RIVER BANKS & BUFFERS

No. 1

River Dynamics and Erosion

This guide is intended to help property owners, town planners and road agents, and other decision-makers better understand how streams work. Use the field assessment sheet (No. 4) to locate and understand factors causing or resisting erosion at a specific site. With these tools, a landowner can feel comfortable working with professionals to decide whether to attempt a stabilization project.

It is the nature of streams to flood and change course.

Free-flowing streams tend to reach a state of equilibrium where erosion at one location is roughly balanced by deposition at another. Even streams which seem to have stable, well defined channels shift over a long period of time. In this state of equilibrium, the erosion and sedimentation process is beneficial to the aquatic ecosystem. It creates gravel beds for fish spawning and a series of pools, riffles and runs that provide rich habitat. However, if human activities increase the rate of erosion and sedimentation, both human uses of rivers and aquatic habitat may be threatened. The river can erode valuable agricultural soils, roads, and other structures, and heavy sediment with attached nutrients may pollute its waters.

A stabilization project can only slow erosion, not stop it.

A major difficulty in addressing erosion is that some solutions can have unintended effects. For example, if the river is prevented from overtopping its banks in a floodplain, this water will move to downstream floodplains where it may cause increased erosion and flooding. A bank stabilization project in one location may worsen erosion on someone else's property downstream, since bank erosion is a natural way in which a stream dissipates energy. In some circumstances, it is better to leave the situation alone rather than interfere with the complex dynamics of the stream. Interrupting stream channel movement is costly, and may be futile in the long run.

STREAMS AS HABITAT

Altering the channel affects a complex web of life.

Rivers and streams provide various kinds of habitat where fish, aquatic insects and other organisms find food, shelter and places to reproduce. The pools offer quiet, cool water with bottoms often covered with sediment, while in the riffles, water travels quickly over rocky bottoms. These pools and riffles are connected by runs where the water moves more slowly, generally over a sand or gravel bottom. The diversity of habitat created by different water depths and velocities, as well as different bottom types, is essential for fish and other aquatic life. A stable stream creates stable and diverse habitat, which allows greater biological diversity.

Overhanging bank vegetation both shades the stream, moderating stream temperature, and provides a source of food and cover for aquatic life. It also helps prevent erosion by increasing the stability of the bank. If streamside vegetation is removed, these functions are eliminated. Stream temperatures may rise, the food supply is reduced, and bank erosion may increase. When banks erode, sediment fills or embeds cracks and crevices in the gravel and cobble streambed, reducing the area where macroinvertebrates such as insect larvae live and feed. This situation is called *embeddedness*. The greater the embeddedness, the poorer the habitat. The net effect of all these changes may be a reach of stream that no longer supports a high quality fishery and its supporting food web.

NATURAL EROSION AND SEDIMENTATION

In reaches with erodible materials and low gradient, most streams develop bends or *meanders*. Even in a straight channel, the main current wanders within it to create pools and riffles.

Figure 1. Straight channel

Fast-moving water on the outside bend erodes the bank (unless it encounters stable material) and picks up sediment that is dropped again when the water slows at the inside of the next downstream bend. This increases the meandering pattern, creating *point bars,* as shown below.

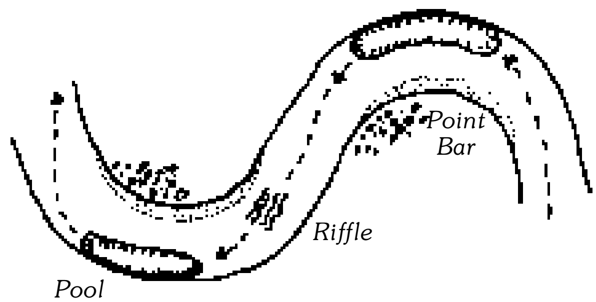

Figure 2. Meandering Channel

This increases the length of the channel, which helps dissipate the energy of the flowing water over a longer distance. The curvature of the meanders may increase so that they actually double back upon themselves (as in ribbon candy) with only narrow strips of land separating them. That is why some farmers on the Vermont side of a meander can watch the sun set over New Hampshire land in some parts of the Connecticut River's floodplain. Eventually, a flood may occur which breaks through these strips of land, cutting a new and straighter channel. The old meander, now cut off from the main channel, becomes a C-shaped pond known as an *oxbow*.

Figure 3. Connecticut River oxbows and meanders at Maidstone, VT and Northumberland, NH

The oxbow, which offers its own rich habitat for waterfowl and other wildlife, may eventually fill in and become part of the floodplain forest, but traces of its former role as a streambed may show centuries later as C-shaped patches of contrasting vegetation.

The process described above is particularly common where the gradient of the river becomes flatter and allows deposition of material carried from upstream. This is how floodplains develop. Over thousands of years, the river moves all over the floodplain, rearranging the landscape by eroding and depositing soil. Therefore, the channel in floodplains is inherently a moving thing. Stopping this movement in a large river or stream is extremely difficult, expensive, and may cause worse problems downstream.

UNDERSTANDING STREAM BANK FAILURE AND EROSION

Bank erosion occurs as stream channels move. Since factors both at the site and upstream in the watershed influence the movement of rivers and streams, it is important to look at the big picture as well as the immediate site.

Bank erosion and bank failure are two distinct processes, although they often occur in combination. *Streambank failure* occurs when a large mass of bank material collapses and slips into the stream. *Streambank erosion* occurs when individual soil particles at the bank's surface are carried away.

Causes of bank failure

A streambank is stable when its shear strength is equal to or greater than the shear stress acting upon it. A bank can fail either when its shear strength is decreased or when the shear stress exerted upon it increases.

Decrease in Shear Strength

Swelling of clays from absorption of water, increased groundwater pressure within the bank, and soil creep all weaken the bank. While swelling clays or excessive groundwater pressure are difficult to observe, cracks developing in the bank parallel to the stream are evidence of soil creep. Absence of bank vegetation to help bind the soil together reduces its shear strength. Large trees leaning over the water may lead to failure of steep banks if the trees fall and dislodge soil as they are uprooted. Surface runoff may turn animal burrows and trails near the bank into gullies.

Increase in Shear Stress

Shear stress increases with changes in channel shape, increase in the load on the top of the bank, or rapid drawdown of water against the bank face.

Causes of bank erosion

Flow

The faster and deeper the flow of moving water, the stronger the shear force it can exert upon the bank. The speed of water flow depends on slope, roughness of the streambed, depth of the water, and cover of upstream banks. The duration of a flood can have a greater impact on bank stability than the volume of flow. More energy is required to overcome initial bank resistance than to maintain the erosion process, and once erosion begins, it can proceed quickly.

Erosion-prone Bank and Bed Material

Sand and silt particles erode most readily. Cobbles and other large particles are heavier and harder to move. Clay particles stick together and so are also difficult to dislodge.

Pressure Imbalance at the Bank Face

A pressure imbalance can occur in two ways. If the groundwater table is higher than the surface of the stream, pressure builds up behind the bank face causing seepage, forcing soil particles to loosen.

Rapid Drawdown
Rapid drawdown can also create a pressure imbalance. When the water level of a stream is high for a sufficient length of time, water tends to move into the bank. When the stream level drops quickly, as with drawdown at a dam, and the bank cannot drain as fast, the water in the bank face increases the outward pressure on the soil in the bank and reduces its stability.

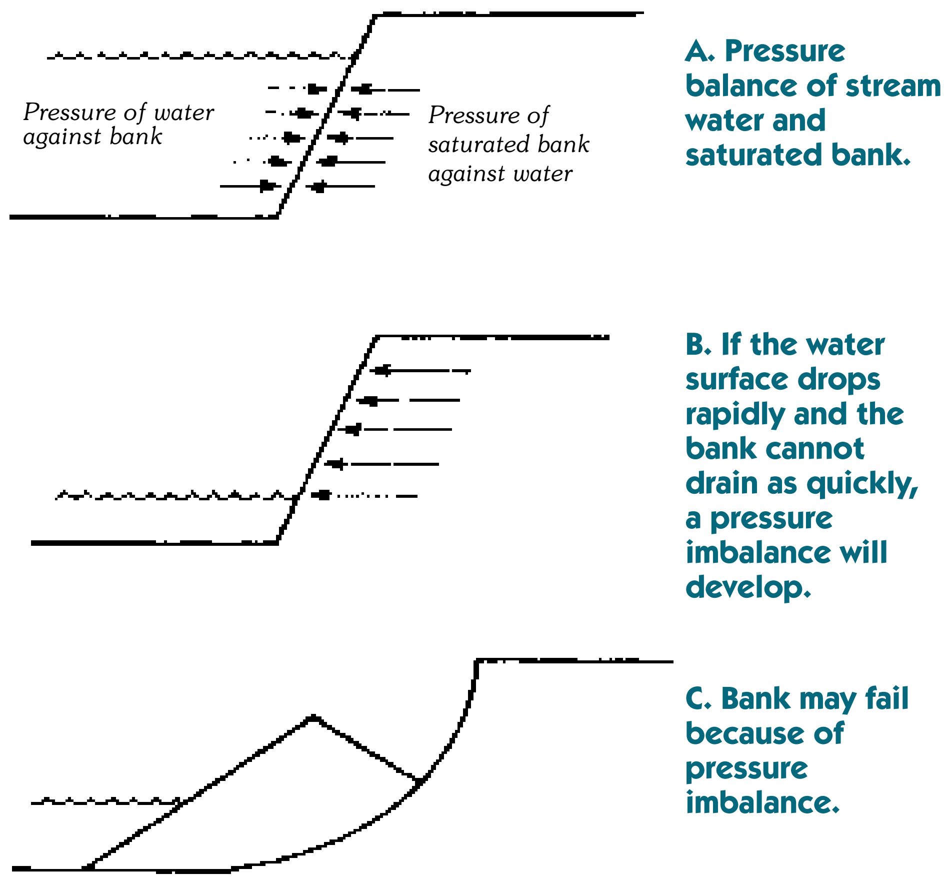

Figure 4. Bank failure due to pressure imbalance.

Absence of Bank Vegetation
Water that does not filter into the soil becomes surface runoff, which can detach more soil particles and cut narrow rills and then wider gullies as it gains in speed and force on its way to the stream. Trees, shrubs, herbaceous plants, and grasses on the bank slow water running off the land. Grasses and other low plants along streams can bend to protect the bank during high flow without obstructing the passage of water. *The loss of streambank and buffer vegetation is often the single greatest contributing factor to increased erosion on small and medium-sized streams.*

Obstacles in the Stream
Obstacles in the stream, either natural or man-made, can alter the natural flow of water, resulting in erosion and/or deposition.

Waves and Boat Wakes
Waves or wakes washing away soil at the base of the bank will undercut it, particularly if it is unvegetated, allowing the unsupported bank material above to collapse into the stream.

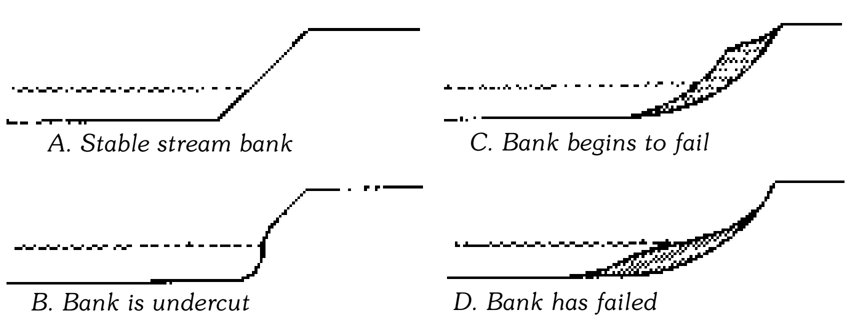

Figure 5. Bank failure due to undercutting at the base.

Freeze-Thaw and Wet-Dry Cycle

When water freezes in the bank, the expanding ice layer pushes soil particles out of position. As the ice thaws, these particles settle back in a looser state, allowing them to be removed more easily by flowing water. When wet clay material dries, it shrinks and cracks, creating a similar erodible surface.

Ice and Debris

Erosion of a streambank by ice often occurs during break-up, when ice is forced along the bank by the flow of water. This abrasion does the least damage if the bank is still frozen, but can scour deeply when the bank is thawed. Other debris can cause erosion if it strikes the bank with sufficient force. Whirlpool action around a piece of ice or debris can cut dramatic holes in a bank. A protective cover of vegetation on the bank face can reduce abrasion from ice and debris.

WATERSHED FACTORS THAT AFFECT BANK EROSION AND FAILURE

Upstream land use

Condition of the bank itself is often a very small part of the problem. There may be larger forces at work that make a bank stabilization project at a particular site an expensive and perhaps wasted effort. Any change in land use that causes water to reach the stream more quickly and with more energy can cause a previously stable bank to erode.

- Wetlands act as natural sponges to hold water during storms and release it slowly. Filling wetlands or removing their vegetation increases the chance of flooding and erosion.
- Vegetation holds soil, slows runoff, and helps water sink into the soil. Trees store more water than smaller plants. Removal of protective plant cover, especially through large-scale deforestation, sends more surface water more quickly into streams and adds to their sediment load.
- Water that cannot sink into the soil will reach the stream faster and with more force than if it met the stream as groundwater. Construction of impervious surfaces such as paved parking areas and shopping centers can cause a stream to suddenly flood and erode its banks, even if the development occurs far upstream in the watershed.
- At high flow, the energy of a stream must be spent. Upstream channelization or bank stabilization projects which prevent a stream from using its floodplain, or deflect the stream's energy rather than absorbing it, can focus the stream's force on a site downstream that otherwise would remain stable.

This is why governments have devised rules for wetlands, construction and development, timber harvesting, and changes to streambanks. Such guidance includes state and federal laws requiring wetland permits, town subdivision regulations and floodplain ordinances, and best management practices for logging and agriculture. They are intended to protect the public and downstream property owners from damage by flooding and erosion, but they do not cover every situation or activity. Therefore, it is also up to each landowner to manage property responsibly.

Seek professional assistance

Streams are complex systems. Each is different, and it is only with professional help that a landowner can determine whether to attempt a stabilization project or to leave the stream to move naturally. If a project is recommended, information about stream shape, ecology, engineering, and soils is required to design a project with the greatest potential for success for the landowner and the stream.

SUGGESTED READING

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Prepared by the Connecticut River Joint Commissions with support from the Rivers and Trails Conservation Assistance Program of the National Park Service through the Connecticut River Valley Partnership Program April 1996

PO Box 1182 • Charlestown NH 03603 • 603-826-4800