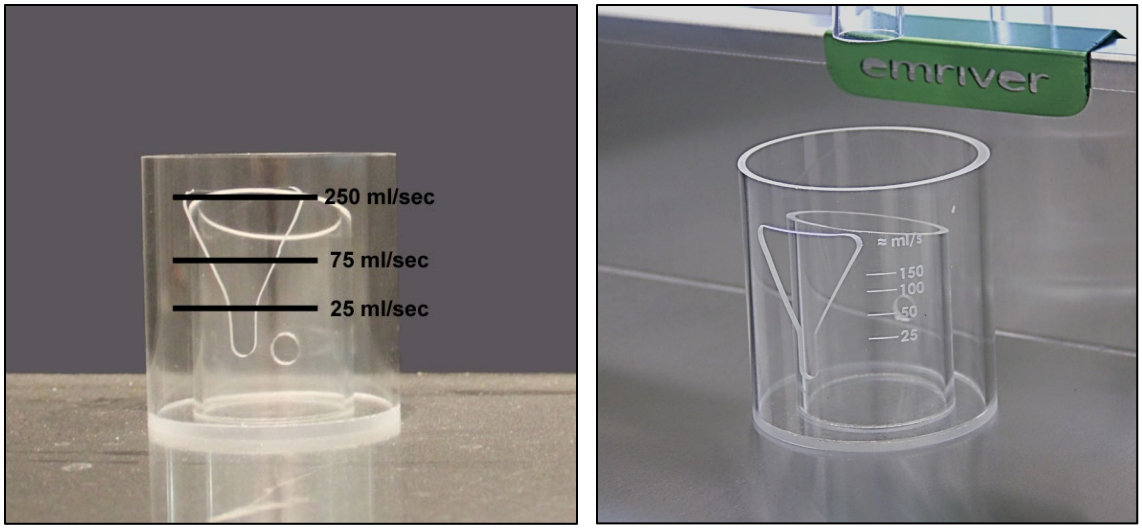
Discharge can be measured using a stopwatch and calibrated volumetric containers (available for purchase from Emriver, Inc as part of the Academic Kit). Simple measuring cups or more precise graduated beakers and graduated cylinders may be used for this purpose.

2.3.3 Discharge Ranges

When you are not measuring discharge as described above, you can estimate discharge by looking at the output from the Energy Dissipater Unit and activity in the box. However, estimating discharge in this manner depends on running the system at full capacity for a few seconds to remove air bubbles from the tubing. If you do not do this, flow rates can be altered.

The range of practical discharges in the model runs from about 25 ml/sec to 250 ml/sec.

- At very low discharges, much of the flow is moving through interstitial spaces in the model and not much will happen in the channel. When flow is slightly above a trickle, discharge is approximately 25 ml/sec.
- At flows above 75 ml/sec, channel beds begin to fully mobilize. This depends, of course, on channel morphology and slopes existing when the flow is increased.



- When water is nearly overflowing out of the mouth of the Em2's EDU, flow is approximately 250 ml/sec.

Figure 2.4 - A view of the Energy Dissipater Unit (EDU) in the Emriver Em2. Various output levels are marked as they correspond to flow rate. Newer-model EDU's (right) are engraved with an approximate flow-rate scale.

When energy is controlled using grade control structures or other means in the model, the highest flows possible with the standard pump, around 350 ml/sec, can be used. Unless such structures are present in the model, flows above about 150 ml/sec will

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create large channels with high sediment transport rates and you will be very busy moving sediment from the trap in the reservoir back into the box.

2.3.4 Creating Hydrographs

It's a simple matter to create hydrographs in the model. First, determine the range of flows and shape of your hydrograph. Set up a table with flow rates and times to maintain each rate. Creating the hydrograph will require at least two people, one to keep time and another to monitor and adjust flow rates using the flow controller.

Using a number of one or two liter containers (large plastic cups will work), it is also possible to measure both the water and sediment discharge at the lower end of the model. Simply catch the model's output in the containers over suitable time periods, recording the time period for each container. Then separate the water and sediment and measure both. Depending on your goals, you may want to dry the sediment before weighing. The sediment absorbs very little water.

In this manner students can produce both hydrographs and sedigraphs from the model. See Chapter 3 for more information.

2.4 Initial Conditions

At a given cross-section in an Emriver model's channel, sediment transport and channel morphology are dependent on the sediment and water regime imposed from upstream.

For many demonstrations, you will want sediment transport and channel morphology to be in an equilibrium condition – i.e., sediment transport will be relatively constant over most of the channel's length. When the model is in this state, perturbations to the channel will show fairly predictable responses. An excavation in the channel mimicking an inchannel mining operation, for example, will produce an upstream-migration headcut.

If the experimental channel is not in equilibrium, however, the channel's trend toward equilibrium will be imposed on your perturbation, and you may not see the response you expect. In general, demonstrations require that you form a channel and allow flow to produce equilibrium long profile and cross sectional conditions. For the most realistic channels, you should send a flood hydrograph through the system to form point bars and floodplains. Methods for flood hydrograph are discussed below.

If you purchased the K500 Digital Flow Controller, you can run a preset hydrograph. For further instructions about preset hydrographs and other use and care guidelines, see the K500 Digital Flow Controller Instructions for Use.

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After returning to lower flows you can visually examine sediment transport rates in the model. When these rates appear to be relatively even throughout the channel's long profile, you may assume continuity of sediment transport in the channel.
When this condition is reached, you may expect relatively predictable responses to channel perturbations.

2.4.1 Floods and Feature Formation

To form a classic meandering channel with a full complement of fluvial features, you may use the following steps:

1. Set box slope and standpipe slope. Send flow into the box to fill the groundwater table at whatever rate you like.

2. Form a meandering channel with at least a full meander wavelength within the box. Figure 2.3 shows an example.

3. Begin with moderate flows of 25 to 55 ml/sec and allow for groundwater table development and sediment transport continuity.

4. Increase flows to about 100 - 150 ml/sec for a short time. This higher flow will fully mobilize bed materials and you will see formation of point bars and small floodplain surfaces. Usually only 20 seconds or so of high flows will be sufficient.

5. Decrease flow to 55 ml/sec or less. As you decrease flow, sediment transport will decrease and you will be left with a compliment of features that includes point bars, floodplain surfaces, cutbanks, pools and riffles.

2.4.2 Valley Shape

For demonstrations of basic channel processes such as response to channelization and gravel mining, you will want to begin with typical natural channel morphology (if indeed there is such a thing). Sediment transport should be in equilibrium along most of the long profile (i.e., sediment transport continuity is present throughout the channel). This condition can be achieved by simply making a proto-channel by hand and then routing flows through the model until you can see that there are no reaches with net erosion or deposition.

In general, a shallow U-shaped valley, shown in Figure 2.5, will produce realistic features as the channel migrates through the model's sediment. As meander bends enlarge, cutbank heights will increase, and various cutbank and bluff heights will show how these features look and behave in nature.

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You may form a U-shaped valley using the triangular scraper and poly float included with the Emriver model. Dig a thin, straight line through the sediment in the box, beginning at the headwaters and moving down to the standpipe. Once flow is turned on and water has saturated the interstitial spaces in the model, a U-shaped channel should form from water flowing through the proto-stream at intervals of low and high flow.

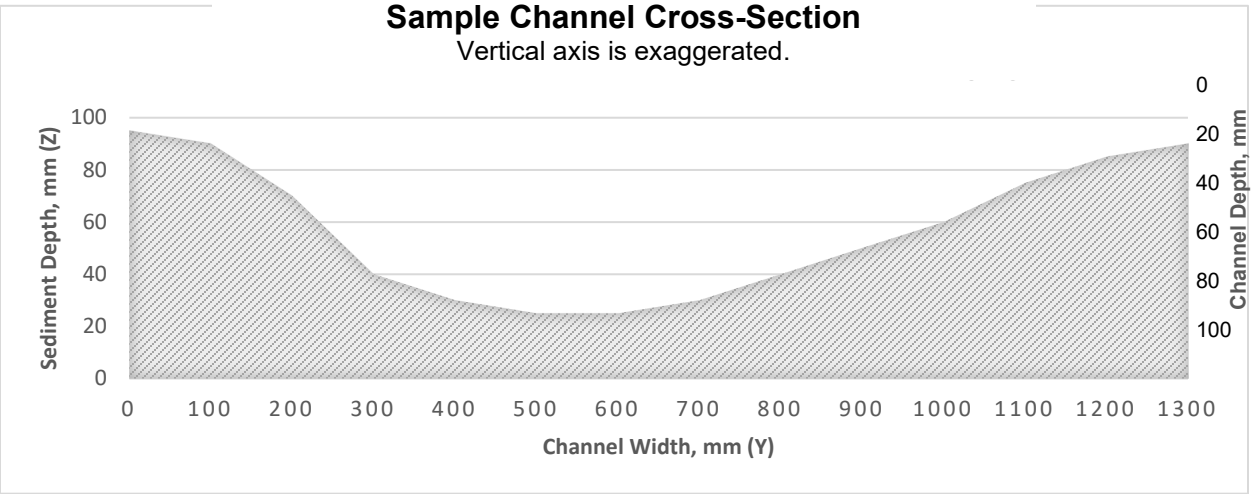

Figure 2.5 - Cross-sectional profile of a typical “valley” morphology formed at the beginning of a demonstration. As meanders in the channel migrate, they will tend to erode away the valley sides, producing steep bluffs. This is only an example. You should experiment with other shapes.

2.5 Sediment Properties

The modeling material used in the Emriver is ground thermoset plastic. Most of the material is the same dense, hard plastic from which countertops are made. Such thermoset plastic is difficult to recycle because it cannot be melted and remolded. The material we use is mostly recycled from industrial materials (it is not consumer-generated).

The material’s specific gravity ranges from 1.4 to 1.6. By contrast, most rock-derived sediments in natural rivers have specific gravity values above 2.6.

Because the plastic sediment is less dense than rock, it moves more readily in the relatively low flows and velocities seen in the Emriver model. The material is highly angular, which allows it to hold shear faces and cutbanks that closely resemble those seen in the field.

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Only bedload transport is modeled in the Emriver; there are no sediment particles fine enough to be considered suspended sediment.

2.5.1 Modeling Media Sizes and Colors

The Emriver Em2 and Em3 geomodels come with non-color-coded ("Alpha") media. The Em2 uses 150 pounds and the Em3 240 pounds. The non-color-coded media is primarily white-based and has other colors speckled throughout the media. You may notice some relationships between size and color in this media, but these are strictly coincidental.

Sediment sizes of the non-color-coded media in the model range from 0.7 to 2.0 mm (0.028 to 0.080 in). Particle size distribution is weighted toward the larger particle sizes in the model.

Color-coded-by-size ("Carbondale" or "Memphis") modeling media is available for purchase from Emriver, Inc. The four colors in this modeling media represent specific particle sizes. Particle sizes of Carbondale mix are:

- Red: 0.4 mm
- Brown/black: 0.7 mm
- White: 1.0 mm
- Yellow: 1.4 mm

Memphis mix is finer than Carbondale.

2.5.2 Groundwater Behavior

Water moves freely through the interstitial spaces in the modeling media. If you use the media to build a dam from the material, for example, you will see seeps forming at the downstream base of the dam. You may also notice seeps forming on the downstream sides of valley walls in some situations.

You will notice that some groundwater movement processes in the model resemble those found in nature. However, the relatively rapid movement of groundwater through the modeling media is, at least for most geological settings, not necessarily representative of field processes.

After you initiate flow in the model, it takes a few minutes for dry sediment in the model to saturate (or for the groundwater table to rise to streambed level) before you can get normal channel flows through the length of the model. Until then, you will observe a "losing" stream.

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For a typical setup, over 35 liters (9.25 gal) of water will remain in the Emriver's modeling media as groundwater after you turn off flow and discharge at the standpipe slows to a trickle. This water can take several hours to drain from the media.

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Emriver Lab Manual

Chapter 3

3 Measurements

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This manual is a companion to the ***Use and Care Manual***, and essential information in that manual is not repeated here. *It is vital that you read and understand the* ***Use and Care Manual*** *before using this Lab Manual.*

In this chapter

3.1 Thalweg and Other Horizontal Measurements

3.2 Vertical Measurements and Laser Levels

3.3 Water Discharge

3.4 Sediment Discharge

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3.1 Thalweg and Other Horizontal Measurements

Measurements of channel length are used in river research and management for many purposes, including hydraulic modeling and characterization of sinuosity. To determine channel slope, for example, we must begin by measuring a horizontal distance along a river channel.

In general, channel distance is measured along the deepest part of a channel (called the thalweg), though other paths can be used, including the centerline of bankfull or other characteristic discharge. Here we will use the deepest part of the channel.

Your Emriver model comes with a measuring tape. To measure channel length, lay the tape in the center of your channel, following its curves as closely as possible. It is usually necessary to turn off flow in the model to do this. The tape disrupts flow and will cause channel changes in your model. The tape will closely follow curves if you lay it on the narrow edge as shown in Figure 3.1.

Figure 3.1 - The Emriver measuring tape will follow channel curves when placed on its narrow edge as shown here.

Always measure from a fixed point in the model. The standpipe makes a good reference point.

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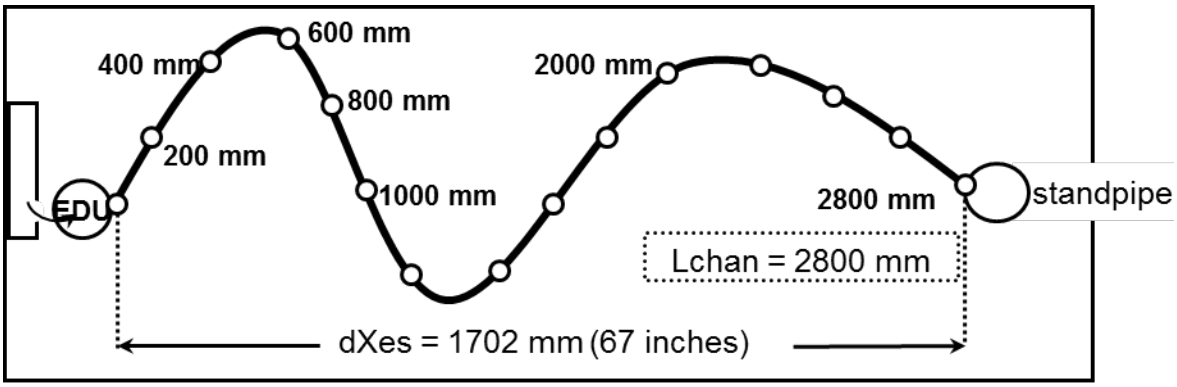

Figure 3.2 - A meandering channel formed in the Emriver Em2 geomodel. The channel is marked in 200 mm increments. Lchan and dXes, two variables used in calculating slope and sinuosity, are shown. See Chapter 2 for a detailed discussion of slope calculations.

3.2 Vertical Measurements and Laser Levels

The crossbeam level rod, part of the Emriver Academic Kit, is used to measure vertical distance from a reference laser beam to various points in the model. The rod is used exactly as a surveyor's level rod, but on a smaller scale.

A small rotating laser with a visible beam works very well. Many surveying levels use an invisible beam and a receiver. These are poorly suited for use with this model because the receiver is too large to use with the Emriver small leveling rod. The rod is red because it allows the red-orange beam of a laser level to be visible in sunlight.

The bracket and beam are not meant as reference points – the gunwales (top rims) of the model are neither level nor straight enough to use as straight edges.

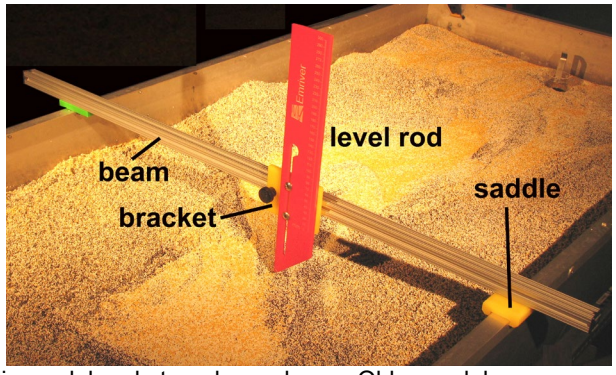

Figure 3.3 - The Emriver leveling rod, bracket, and crossbeam. Older models may use a slightly different design.

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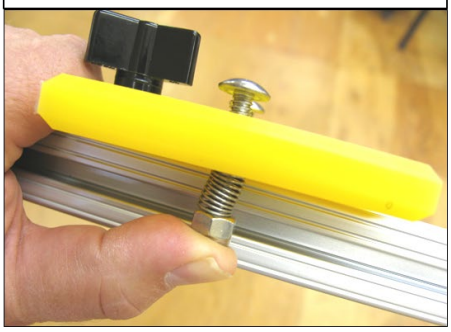
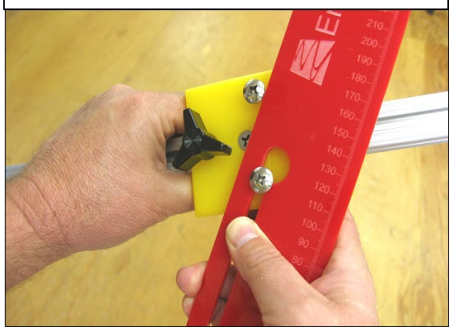
The crossbeam should be near level, but is not reliable as a reference line. The crossbeam slides longitudinally on the box gunwales while the rod bracket moves side-to-side on the crossbeam, allowing measurement of most of the surface area inside the Emriver box. The level rod slides vertically on the rod bracket to allow careful positioning of its tip against the surface to be measured. The level rod is easily removed from the rod bracket for accessing other points. Figure 3.4 demonstrates how to assemble the rod and bracket.

To survey points within the model, set up your laser so that the beam is about 10 cm above the box gunwales. Verify that you can find the beam at all points in the box – at the corners and at the lowest and highest points you'll want to survey. Once you've done this, you can measure relative elevations of features throughout the box.

1. With your left thumb, depress the spring on the lower bolt.



2. Insert the bolt head through the opening at the top of the level rod.



3. Fit the same opening over the head of the top bolt and release the spring.

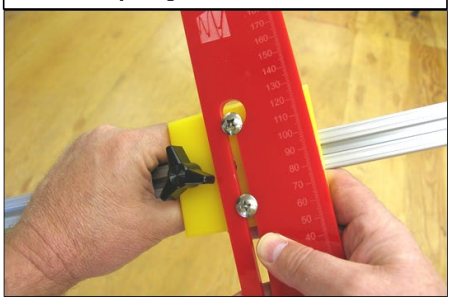


Figure 3.4 - Assembly of the level rod, bracket and crossbeam (available for purchase from Emriver, Inc).

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Figure 3.5 shows basic leveling setup. Emriver models make excellent teaching tools for field methods, especially when used with a rotating laser, because the surveying methods are essentially the same as those used in the field.

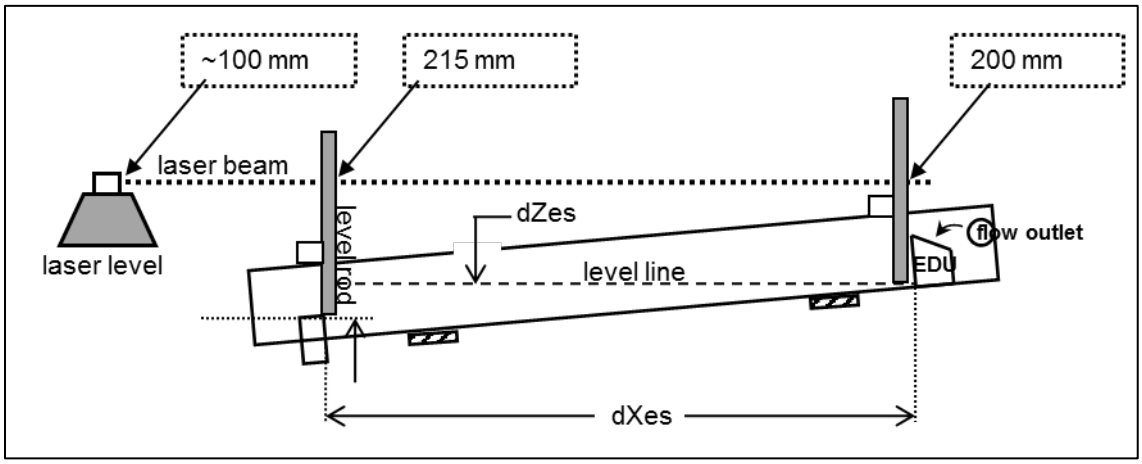

Figure 3.5 - Schematic showing basic leveling. Here a rotating level is set up and leveled so its beam is about 100 mm above the Emriver box. The level rod is depicted as a grey line at two different positions. Readings on the level rod show that dZes is 15 mm. If dXes is 1,320 mm, then slope for a straight channel between the two points would be 15 mm/1,320 mm = 0.011. The level reference line is drawn for clarification only.

Channel long profiles may be surveyed using the measuring tape and a laser level. Using the level rod, measure bed elevation at the thalweg (the deepest channel point) along the entire length of the channel. Be sure to also get elevations for the standpipe lip and any points where the box bottom is exposed by scour. Plot these data as shown in Figure 3.6. Some advanced exercises involve before and after long profiles in which you can see the effects of channel manipulations.

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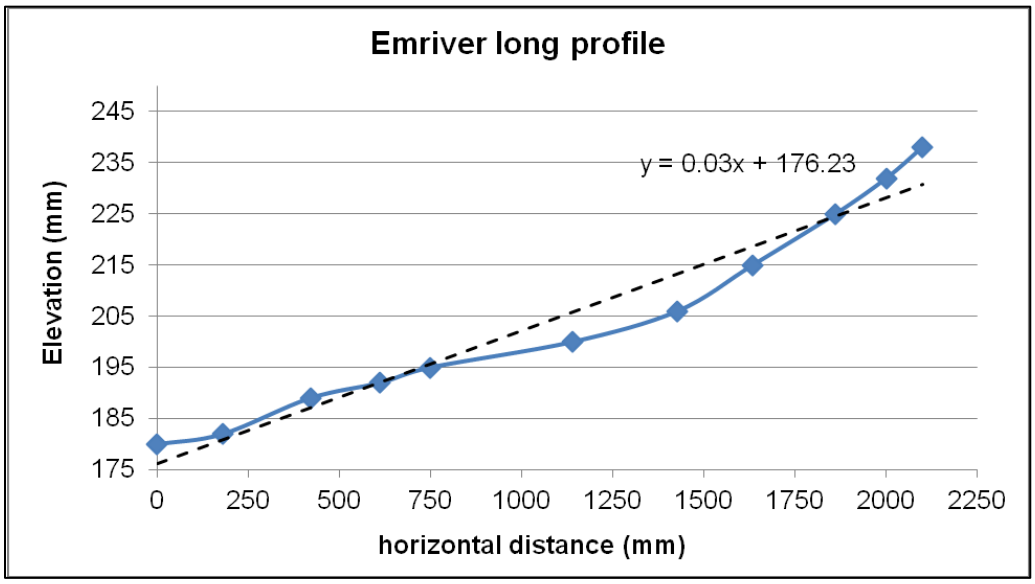

Figure 3.6 - Example of a long profile in a meandering channel in an Emriver model.

3.3 Water Discharge

Input of water through the model can be measured using a graduated cylinder and a stopwatch. Given the modeling media properties and Emriver Em2 box size, the usable range of discharge flows starts from about 25 ml/sec to 250 ml/sec.

Discharge from the standpipe can be measured using multiple timed captures. A stopwatch and graduated cylinder are required. You'll need at least two capture containers, two watches, and two people to capture discharge. To capture all discharge, you'll need to alternately switch containers without losing any flow as they become nearly full.

You may use fine screens to filter the sediment from captured flow before measuring its volume.

3.4 Sediment Discharge

By using a number of one- or two-liter containers it is also possible to measure both the water and sediment discharge at the lower end of the model. Simply catch the model's output in the containers over suitable time periods, recording the time period for each container. Then, separate the water and sediment and measure both. Depending on your goals, you may want to dry the sediment before weighing. The individual sediment

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particles absorb very little water. You can dry the sediment in an oven. The modeling media should only be oven-dried **until constant weight**. Recommended maximum oven temperature is **100°C** (212°F).

As an alternative to oven-drying the media to constant weight, it is possible to determine bedload discharge per collected volume of water. This method should work for simple exercises and classroom experiments, and the required calculations (and examination of assumptions) would provide a good learning experience.

- First, collect the sediment and water output at the model's standpipe within a given time period.
- Next, pour the collected sediment-water mixture into a large graduated cylinder and note the volume of each.
- Then, determine the volume of dry sediment collected in your wet sample. The pore volume of the wet sediment is approximately 50%. Based on this, you can calculate material volume of dry sediment.
- Mass of the sediment collected can now also be determined. The bulk density of the dry Emriver sediment is 0.75 g/cc. Based on this, you can convert volume to weight of modeling media and use this to calculate bedload transport.

Here is an example calculation:

- You collect a total of 100 ml of sediment-water mixture from the output at the standpipe.
- You then measure that 20 ml of the mixture is wet sediment.
- Based on 50% pore volume (50% x 20ml), you can calculate that 10 ml of dry model sediment were collected in the 100 ml sediment-water mixture.
- Since the bulk density of dry Emriver sediment is 0.75 g/cc (or 0.75 g/ml), you can also calculate (0.75 g/ml x 10 ml = 7.5 g) that 7.5 g were collected per the 100 ml sediment-water mixture. Therefore, the bedload transport rate is 0.075 g/ml.

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Chapter 4

4 Demonstrations

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In this chapter

4.1 In-channel Gravel Mining

4.2 Sediment Transport Measurement, Continuity, and Channel Stability

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4.1 In-channel Gravel Mining

Although outlawed or heavily regulated in many parts of the world, mining of sand and gravel from stream channels is common in some regions. The Emriver model is particularly useful for demonstrating the effects of gravel removal from channels, especially the offsite impacts that are usually unknown to laypeople. These include channel downcutting (also called incision) upstream and downstream of the site, increased lateral migration, and bank erosion upstream of the mined area.

Setup for gravel mining demonstration

(Maximum slope) **Smax**	variable, about 0.020 (2%)
(Slope of meandering channel) **S**	approx. 0.015
Planform	gentle meanders, at least a full meander wavelength, sinuosity about 1.3; alternatively, a straight channel
(flow) **Q**	35 - 55 ml/sec
Initial conditions	consistent sediment transport continuity, meanders with point bars and well-formed channel features; high banks will show erosion processes more strongly

Begin with a standard meandering channel with a sinuosity of about 1.3. Alternately, you can begin with a straight channel. In either case, route flow pulses of about 150 ml/sec through the model for at least 15 seconds to form channel features. In the straight channel, you should allow alternate point bars to form. Adjust flow discharge (Q) to 35 - 55 ml/sec. After decreasing the flow, make sure that the channel is metastable and sediment transport continuity is consistent throughout the channel.

You may want to mark the water surface elevation upstream of your mining site to better visualize the incision that usually takes place. If you purchased the Academic Kit from Emriver, Inc, you may use the leveling rod to do this. By setting the rod tip just at the water surface elevation, you can observe and measure upstream incision. Without a reference point like this, most people will tend to underestimate the degree of incision that occurs. Use a sieve, perforated scoop, or your bare hand to remove sediment from the center of the channel. Remove about 250 ml of material (about one cup).

You should observe several processes, which are shown in Figures 4.1 and 4.2 below.

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- Sediment continuity is completely disrupted as the mined area becomes a sink for bedload. Note that little or no bedload moves through the mined area.

- The increased bed slope at the mined area will encourage increased sediment transport, causing a headcut to form and migrate upstream.

- The banks and bed of the channel upstream of the mined area will erode. This part of the channel will show a net export of sediment. You will usually see relatively high bedload transport rates in this reach compared to the reaches farther upstream. This increase in transport rate is balanced by erosion of the banks and beds. You can thus visually observe the downstream changes in sediment transport rates that show the discontinuity. In a sense, you can say that gravel is being mined from reaches upstream of the actual removal area.

- As headcutting occurs, you may see sharp edges (or “scarps”) form in the bed, usually in gravel bars. We see these features in the field, and they can be strong indicators of rapid incision.

- One or more dunes will form in the mined area, with downstream slipfaces. The slipfaces will migrate downstream as the hole is filled. As shown in Figure 4.2, the channel will tend to restore the original bed grade as it seeks sediment transport continuity.

- The downstream end of the mined area will erode as sediment is removed by the channel to regain sediment transport continuity. At real-world mines, we often see downstream riffles destroyed in just this manner.

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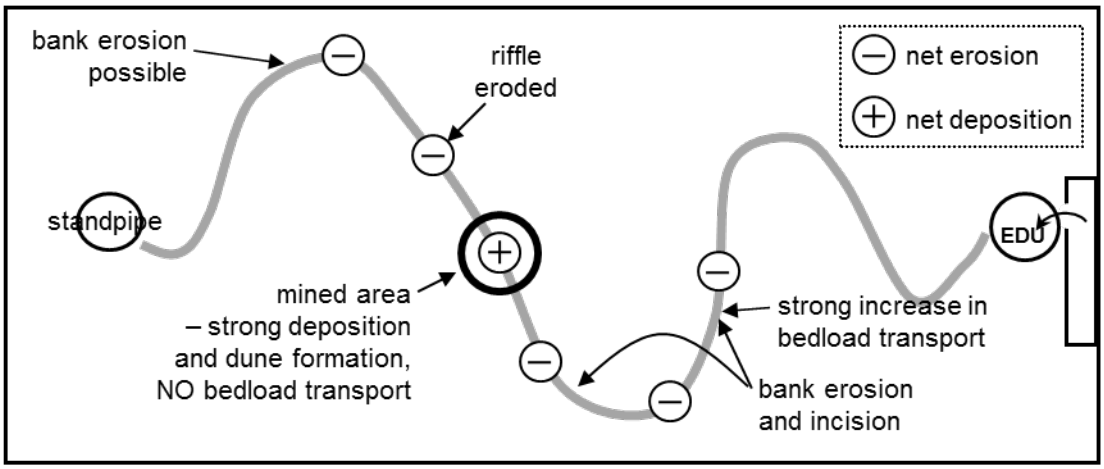

Figure 4.1 - Expected response to removal of bed material in an inchannel mining simulation. Usually, you can see a very strong increase in bedload transport rates upstream of the mined area. This net increase in transport is balanced by erosion of the channel's bank and beds.

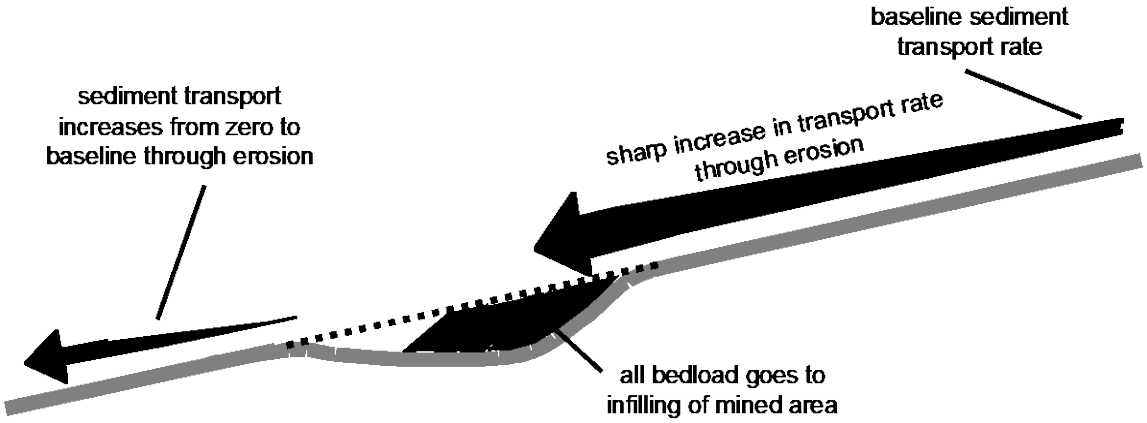

Figure 4.2 - Schematic showing an Emriver long profile after bed material has been mined. Width of the arrows corresponds to sediment transport rates, which (usually) are clearly observable in the model. Note how the original grade and sediment transport rate tend to be restored by deposition as the channel seeks continuity in sediment transport.

You may remove sediment from the mining site again to show the effects of repeated removals from a given area, as is often the case with real-world operations. You will usually see the processes shown in Figures 4.1 and 4.2 continue, with bank erosion and incision worsening.

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If you begin with relatively high banks on the outside bends, you will see dramatic bank slumping in the incising bends. This effect tends to make a strong impression on observers, and also illustrates geotechnical processes – the banks slump not only from toe scour, but also from increased bank height caused by the incision.

4.2 Sediment Transport Measurement, Continuity, and Channel Stability

River morphology is a product of both water and sediment flows. This experiment centers on sediment transport processes and their measurement.

Much interest in river systems focuses on stability. Most people consider a river stable if its morphology and position in space do not change over time. This is a logical assumption, but it is an unrealistic condition. Instead, alluvial rivers are products of the sediment and water they transport, and almost always change over time. Sediment is eroded from the channel bed and banks, and unless the channel's cross-section changes, it is deposited as well. If erosion and deposition in a reach are equal, then we can say that the reach is stable at least by one definition. In other words, if the sediment entering a reach equals the sediment leaving, the reach is stable. The channel may still migrate across its floodplain, but it is, in a geomorphological sense, stable.

You can observe these processes in the Emriver model. Sediment in the model moves as bedload, bouncing off the bottom of the channel. There are no particles in the model fine enough to move as suspended load. We can observe this movement and visually compare the sediment transport rate in one reach to that in another. It is possible to measure the transport rate only by capturing sediment leaving the standpipe. This problem demonstrates real-world difficulties in measuring bedload transport.

In this exercise, you will build on the procedures given for the inchannel gravel mining demonstration above.

Steps

1. Set up the model using the initial conditions and instructions given for the gravel mining demonstration. Form a meandering channel and use a flood pulse to form small floodplain surfaces (bar tops). Then reduce flow to about 55 ml/sec to establish an equilibrium channel.

2. Once you have established an equilibrium channel (in which sediment transport appears to be about the same throughout your experimental channel), record the discharge value. Then measure the sediment discharge rate from the standpipe. For this exercise, you may use either the drained weight of sediment or a volumetric measurement. The latter will be easier.

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3. Next, turn off the water flow. With the flow turned off, survey the channel long profile. Use a spreadsheet program or graph paper to plot the long profile. Leave your measuring tape in place – you will be using it again to resurvey part of the channel.

   Option: In addition to the thalweg survey, record the elevations of bank heights and bar tops. Plot these as well, using different data groups for the thalweg, banks, and bar tops.

4. Calculate channel slope and sinuosity.

   Option: Photograph the channel, using a camera mounted on a tripod or other fixture that will allow you to take photos from exactly the same vantage point later in the experiment.

5. Remove sediment from the channel using the guidelines for the inchannel gravel mining demonstration. Record the volume of the sediment to within at least 10% of the total using a graduated cylinder or beaker.

   Option: Take a photograph (as part of your series) of the channel to show the excavation.

6. Resurvey the section of the channel from which you removed the sediment. Plot this on your previous long profile plot.

7. Study the expected responses to the excavation. These are given above. You will have to quickly observe these processes as flow is restored. Video clips demonstrating these responses in an Emriver model can be seen on the River Geomorphology DVD included with this manual.

8. Restore water flow, carefully increasing flow so that groundwater is restored (if it was depleted during your surveying). Then, reestablish the water discharge value recorded in Step 2.

9. As flow is restored, carefully observe sediment transport processes. You should observe most or all of the processes shown in Figures 4.1 and 4.2.

   Record your observations, comparing them to the expected responses given above.

   Run the model at this flow until it appears that sediment transport continuity has been restored throughout the experimental channel.

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Option: As soon as sediment is exported from the standpipe, begin to sample sediment discharge and continue until the channel again reaches equilibrium. Plot these values against time, also noting changes in the excavated area so you can correlate these with sediment transport rates at the standpipe.

10. Shut off water flow. Again survey the long profile, plotting it against the other two. Calculate channel slope and sinuosity.

    Option: If you surveyed bar tops and banks, resurvey these as well. Take another photo.

Questions

1. Did you observe the expected responses to the excavation? In particular, how was sediment continuity affected throughout your experimental channel?

2. Defenders of inchannel gravel mining (now illegal or highly regulated in most of the United States) often say these mines remove only a very small portion of the total bedload.

   - In your experiment, how would this argument hold up? How does the amount of sediment you “mined” compare to the transport rate you measured?
   - Is the mined volume a very small fraction of the transport rate?
   - How do you reconcile the responses you saw with the transport rate and the volume (or weight) of “mined” sediment?
   - Could you recommend a volume rate of sediment “mining” that would cause no change in channel morphology?

3. If you saw changes in the long profile plots, how do you explain them? If you plotted bar top and bank elevations, compare thalweg elevations to corresponding bar and bank elevations. Can you see evidence of incision?

4. Based on all your measurements and observations, can you make a schematic sketch of your experimental channel showing areas of net sediment deposition and erosion during your run?

   Considering the base or equilibrium transport rate (which you measured in Step 2), and your long profile plots, how much sediment do you think was eroded from the reach upstream of the mine? This will be an estimate, but will give an idea of the magnitude of disruption in sediment transport continuity. If this were a real world situation, it might tell you how much gravel a mine owner got from his upstream neighbor’s stream channel.

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Emriver Lab Manual

Chapter 5

5 Exercises and Experiments

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In this chapter

5.1 Channelization
5.1.1 Straightening
5.1.1.2 Advanced Channel Straightening Exercise
5.1.2 Widening

5.2 Bank Armoring
5.2.1 Soft Armor
5.2.2 Hard Armor
5.2.3 Setup for Bank Armoring Demonstrations

5.3 Modeling Riprap

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5.1 Channelization

"Channelization" is commonly used as a catch-all term for channel modification. Channels may be both realigned and enlarged through channelization. Often channelization means removal of a meander bend. Other projects simply enlarge the channel in attempts, often misguided and unsuccessful, to increase flood flow conveyance through the reach. Channel enlargement almost always fails, or at least requires frequent maintenance through sediment removal when channels carry significant coarse sediment loads.

The Emriver model is particularly useful for showing the processes that result in the failure of both channel relocation and enlargement projects.

5.1.1 Straightening

In the United States, thousands of miles of river channels have been straightened in attempts to control flooding, increase farmland drainage, and realign channels that conflicted with bridges and other built structures. Often sediment transport processes are not considered in these projects, which is one reason they often fail or cause serious offsite impacts.

In the Emriver model, we can straighten a stable meandering channel to observe typical processes that occur in real-world rivers after straightening.

Setup for channel straightening demonstration. Also see Figure 5.1 below.

(Maximum slope) **Smax**	variable, about 0.020 (2%)
(Slope of meandering channel) **S**	approx. 0.015
Planform	gentle meanders, at least a full meander wavelength, sinuosity about 1.3; alternatively, a straight channel
(flow) **Q**	45 – 60 ml/sec
Initial conditions	well-established sediment transport continuity, meanders with point bars and well-formed channel features

As before, begin with a meandering metastable channel. Visually check sediment transport continuity. Discharge should be set at about 45 - 60 ml/sec.

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Pick a meander bend in the middle of the model. You will want to observe channelization impacts both upstream and downstream of your straightening. Figure 5.1 shows a typical setup. Use the level rod and bracket (optional accessory, part of the Emriver Academic Kit) to mark the water surface elevation upstream of the channelization site. Place the rod tip just at the water surface and leave it there throughout your demonstration.

Note the difference in streambed elevation above and below your proposed channelization site (points H and J, Figure 5.1). You may also want to note or measure the thalweg distance between these two points. These two values give you the channel slope.

Next, use a scoop to excavate the new channel. Put this material in the old channel as shown in Figure 5.1-C.

As shown in Figure 5.1, the straightened channel will show the same elevation drop, but over a shorter distance. The new channel will thus have a steeper slope, sometimes twice the slope. This change in slope will produce a “step” in the long profile (as illustrated in Figure 5.1-B). This steeper section is out of equilibrium with sediment transport processes up and downstream, and is thus unsustainable. The increase in slope will result in higher flow velocities (which is often the rationale for straightening – to increase flood flow conveyance) and erosion in the channelized reach. The long profile tends to adjust to achieve sediment transport continuity by eroding upstream and depositing sediment downstream of the straightened reach.

In summary, you will usually see:

- Velocity within your channelized reach will be higher than in adjacent reaches, because the channel is usually narrower, and because it has been made much steeper by the straightening.

- Sediment transport rates will be high within the reach, making it a net exporter of sediment.

- A headcut will form within the reach and will usually migrate some distance upstream. As the headcut moves upstream, sediment will be sent downstream and you will see bank failures as banks are undermined.

- Downstream reaches are flooded with sediment. The channel will gradually reclaim sediment transport continuity by forming the long profile shape shown in Figure 5.1-D. In general, the downstream reach is graded and the upstream reach is incised. You will usually see very high sediment export rates at the standpipe during this demonstration.

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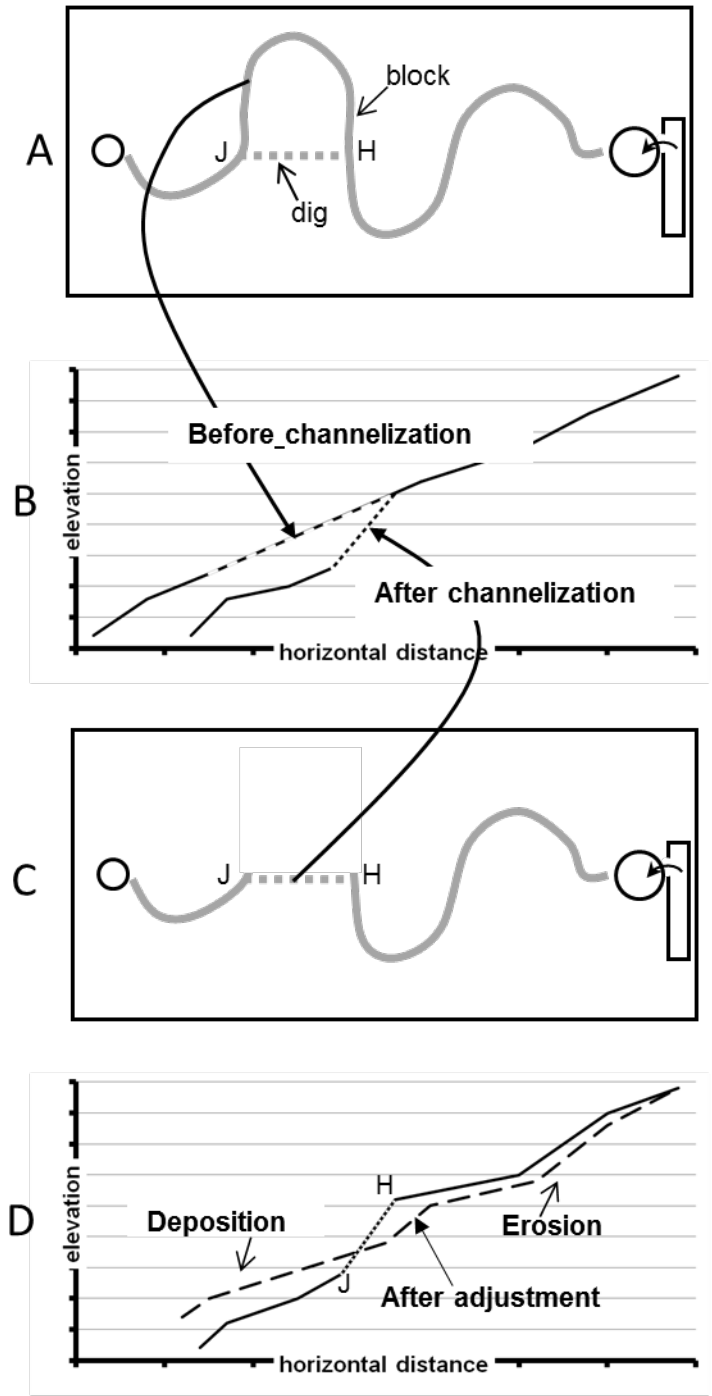

A. Form a meandering channel with a channelization site well away from either end of the model. Note the difference in elevation between the points H and J. Dig the straight channel as shown and block the old channel.

B and C. The new channel drops the same distance between H and J, but is much shorter, and therefore steeper. An unsustainable "step" is formed in the channel's long profile. The unaltered channel is depicted as a solid line.

You will usually see increased current velocity and sediment transport in the straight reach, and a headcut will move upstream.

D. As adjustment continues, the channel attains sediment transport continuity by eroding upstream reaches and depositing sediment downstream. Notice the "step" has been eliminated.

Figure 5.1 - Channelization by replacement of a meander bend with a straight section, and expected effects and adjustments in an Emriver channel.

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5.1.1.2 Advanced Channel Straightening Exercise

Using the crossbeam level rod available for purchase in the Academic Kit from Emriver, Inc, and a laser level, you can do three surveys (before, during, and after channelization) to show how the long profile changes when rivers are straightened. The essential steps are:

1. Establish a stable, meandering channel as discussed previously.
2. Turn off flow and survey the long profile. This is your “before” condition.
3. Straighten the channel.
4. Resurvey the long profile, taking care to note the new and old channel profiles as shown in Figure 5.1. This is the “during” or as-built condition.
5. Reestablish flow and allow the channel to adjust.
6. Turn off flow and resurvey. This is your “after” survey. Your results should look roughly like the schematic in Figure 5.1, though many variations are possible. You may see upstream incision without downstream deposition, for example.

5.1.2 Widening

Channelization through cross-sectional enlargement, usually widening, is commonly done to increase hydraulic conveyance. It may also be used in attempts (which are almost always unsuccessful) to stabilize channels. In urban areas or around bridges, widened channels may be lined with concrete or riprap.

Widening causes abrupt changes in process continuity. Flow entering the enlarged cross section invariably slows, and sediment is deposited. The widened reach becomes a sediment sink and usually begins to regain its former dimensions. This, of course, will negate any project benefits. If widening disrupts a stable, tree-lined reach, the resulting reach, after filling with sediment, may be much less stable than before.

We can also see a less stable channel after the deposition process because well-consolidated bank sediments, which may have contained cohesive materials like clay and silt, are often replaced with sands and gravels that are much less resistant to fluvial erosion and not as easily colonized by woody plants.

The disruption in sediment continuity and “hungry water” effect may cause net erosion of bed and banks in downstream reaches after channel widening.

Channel widening involves many of the same processes and responses as inchannel mining, and the demonstration is thus very similar. Given similar initial conditions, you may see less dramatic effects with widening. As with the gravel mining demonstration, negative impacts on the channel come largely from disruption in sediment transport continuity.

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As with inchannel mining, the channel cross-sectional area is greatly increased. The response can be complex, but in the simplest terms, the widened reach will show decreased sediment transport capacity because flow velocity for a given discharge will decrease. Since current velocity in a channel is directly related to this area (by V = Q/A, where V is current velocity, Q is discharge, and A is cross-sectional area), average velocity in the widened reach will almost always decrease relative to the unmodified reach upstream. Usually, sediment is deposited until the reach is in equilibrium (with respect to sediment transport) with adjacent reaches. In heavily managed rivers, this process is kept in check by periodic removal of the deposited sediment – it is not a naturally sustainable condition.

To begin this demonstration, start with a metastable channel and consistent sediment transport continuity. Pick a reach in the center of the model and widen it using a scoop, sieve or your hand.

You will usually observe several processes:

- Average current velocity is greatly reduced in the widened area. Sediment continuity is completely disrupted as the widened area becomes a sink for bedload.

- A steeper hydraulic grade line, caused by the increase in cross-sectional area, may encourage increased sediment transport above the widened area, causing a headcut to form and migrate upstream.

- The banks and bed of the channel upstream of the widened area will sometimes erode. This part of the channel will show a net export of sediment. As with the inchannel mining demonstration, you may see relatively high bedload transport rates in this reach compared to the reaches further upstream. You can thus visually observe the downstream changes in sediment transport rates that show the discontinuity.

- One or more dunes may form in the widened area, with downstream slipfaces. More likely, though, you will see one or more bars form as the channel regains its former cross-sectional area.

- The downstream end of the widened area will erode as sediment is removed by the channel to regain sediment transport continuity.

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5.2 Bank Armoring

Bank armoring is likely as old as civilization. Where people settle or build structures near rivers, they encounter channel movement across the floodplain that threatens those structures. Channel migration is, of course, part of the process that built fertile, flat floodplains, but people are in constant conflict with it.

Armoring schemes are limited only by the imagination, economics, and materials at hand, ranging from old automobiles, junk, and tires dumped on banks by a landowner to multibillion-dollar engineered projects along big rivers like the Mississippi. Environmental values can suffer from both types.

5.2.1 Soft Armor

Soft armoring involves the use of living plants, either alone or in combination with natural material structures, to protect a riverbank against erosion. Planted vegetation protects a riverbank in numerous ways including holding soil together through root structures, absorbing rainwater, dissipating the impact of rainfall through leaves, and helping to slow water flows and encourage sediment deposits that can help build up the shoreline rather than wear it away. Bioengineering is generally less expensive than hard armoring, and supports natural habitat for both terrestrial and aquatic wildlife, but it has practical limitations. The riverbank must be stable enough to support vegetation, and even strong trees are sometimes no match for freezing, thawing, and ice scouring, or large-scale seasonal floods.

5.2.2 Hard Armor

Hard armoring is a riverbank stabilization technique in which the bank is graded to a low angle, then covered with materials such as stones, called rip-rap, or stacked with rock-filled wire baskets called gabions. Hard armoring may be appropriate in severe situations where more environmentally friendly solutions like seeding or planting are unlikely to hold. Hard armoring can be expensive and may not be aesthetically pleasing but it does provide excellent stream bank protection. An alternative to installing gabions parallel to the shore is to build groynes, or a series of walls running perpendicular to the shore, anchored in the riverbank and extending into the river to slow and redirect the water flow.

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5.2.3 Setup for Bank Armoring Demonstrations

For most bank armoring demonstrations, you may either begin with a meandering channel or form a straight channel and allow small meanders to develop. Most observers find a meandering channel to be within their river experience (and more visually interesting). With bank armoring demonstrations, you may want to experiment with higher discharges, which usually accelerate fluvial adjustment and structure failure processes. If you form three or more meander bends and use relatively low flows, you may be able to contrast the response of armored and unarmored bends.

(Maximum slope) **Smax**	variable, about 0.020 (2%)
(Slope of meandering channel) **S**	approx. 0.015
Planform	gentle meanders, at least a full meander wavelength (preferably more), sinuosity about 1.3; alternatively, a straight channel
(flow) **Q**	35 - 110 ml/sec
Initial conditions	well-established sediment transport continuity, meanders with point bars and well-formed channel features

5.3 Modeling Riprap

The Emriver model is supplied with small limestone stones that can be used to simulate riprap. The density of limestone is approximately 2 g/cm^3. Note that the limestone stones will have a tendency to scour into the streambed – a process that does occur in real-world rivers, but usually not as readily as in the Emriver model. Also included are acrylic stones to simulate riprap made from different materials. The lighter-density acrylic material can show that at higher storm discharge rates, riprap will eventually fail and bank incision will occur. Acrylic and stone objects give very useful and interesting demonstrations of effects and processes related to bank armoring.

After constructing a stable, meandering channel, try armoring an outside bend with riprap. Observe the response at low flows, and try higher flows as well.

Figure 5.2 depicts a process the Emriver model shows particularly well: the interaction of hard, stationary bank armor with migrating meanders. The effects of a particular bank armoring project on fluvial process are complex, and you will no doubt see varied results. In general, you may observe these processes:

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- Increased shear stress at the toe of the riprap, and resulting scour of bed material that may cause stones to roll into the bed and downstream. Note that riprap tends to focus rather than dissipate hydraulic energy.

- Sometimes you will see scour in upstream and downstream riffles as well. This results from the alteration of energy and sediment transfer in the armored reach.

- The downstream bend may erode for the same reason.

  Meander migration may cause deposition to occur at the upstream end of the riprap. You may see channel alignment change dramatically as the meander bend moves through the site as shown in Figure 5.2. This demonstration shows one of the problems with hard structures in alluvial channels: unless the channel's planform never changes, the structure is certainly doomed to obsolescence due to movement of the channel across the floodplain, however slow this process may be. In the case shown in Figure 5.2, accelerated downstream erosion and channel migration would more than offset any benefits from the area protected by riprap (unless the riprap is protecting a high value structure such as a house). This can be visualized easily with the houses from the Emriver Structures Kit.

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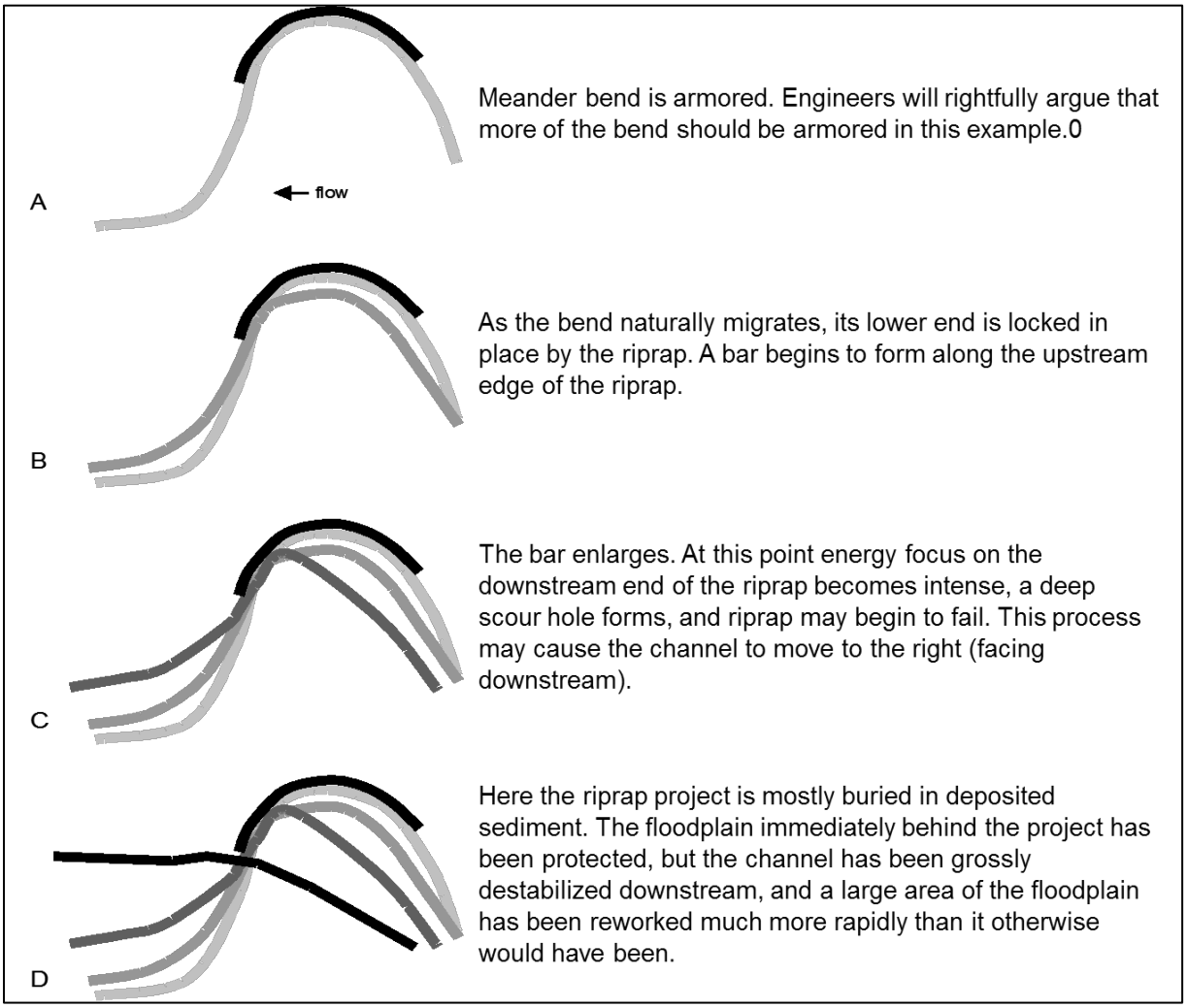

Figure 5.2 - Hypothetical planform channel response to armoring with stone riprap. Depending on channel characteristics, sediment, and water flow regime, many different responses are possible.

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