Vermont Agency of Natural Resources
Rivers and Roads Training Program

Tier One:
An Introduction to
River Processes and Management

Developed in Partnership with
The Vermont Agency of Transportation
An Introduction To
River Processes and Management

Training Overview

This training module presents an exploration of:

✓ rivers and the physical adjustments they undergo in response to changes on the landscape and to their channels;

✓ the historic approaches to river management and their consequences; and

✓ alternative management practices to minimize impacts on the stream processes that naturally maintain river stability.
An Introduction To
River Processes and Management

Training Organization
This training is organized into the following lessons and sections.

- **Lesson 1: An Introduction to Rivers**
  - The Values of Rivers
  - Hydrologic and Sediment Regimes

- **Lesson 2: Understanding River Behavior**
  - River Morphology
  - River Equilibrium
  - Channel Evolution

- **Lesson 3: Rivers and Human Developments**
  - Flood and Erosion Hazards
  - Controlling the River to Resolve Conflicts

- **Lesson 4: River Management Going Forward**
  - Managing For Equilibrium
An Introduction To
River Processes and Management

Navigating This Training Module

This training is a self guided presentation containing a combination of static slides, narrated slides, short videos and a series of questions at the end of each section. This training is not intended as a tool for measuring knowledge. Accordingly, responses to questions are not recorded.

To advance slides, activate narrations and videos and view the answers to the questions, simply click where instructed by the text on the slide. You can “right click” to see more navigation options including going back, advancing to a selected slide or ending the training.
Why a Rivers and Roads Training Program?

- Time and time again we are reminded how vulnerable our roads and bridges are to apparently unpredictable river instabilities.
- River processes are not as unpredictable as they may at first seem, we understand what causes rivers to be unstable.
- We can use our understanding of river processes to reduce flood related damages and associated rebuilding expenses to our roads and bridges.
- The Rivers and Roads Training Program aims to provide participants with this understanding of river processes.
Lesson 1: An Introduction to Rivers
Lesson 1: An Introduction to Rivers

The Values of Rivers

The rivers of Vermont are an important asset to all Vermonters. And managing them for long term health is in our collective best interest.
Lesson 1: An Introduction to Rivers

The Values of Rivers

Rivers and adjacent riparian areas serve as some of the most biologically productive and diverse habitat in the state.
Lesson 1: An Introduction to Rivers

The Values of Rivers

Healthy rivers can provide clean drinking water for human consumption.
Lesson 1: An Introduction to Rivers

The Values of Rivers

Vermonters and tourists alike are drawn to and rejuvenated by the scenic beauty of Vermont’s rivers.
The Values of Rivers

Stable rivers serve as self-maintaining drainage networks that transport millions of gallons of water from mountains to lakes and ponds. Consider the cost of constructing and maintaining such a drainage system.
Lesson 1: An Introduction to Rivers

The Values of Rivers

Angling, boating and swimming are part of Vermont’s **recreational heritage** and overall economy. These activities play an important role in defining our quality of life and shaping our culture and generate substantial economic activity.

The US Fish and Wildlife Service estimates that $131,000,000.00 was spent on fishing related expenditures in 2011 alone.
Lesson 1: An Introduction to Rivers

The Values of Rivers

Questions:

What values are provided by rivers?

Click For Answer

Click For Answer

Click For Answer

Click For Answer

Click For Answer
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

The size, shape and movement of a river are dictated by the water and sediment delivered to it from its watershed (the surrounding landscape) and are therefore a reflection of the characteristics of that watershed.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

The hydrologic and sediment regimes of a river describe the amount and rate at which water and sediment enter and move through the river.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

When changes to a watershed shorten the time it takes rainfall to reach the river, the flood volume in the river becomes concentrated and develops a heightened peak. Higher floods result in river erosion.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

The hydrologic and sediment regimes are affected by certain characteristics of the watershed.
Hydrologic and sediment regimes are strongly affected by **land use** and **land cover**.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

**Land uses** that require constructed drainage networks increase the rate at which rainwater is delivered to the river.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

Land cover such as vegetation absorbs rainwater and prevents erosion of sediment greatly reducing the amounts of each that are delivered to the river.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

Land cover such as pavement and other impervious surfaces rapidly shed the majority of rainwater, resulting in a river that rises more dramatically in response to rain and snowmelt events.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

Lakes, ponds, wetlands and floodplains provide storage of runoff during storm and snowmelt events.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

Steep slopes shed water more rapidly and produce more landslides and other erosional events than flat slopes.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

Thick organic **Soils** soak up rainwater and snowmelt and resist the erosive forces of flowing water.
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

Wetland Storage, Soils and the Hydrologic Regime of the Otter Creek

(Click play button at top right corner of slide to play video.)
Lesson 1: An Introduction to Rivers

Hydrologic and Sediment Regimes

Questions:

The hydrologic regime describes the amount and rate at which

Click For Answer

is delivered to the river from its watershed?

The sediment regime describes the amount and rate at which

Click For Answer

is delivered to the river from the watershed?

What characteristics of a watershed affect the hydrologic and sediment regimes?

Click For Answer  
Click For Answer  
Click For Answer  
Click For Answer  
Click For Answer  
Click For Answer
Lesson 2: Understanding River Behavior
Lesson 2: Understanding River Behavior

River Morphology

A river’s morphology is simply its shape. The morphology of a river is most strongly influenced by its Valley setting as defined by valley slope, valley width and geology.
Lesson 2: Understanding River Behavior

River Morphology

A river’s morphology is described by its:

- Cross Section
- Profile
- Planform and
- Bedforms
Lesson 2: Understanding River Behavior

River Morphology

The cross section includes the width and depth of the floodplain and channel.
Lesson 2: Understanding River Behavior

River Morphology

The **longitudinal profile** is a detailed description of the channel slope.
Lesson 2: Understanding River Behavior

River Morphology

**Planform** describes channel sinuosity and the shape of a river’s meanders or bends.

**Slope** is a function of **Planform**
- high sinuosity = lower slope
- low sinuosity = greater slope
Lesson 2: Understanding River Behavior

River Morphology

The **bedform** is a description of the vertical undulations or ups and downs of the bed and the size of the **boundary materials** such as gravels, cobbles and boulders that are part of those undulations.
Lesson 2: Understanding River Behavior

**River Morphology**

Questions:

The width and depth of the river and its floodplain are described by what aspect of its morphology?

[Click For Answer]

The slope of the river is described by what aspect of its morphology?

[Click For Answer]

What aspect of a river’s morphology describes the vertical undulations of its bed?

[Click For Answer]
Lesson 2: Understanding River Behavior

River Equilibrium

As discussed in Lesson 1, hydrologic and sediment regimes describe the amount and rate at which flow and sediment are delivered to the river. In the river, the power of the flow overcomes the resistance of the sediment and transports it downstream, thereby shaping the river.

The sediments delivered to the river from the watershed are transported down the river by the flow.
Lesson 2: Understanding River Behavior

River Equilibrium

When the flow power is sufficient to transport the sediment load, the river is in balance or equilibrium, meaning it is generally stable over time.
Lesson 2: Understanding River Behavior

River Equilibrium

When the flow power is less than what is necessary to transport the sediment load, the channel aggrades or fills in.
Lesson 2: Understanding River Behavior

River Equilibrium

When the flow power is greater than what is necessary to transport the sediment load, the channel degrades or erodes, becoming larger.
Lesson 2: Understanding River Behavior

River Equilibrium

Flow power is determined by the following factors:

- Amount of Flow (Volume)
- Flow Depth
- Slope
Lesson 2: Understanding River Behavior

River Equilibrium

*Volume, depth and slope* are directly related to flow power. If any of these factors increase, the flow power will increase and the river will degrade.
Lesson 2: Understanding River Behavior

River Equilibrium

Depth depends not only on the discharge but also the channel width. A wider channel will contain a given amount of flow at a lower depth than a narrower channel will.
Lesson 2: Understanding River Behavior

River Equilibrium

Where rivers are well connected to floodplains, high flows are able to spread out across those floodplains thereby reducing the flow depth and power in the channel during high flow events.
Lesson 2: Understanding River Behavior

River Equilibrium

**Slope** depends not only on the valley slope but also the extent to which the channel meanders back and forth across the valley.
Lesson 2: Understanding River Behavior

River Equilibrium

**Resistance** is determined by the following factors:

- Sediment Size
- Sediment Amount (Volume)
- Roughness
Lesson 2: Understanding River Behavior

River Equilibrium

Sediment size, sediment volume and roughness are directly related to resistance. If any of these factors increase, the resistance will increase and the river will aggrade.
Lesson 2: Understanding River Behavior

River Equilibrium

**Roughness** is created by bed forms such as steps and pools which dissipate the energy of the flow thereby reducing erosion of the channel.
Lesson 2: Understanding River Behavior

River Equilibrium

**Roughness** is created by meanders which cause the flow to spiral, slowing it down and reducing its energy.
Lesson 2: Understanding River Behavior

River Equilibrium

**Roughness** is created by gravel bars which are the first sediments to be transported during high flows and thereby absorb energy of the flow that would otherwise work to erode the boundary materials.
Lesson 2: Understanding River Behavior

River Equilibrium

Roughness is created by large woody debris that creates a physical obstacle to the flow thereby slowing and dissipating its energy.
Lesson 2: Understanding River Behavior

River Equilibrium

Bed forms, meanders, gravel bars and woody debris are all important components of habitat features for fish and other aquatic wildlife.
Lesson 2: Understanding River Behavior

River Equilibrium

The Role of Bedforms and Floodplains in Moderating Flow Power

(Click play button at top right corner of slide to play video.)
Lesson 2: Understanding River Behavior

River Equilibrium

In summary, **river equilibrium** requires that the channel have the right combination of depth, slope and roughness to create just enough flow power to transport the sediment load, but where the channel does not move vertically i.e., erode or fill in over time.
Lesson 2: Understanding River Behavior

River Equilibrium

Lane’s Balance and Equilibrium

(Click play button at top right corner of slide to play video.)
Lesson 2: Understanding River Behavior

**River Equilibrium**

Questions:

What factors determine how much power the flow contains?

- Click For Answer
- Click For Answer
- Click For Answer
- Click For Answer

What is the term used to describe the condition in which the flow power is just great enough to transport all of the sediment without filling in or eroding?

- Click For Answer
Lesson 2: Understanding River Behavior

Channel Evolution

When subtle changes occur within a watershed or river that affect its equilibrium, one or more of the remaining factors will adjust such that the balance between flow power and sediment load is restored.

Such adjustments occur frequently without consequence and typically go unnoticed.
Lesson 2: Understanding River Behavior

Channel Evolution

Sudden large scale changes in a watershed and/or river can result in dramatic *disequilibrium* which persists for tens to hundreds of years before equilibrium is restored. This five stage process is know as *channel evolution*. 

![Diagram of channel evolution stages]
Lesson 2: Understanding River Behavior

Channel Evolution

(Click play button at top right corner of slide to play video.)
Lesson 2: Understanding River Behavior

Channel Evolution

Using Lane’s Balance and the Channel Evolution Model to Predict Channel Adjustments

(Click play button at top right corner of slide to play video.)
Lesson 2: Understanding River Behavior

Channel Evolution

Questions:
What is the long term process that a river which has been destabilized by sudden and major watershed and/or channel changes goes through to reach a new equilibrium condition? Click For Answer

What are the consequences of channel evolution?
Click For Answer  Click For Answer  Click For Answer
Lesson 3: Rivers and Human Developments
Lesson 3: Rivers and Human Developments

Flood and Erosion Hazards

The flood-related processes, erosion and deposition, are the physical adjustments by which rivers maintain an equilibrium condition.
Ironically, those flood processes, which erode and deposit sediment, form level lands that are the most easily developed for roads and buildings, and, at the same time, are the most hazardous.
Flood and Erosion Hazards

Managing public infrastructure in erodible, hazardous areas requires the knowledge to minimize conflicts with the channel adjustment processes imperative to the maintenance of equilibrium conditions.

For instance:
How does road and bridge infrastructure change flow and sediment regimes or channel slope, depth, and roughness and cause disequilibrium, where severe erosion hazards may follow?
Lesson 3: Rivers and Human Developments

Flood and Erosion Hazards

Flooding, Channel Adjustments and Erosion Hazards

(Click play button at top right corner of slide to play video.)
Lesson 3: Rivers and Human Developments

**Flood and Erosion Hazards**

Questions:

What river processes are responsible for much of Vermont’s flat landscapes?

- Click For Answer

What type of flood damage has resulted in the greatest loss in Vermont?

- Click For Answer
Controlling the River to Resolve Conflicts

For centuries we have attempted to control rivers in order to settle conflicts between the natural adjustments of rivers and human land uses and developments. This approach has had consequences.
Lesson 3: Rivers and Human Developments

Controlling the River to Resolve Conflicts

Historic watershed-scale land cover changes have dramatically changed flow and sediment regimes, thereby altering river equilibrium.
Lesson 3: Rivers and Human Developments

Controlling the River to Resolve Conflicts

Land cover changes such as the conversion of agricultural lands to urban, continue to alter watershed hydrologic regimes today.
Lesson 3: Rivers and Human Developments

Controlling the River to Resolve Conflicts

River straightening to make way for roads and other developments has resulted in increased channel slopes thereby altering the equilibrium of the river.
Lesson 3: Rivers and Human Developments

Controlling the River to Resolve Conflicts

Channel dredging and armoring has altered the depth and roughness of channels thereby creating river disequilibrium.
Dredge and armor activities have also significantly degraded the habitat value of rivers.
Lesson 3: Rivers and Human Developments

Controlling the River to Resolve Conflicts

These land use and channel management activities have resulted in significant channel evolution.

Of 1,500 river miles assessed in Vermont, 75% have been found to be in the incising, widening and stabilizing stages of the evolution process.
Lesson 3: Rivers and Human Developments

Controlling the River to Resolve Conflicts

A History of River Management

(Click play button at top right corner of slide to play video.)
Lesson 3: Rivers and Human Developments

Controlling the River to Resolve Conflicts

Questions

What river process has been triggered by the widespread watershed and river alterations traditionally implemented to settle conflicts between river adjustments and human land uses and developments.

What percentage of the 1,500 miles of river assessed by the River Management Program has been found to be in an unstable stage of channel evolution?
Lesson 4: River Management Going Forward
Managing for Equilibrium

If we can begin to use our understanding of rivers to work with their natural processes and manage them toward the equilibrium condition we can greatly reduce erosion hazards and increase public safety, improve fish and wildlife habitat and protect water quality.
Managing for equilibrium requires the planning for future development with consideration to maintaining stable hydrologic and sediment regimes.
Lesson 4: River Management Going Forward

Managing for Equilibrium

Managing for equilibrium requires respect for river floodplains so they may serve their critical energy dissipation role and provide room for rivers to adjust as necessary to maintain an equilibrium condition.
Managing for Equilibrium

Managing for equilibrium requires design and maintenance of roads and crossings with consideration to the channel depth, slope and roughness factors that determine flow power and the erosion and deposition processes that govern equilibrium conditions.
### Managing For Equilibrium: Activities to Avoid

<table>
<thead>
<tr>
<th>Activity</th>
<th>Resulting Change to Equilibrium Factors</th>
<th>Channel Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over Dredging</td>
<td>Increased Depth</td>
<td>Erosion</td>
</tr>
<tr>
<td>Channel Narrowing</td>
<td>Increased Depth</td>
<td></td>
</tr>
<tr>
<td>Channel Berming</td>
<td>Increased Depth</td>
<td></td>
</tr>
<tr>
<td>Channel Straightening</td>
<td>Increased Slope</td>
<td></td>
</tr>
<tr>
<td>Increased Runoff Rate</td>
<td>Increased Depth &amp; Slope</td>
<td></td>
</tr>
<tr>
<td>Undersized Culvert</td>
<td>Decreased Slope Upstream</td>
<td>Filling</td>
</tr>
<tr>
<td>Channel Widening</td>
<td>Decreased Depth</td>
<td></td>
</tr>
<tr>
<td>Upstream Landslides</td>
<td>Increased Sediment Volume</td>
<td></td>
</tr>
</tbody>
</table>
Lesson 4: River Management Going Forward

Managing for Equilibrium

Going Forward: Managing Rivers Toward the Equilibrium Condition

(Click play button at top right corner of slide to play video.)
Lesson 4: River Management Going Forward

Managing for Equilibrium

Questions

How can we manage our rivers for equilibrium when designing and building transportation infrastructure and other developments?

What landscape feature must we protect if we are to manage our rivers for equilibrium and thereby reduce flood future flood damages?
Rivers have a natural level of stability that is realized when the power of the river flow is in equilibrium with the sediment load. This balance can be tipped when activities on the landscape or in the river change the amount of flow and sediments delivered to the rivers and/or the amount of power created by the flow and resistance provided by the river channel. When the balance is tipped, the river enters a disequilibrium condition and potentially a channel evolution process and the threat to property and developments adjacent to the river is increased. Working with the natural tendencies of rivers to manage for equilibrium is the most cost effective way to reduce river related damages and threats to public safety.
Thank You for Participating in The Vermont Rivers and Roads Training Program

For more information on the Rivers and Roads Training Program or technical assistance contact:

Todd Menees:
(802) 490-3510
todd.menees@vermont.gov

For more information about the Vermont River Management Section visit us at http://dec.vermont.gov/watershed/rivers

For a complete listing of River Management Section staff contact info see http://dec.vermont.gov/watershed/contacts#Rivers