FACTSHEET

Diagnosis and Solutions for Bank Erosion Problems

Introduction

The banks of a number of streams in Quebec are showing signs of accelerated degradation. Improvements to the drainage network, stream straightening for agricultural purposes, larger areas planted to annual crops and more frequent extreme weather events have contributed to increased peak flows, flow velocities and, as a result, streambank erosion. In order to ensure that appropriate corrective measures are taken, a complete diagnosis of the sites to be restored must be conducted, taking the following factors into consideration: bed slope, current direction, magnitude of peak flow, presence of obstructions in the streambed, bank vegetation cover, bank shape and soil resistance. It should be noted that bank restoration cannot solve erosion problems that originate in fields. Restoration should therefore be viewed as a complement to good farming practices and hydro-agricultural installations.

This fact sheet describes frequently observed bank erosion problems and recommends installations to correct each situation. If major problems exist, experts should be consulted.

Source: Victor Savoie (MAPAQ)

Processes that contribute to bank degradation

Bank degradation is generally the result of a process that combines the **erosive power of water** and the effect of gravity. In some cases, a more specific phenomenon, known as **piping**, also occurs.

Note

Bank protection installations must not be built systematically. The selection of an appropriate solution must include a cost/benefit analysis that will allow specific objectives to be established. Will valuable property have to be protected (building, productive agricultural land); will improvements be made to the quality of water used for multiple purposes (drinking water system, swimming, fishing), etc? It is also important to properly measure the impacts that installations will have on the upstream and downstream portions of the stream.

• Erosive power of water

Erosion occurs when current velocity and turbulence are more powerful than the weight of the soil particles and their cohesive strength. Therefore, cohesive soils (e.g., clay soils) are more resistant to erosion than non cohesive soils (e.g., sandy soils). It should be noted that the raveling force is stronger when the direction of the current forms an angle with the soil surface.

Pockets of erosion can be caused by anything that changes the direction of flow or increases the water velocity. Stream obstructions, channel narrowing, improperly installed drain outlets, centrifugal force on the outer bank of a bend and steeply sloping streams are all factors that can contribute to changing the direction of flow or increasing the water velocity. Bare soil surfaces are also more prone to erosion than surfaces covered with vegetation.

Erosion can occur on streambanks, but also in streambeds; this is known as downcutting. This type of erosion lowers the bed elevation, increases the angle of the bank and weakens its toe. In cohesive soil, it almost always causes slope failure (see next section).

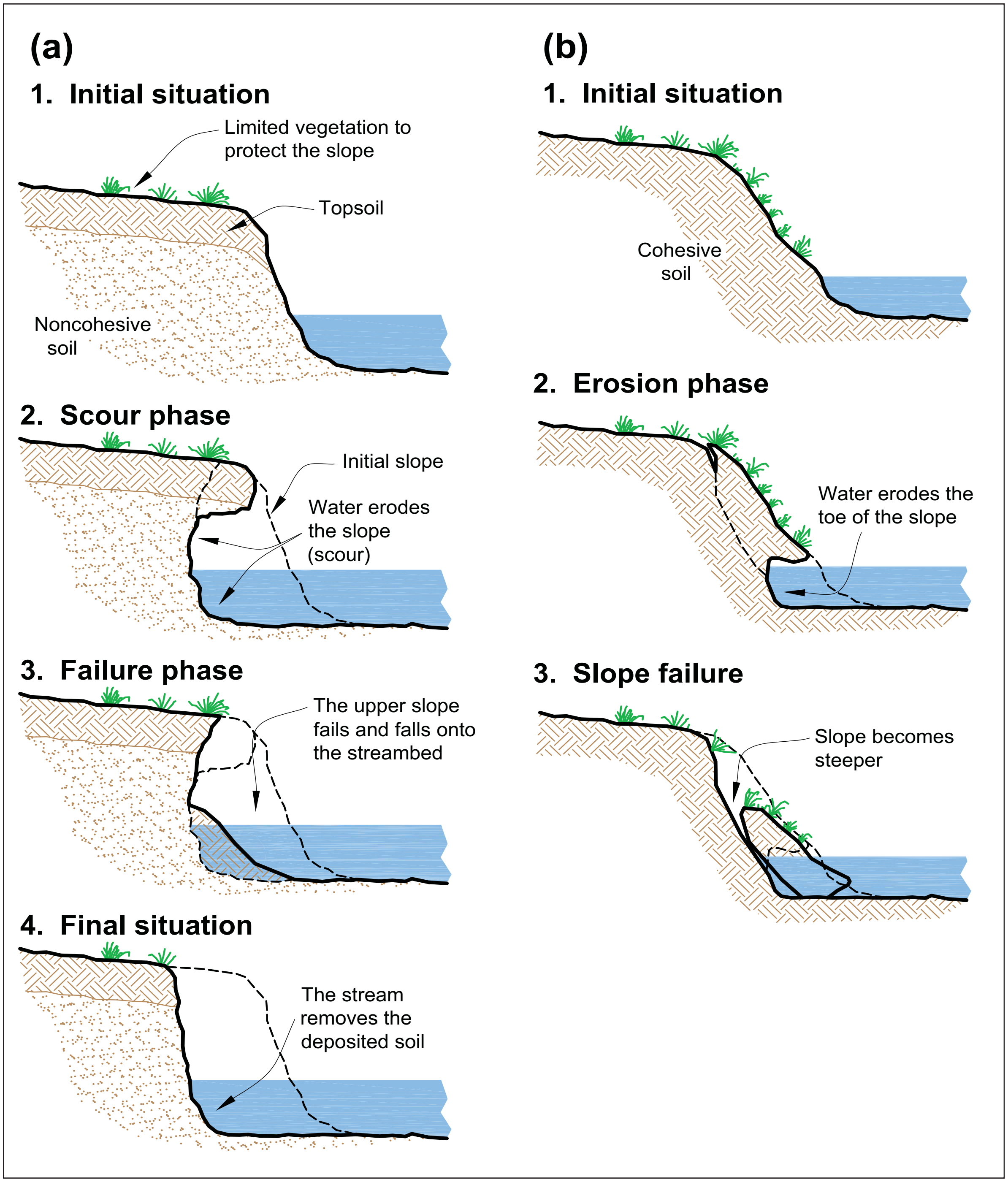

Figure 1 (a and b): Bank erosion process encountered in (a) non cohesive soil and (b) cohesive soil when flow rate is high
Source: Luc Lemieux, MAPAQ, adapted from Bentrup G. and Hoag J. C. (1998)

Photo 1: The erosive power of water
Source: Luc Lemieux, MAPAQ

• Effect of gravity

Slope failure occurs when the materials that make up the banks are no longer able to resist the forces of gravity. This mechanism occurs primarily in cohesive soils that are able to retain **large quantities of water**, which adds weight to the bank and reduces the cohesive forces between particles (lubrication). As a result, the slope becomes even more susceptible to failure.

When the **slope or height of the bank** is increased, the weight of the soil eventually exceeds the cohesive forces holding it together, the top of the bank cracks and sections slide downward. In cohesive soils, the failure surface has a characteristic circular arc shape. The less cohesive the soil, the straighter the failure surface.

Photo 2: The effect of gravity
Source: Robert Beaulieu, MAPAQ

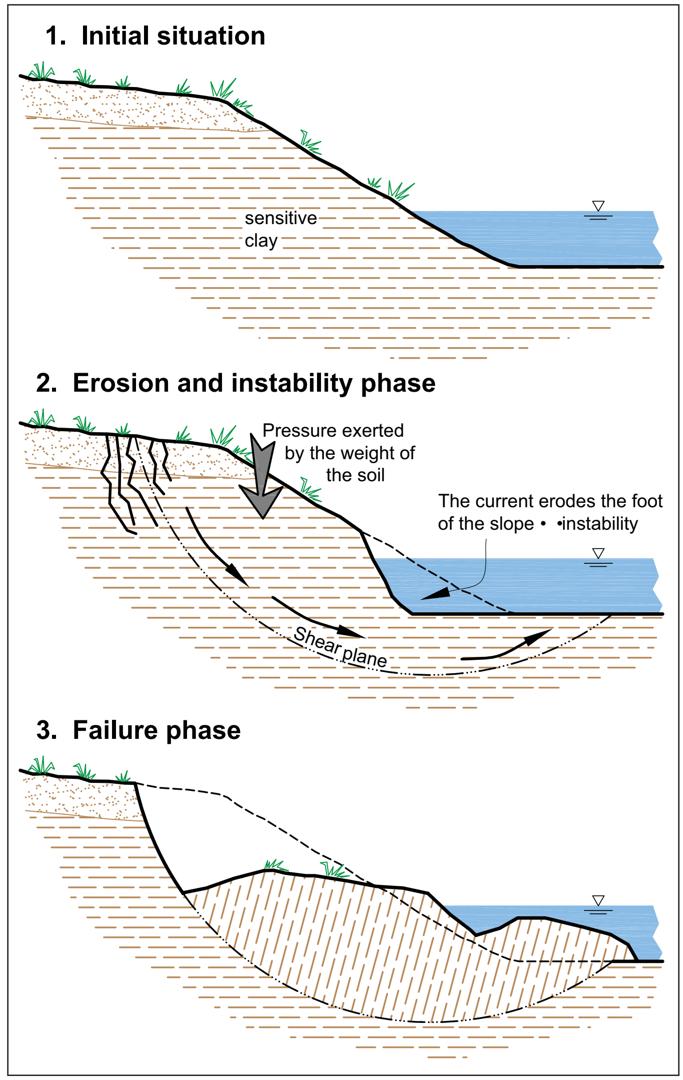

Figure 2: Circular arc bank failure
Source: Luc Lemieux, MAPAQ, adapted from USDA-NRCS Stream Restoration Design Handbook, Technical Note 14A, 2005

Failure generally occurs after heavy rain or during rapid recession when the banks are saturated with water. However, other circumstances also contribute to failure, such as freeze/thaw or saturation/drying cycles in certain soils, vibrations created by machinery passing too close to the bank, an added load on the bank (backfill, tall trees), accumulation of water along the bank caused by a furrow, etc.

• Piping

Failure is also frequently observed when water table resurgence appears in the bank. Layered soils that consist of a non cohesive soil horizon overlying a cohesive soil horizon are most vulnerable to this type of erosion. This type of failure is caused by the pressure exerted by the groundwater on the bank when the level of the water table is higher than the level of the surface of the stream. This phenomenon is known as "piping."

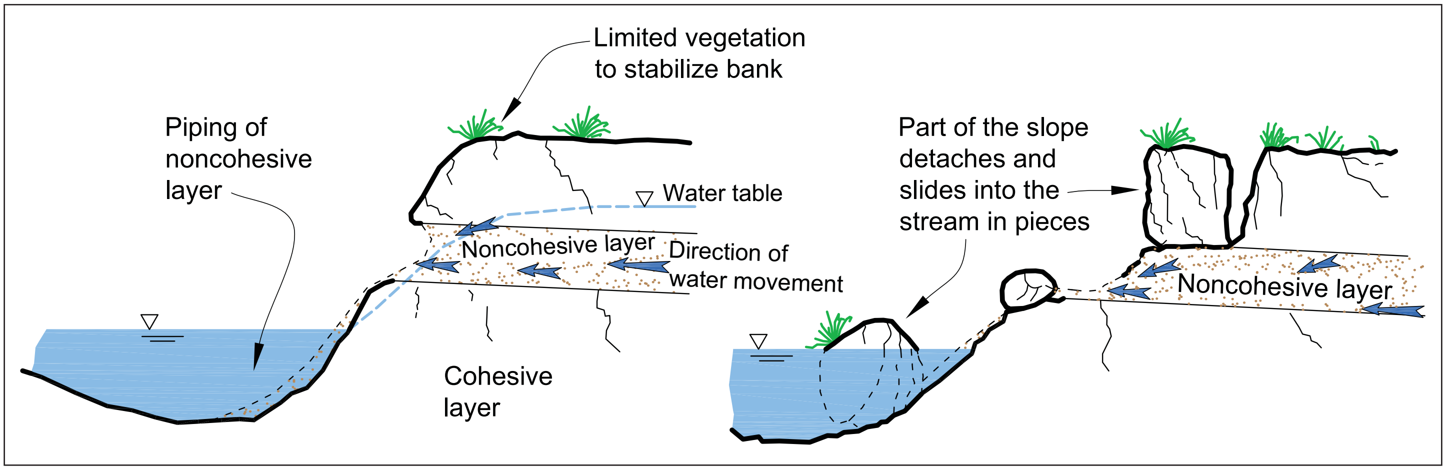

Figure 3: Piping
Source: Luc Lemieux, MAPAQ, adapted from Bentrup G. and Hoag J. C. (1998)

Photo 3: Piping caused by excavation of a stream in soil with an elevated water table
Source: Victor Savoie, MAPAQ

Photo 4: The erosive power of water
Source: Victor Savoie, MAPAQ

Note

It is easier to observe the banks and make a better diagnosis in the spring or late fall when vegetation is less developed. **See Checklist Sheet**.

Erosive power of water: Diagnosis and solutions

Diagnosis

Careful examination of the banks will reveal the following:

- Loss of vegetation, bare soil on the bank.
- Absence of soil at the toe of the bank (the eroded soil is carried away by the stream).
- Turbulent or high-velocity flow.
- Erosion of the outer bank of a bend.
- Signs of overflow (secondary channels, gullying and materials deposited outside the streambed).
- Presence of more vulnerable non cohesive layers (sand).
- Presence of obstructions (branches on the bed, etc.).
- Progressive bank erosion, year after year (research required).

Solutions

- Reduce the slope of the bank, depending on soil type.
- Protect the bank using riprap or bioengineering techniques. Bioengineering techniques have the advantage of adding shrubs and bushy plants that stabilize the bank with their root systems and that regenerate if damaged. These techniques are often more costly than riprapping. In many cases, protection of the toe of the bank with riprap, complemented by vegetation of the top of the bank, combines the advantages of both techniques.

- In all cases, plant shrubs and/or perennials at the top of the bank.
- Reduce water flow by installing energy dissipating sills.
- In bends:
  - Round out bends before establishing protection.
  - Build rock or willow pole groins (other techniques also exist) to divert the current toward the centre of the stream.

Photos 5 (a, b): Installations in a bend
Source: Mikael Guillou MAPAQ

Specific cases

Downcutting

The deepening of the bed of a watercourse streambed is related to associated with an increase in water velocity that exceeds the resistance capacity of the soil. As it the streambed deepens, the watercourse increases the height of the banks increases. Once the height exceeds the load-bearing capacity of the soil, failure occurs.

These situations are generally visible in streams that have high flows combined with a steeply sloping bed or narrow banking of the bed.

Diagnosis

Careful examination of the streambed will reveal the following:

- Streambed deepening (compared with previous longitudinal profiles).
- Signs of meanders and sedimentation in the bed during low-flow periods.
- Rapid flow, where water is present.
- If a culvert is present: a vertical wall at the culvert outlet (downstream).
- Exposed roots (to differentiate from undercutting).
- Slumping of both banks, particularly along a straight line.
- No aquatic vegetation or sedimentation.
- Steep slope and deep soil (no bedrock).
- Soil layer change in the streambed.
- Formation of a deepened bed in the centre of the stream, with vertical banks (see Figure 4 and Photo 6).

Photos 6 (a and b): Downcutting
Source: Luc Lemieux and Mikael Guillou, MAPAQ

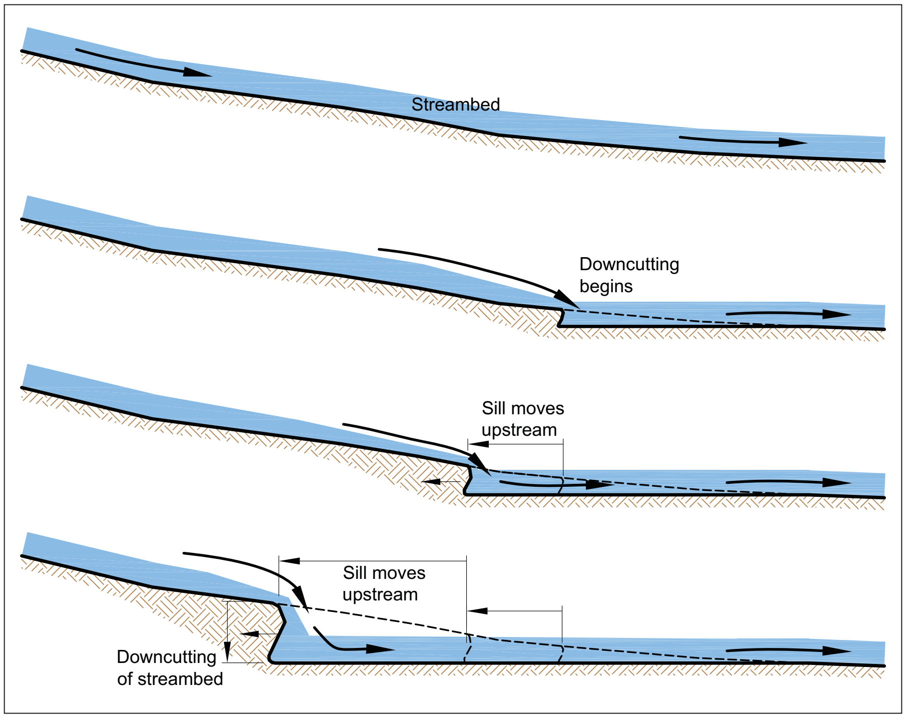

Figure 4: Downcutting
Source: Luc Lemieux, MAPAQ adapted from Morgan RPC, 2005.

Photos 7 (a and b): Energy dissipating sill
Source: Jacques Goulet and Victor Savoie, MAPAQ

Solutions

Measures to correct bed deepening must only be undertaken if the stream is deepening significantly (30 cm or more).

- Localized riprapping of the streambed.
- Energy dissipating sill to slow water flow.
- Channelling: Only in the case of a ditch.

Bridges and culverts

Bridges and culverts alter the natural course of streams by creating an area of restriction during high flows, thereby slowing streamflow upstream. This can lead to sedimentation and even flooding of land upstream. The restricted area also creates increased water velocity and turbulence on both sides of the culvert outlet, which can cause a widening and deepening of the bed downstream from the culvert. If the area around the culvert is not properly backfilled (i.e., installation of a geotextile fabric and riprap), water can flow between the pipe and the bank and erode the fill.

Diagnosis

Careful examination will reveal the following:

- Presence of pockets of erosion in the bank around the culvert.
- Widening and deepening of the streambed downstream.
- Upstream sedimentation.

Photo 8: Widening of the streambed downstream of a culvert
Source: Mikael Guillou, MAPAQ

Solutions

- Re-sizing and replacement of the culvert.
- Protection of banks and culvert approaches.
- Regular inspection of the culvert and removal of debris that could obstruct it.

Photo 9: Protection upstream of the culvert
Source: Mikael Guillou, MAPAQ

Presence of obstructions in the streambed

All objects large enough to obstruct the streamflow (uprooted trees, invasive vegetation, large rocks, slabs of earth from slope failure, etc.) can lead to erosion. Sediment and debris accumulate in front of an obstruction. When the obstruction is not submerged, the current is diverted by a rebound effect. The energy of the stream is then directed from one bank to the other in a wave motion. If the process is not stopped, it can lead to a series of meanders.

If the obstruction is submerged, the current crosses it at a right angle. Submerged obstructions can either bring the water back toward the centre of the stream (Figure 5a) or, if they are obliquely angled in a downstream direction, they can cause an erosion niche in a bank (Figure 5b).

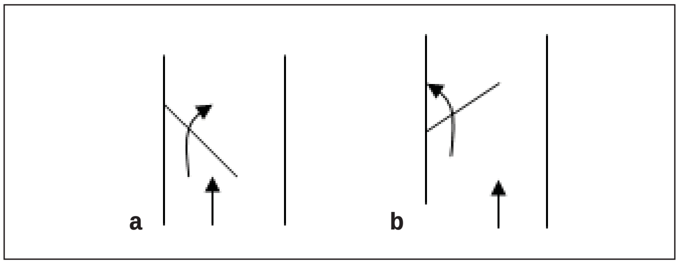

Figure 5 (a and b): A submerged obstruction directs the current (a) toward the centre of the stream (groin principle) and (b) toward the bank.

The obstruction could be the result of a natural event, such as a broken branch, fallen tree or simply the growth of the vegetation on the streambank or in the streambed. It could also be the result of human activity and be composed of material such as prunings or various types of waste.

Diagnosis

- Presence of obstructions.
- Accumulation of sediment and debris upstream of the obstruction.
- Presence of pockets of erosion in the banks.
- Widening of the streambed and appearance of meanders.

Photo 10: Bank erosion caused by an obstruction in the streambed.
Source: Victor Savoie, MAPAQ

Solutions

- Inspect the stream regularly (after the snow melts and at the end of fall).
- Remove obstructions.
- Trim shrubs encroaching on the streambed.
- Protect the bank if it has begun to erode.

Ice

When ice forms on the surface of a stream, it traps some of the materials on the banks. During the winter, if the water level rises, the ice lifts and detaches the materials in its grip. Vegetation, riprap with rough surfaces and bioengineering materials (such as willow poles) can be carried away following changes in water and ice levels.

In the spring, the ice cover breaks into pieces, forming sharp edges. Carried by strong currents, these sharp edges strike the banks, scarifying the surfaces. Bends are particularly vulnerable to this phenomenon.

Diagnosis

- Banks are marked by deep notches or bare cavities.
- The bank has been lifted and detached by ice movement.
- Pockets of erosion may appear in banks, as though the ice had acted as an obstruction (see previous section).
- Trees may have horizontal scars on their bark, indicating the highest water level reached.

Photo 11: Ice erosion
Source: Mikael Guillou, MAPAQ

Solutions

- Reduce the slope.
- Protect the bank with smooth riprap and/or flexible shrubs.

Drain outlets

Poorly installed drain outlets can not only cause bank erosion, but can also reduce the effectiveness of the drainage systems and, as a result, reduce crop yields.

Diagnosis

- The soil around and under the drain outlet is eroded.
- The drain outlet may be detached, blocked, sunken or buried.
- The opposite bank is damaged.

Photo 12: Erosion at a drain outlet
Source: Mikael Guillou, MAPAQ

Note

For more information, consult the fact sheet entitled **Design of Drain Outlets**.

Solutions

- Clean drain outlets regularly.
- Protect them against erosion.
- Protect them from rodents.
- Put in place an identification system to facilitate regular maintenance of drain outlets and to prevent them from being damaged if any work is carried out in the stream.

Photo 13: Erosion protection at a drain outlet
Source: Mikael Guillou, MAPAQ

Confluence and gullying

Erosion problems can also occur at the confluences of streams with ditches or channels, and bank erosion can also be caused by field gullying. These two situations are addressed in the fact sheet entitled **Diagnosis and Solutions for Field Erosion and Surface Drainage Problems**, which is part of the same series.

Photo 14 (a and b): Gullying originating in a field.
Source: Victor Savoie, MAPAQ

The effects of gravity: Diagnosis and solutions

Streambanks can also deteriorate independently of the velocity and force of streamflow. When the materials that form the bank can no longer resist the forces of gravity (as a result of an excessive load, an excessively steep bank or soil that is saturated with water, causing a change in the cohesive properties of the soil), the bank collapses and the material is deposited on the streambed.

Diagnosis

- Often occurs in cohesive soils (clay or silty soil).
- Presence of soil at the toe of the bank.
- Circular arc failure in clay soils.
- Cracks parallel to the bank in silty or sandy soils.
- Presence of a furrow parallel to the streambank and in which water is accumulating.
- Vibrations and excessive loads.

Photo 15: Bank failure.
Source: Robert Beaulieu, MAPAQ

Solutions

- Reduce the slope, according to soil type.
- Install a drain parallel to the bank to lower the water table and capture the water from the furrows, thereby reducing pressure and preventing entrainment of soil particles.
- If the conditions do not allow the slope to be modified, the toe of the slope can be riprapped (in this case, a large riprap key rock will be required as a counterweight).
- Vegetate the bank (seed herbaceous vegetation, plant shrubs).

Photos 16 (a and b): Bank stabilization
Source: Victor Savoie, Ghislain Poisson, MAPAQ

Specific cases

Excessive loads and vibration

Excessive loads can cause bank failure. Loads can be static, e.g., the weight of a tree or pile of soil, or dynamic (variable loads that cause vibrations), e.g., passing machinery. Tracked vehicles are particularly problematic.

Photo 17: Failure caused by an excessive load
Source: Mikael Guillou, MAPAQ

Diagnosis

- Presence of a farm road less than 10 metres from the bank.
- Cultivated land very close to the bank.
- Trees overhanging the bank or very close to it. Trees with superficial root systems (e.g., poplars and conifers) are easily de-stabilized. When they are inclined, they create a lever effect in the bank.
- An embankment or berm that has been created along the stream.

Solutions

- If possible, remove the excessive load.
- Maintain a buffer strip that is sufficiently wide.
- Install an interception drain (if the weight of the water is the cause).

Trampling by livestock

Because livestock hooves have a small load-bearing surface, they exert a significant amount of pressure on the soil. Livestock also have a tendency to always return to the same areas. By repeatedly using the same paths to access or cross streams, they destroy vegetation, weaken banks and initiate the formation of pockets of erosion. Streams used by livestock for watering can also be contaminated by excrement.

Photo 18: Trampling by livestock
Source: Mikael Guillou, MAPAQ

Diagnosis

- The banks are bare.
- Signs of trampling are visible.
- Pockets of erosion are apparent.

Solutions

- Install a fence to prevent livestock from accessing the stream (outside the standard buffer strip).
- Install controlled watering sites.
- Install culverts and ford crossings to allow livestock to cross the stream.

WARNING

Under section 4 of the **Agricultural Operations Regulation**, except for fording across watercourses, it has been prohibited to allow livestock to access watercourses, bodies of water or their shorelines since April 2005 (O.C. 695-2002, s. 4.).

Animal burrows

Animal burrows can compromise bank stability. Runoff water from fields can pass through these burrows to streams. During flooding, the water rushes into the burrows creating pockets of erosion that cause bank instability and even failure.

Particular attention should be given to muskrat burrows. Because one of the access routes to a muskrat burrow is always located below the water level, the pressure exerted by flooding can cause large amounts of water to easily enter the burrows. Furthermore, since muskrats prefer to live in colonies, long sections of banks can become riddled with tunnels.

Diagnosis

Burrow holes are easy to identify before the bank collapses.

Photo 19: Burrows in banks
Source: Nicolas Stampfli

Solutions

Buffer strips planted with shrubs and trees attract predators like Red Foxes and American Minks. Planting shrubs that develop major root systems that are difficult to penetrate, such as the Arctic Willow or the Dogwood, also keeps away burrowing animals, which will prefer to find habitat elsewhere.

Piping: Diagnosis and solutions

Piping is related to a weakening of the bank caused by groundwater resurgence. Because this type of seepage often occurs at the toe of the bank, it is not always easy to identify.

Diagnosis

- Soil stratification (permeable soil overlying a layer of less permeable soil).
- Presence of an elevated water table.
- Water seepage into the bank (before the soil collapses).
- Presence of wet areas without vegetation in the bank.
- Presence of mudflow.

Solutions

- Install an interception drain parallel to the bank (Figure 6).
- Reduce the slope.
- Vegetate the bank.
- Riprap the toe of the bank: Installing riprap with geotextile fabric strengthen the toe of the bank and allows the groundwater in the bank to drain into the stream without carrying soil particles (the geotextile fabric acts as a filter).

Photos 20 (a and b): Piping
Source: Victor Savoie, Robert Beaulieu, MAPAQ

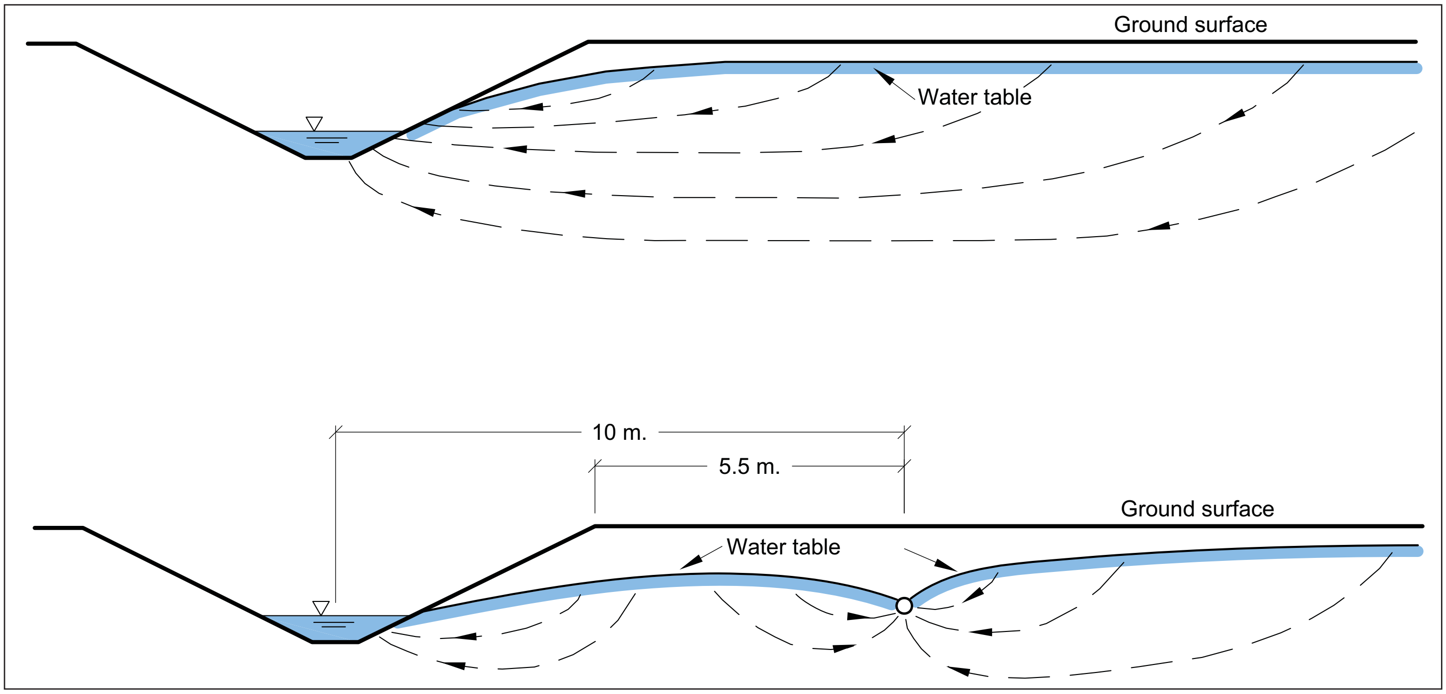

Figure 6: Correction of piping by the installation of an interceptor drain
Source: Luc Lemieux adapted from McNeely (1982)

NOTICE

Before work is carried out in a stream or on its banks, the necessary authorization must be obtained from the municipality or Regional County Municipality (RCM). Some work requires a certificate of authorization from the Ministère du développement durable, de l'environnement et des parcs (MDDEP), in accordance with the **Environment Quality Act**, as well as authorization from the Ministère des Resosources Naturelles et de la Faune (MRNF), under the **Act Respecting the Conservation and Development of Wildlife**. The **Fisheries Act** of Fisheries and Oceans Canada (DFO) also regulates habitat protection and free passage of fish. If the work undertaken by a contractor contravenes this legislation, the contractor may be subject to legal action and heavy fines. An application can be submitted to either MDDEP or the MRNF by completing the appropriate form.

Diagnosis and Solutions for Bank Erosion Field Checklist

When is the best time to look for problems?

The best time for observing and diagnosing bank erosion is in the spring, before vegetation develops, and at the end of the fall. It is also important to ask shoreline residents for detailed information about the behaviour of the stream (water depth, flow rate, overbank flow) during extreme events (snowmelt, floods, heavy rains).

Before going to the field

- Obtain a map of the site, aerial photograph or a map of the farm
- Obtain stream maps and profiles, where available from the RCM or MAPAQ
- Consult soil maps and reports
- Consult the weather data for the region
- Equipment:
  - Rubber boots
  - Pencils, notepad, camera, clinometer (optional)
  - Checklist of points to observe
  - Surveyor's tape measure to measure water depth, height of erosion marks and bank height
  - Basic GPS (Garmin or other) (optional)

What to observe in the field (note and photos)

- Note the stream orientation (north-south or east-west)
- Identify the bank being observed. When the observer is looking at the stream in the direction of the current, the right bank is on the observer's right, and the left bank is on the observer's left.
- Note areas of soil that are bare or have vegetation.
- Identify the presence of trees, shrubs, grasses. Is there any vegetation on the streambed? Does it interfere with flow?
- Note the various layers that make up the bank.
- Describe the grain size of materials on the streambanks and streambed.
- Identify signs of erosion:
  - Originating in a field
  - Slides (slumps)
  - Location of cracks in the bank terrace along the stream
  - Erosion of the toe of the bank (horizontal displacement or widening of the streambed)
  - Deepening of the streambed (downcutting)
- Indicate changes in the direction of streamflow
- Other details to note:
  - Culverts. What is their general condition? How are the ends protected? Look for signs of erosion both upstream and downstream (if a culvert is too small, a stream widens downstream)
  - Farm roads near banks
  - Evidence of livestock
  - Furrow or ditch outflows in bank margins
  - Buffer strips - note widths
  - Animal burrows
  - Drain outlets
  - Obstructions on the streambed

What to measure in the field

- Bank height (to assess the scope of work to do and to compare with historical profile, to be able to diagnose a downcutting).
- Bank slope angle
- Damage bank length
- Bed watercourse length (at the toe and top of the slope)
- Water depth at the visit date
- Water depth at flooding time
  - Identify evidence of overbank flows: secondary channels, presence of objects or logs transported by the current, presence of plant debris (leaves, branches) left on the bank by high waters (*)
  - Note the presence on trees of marks
  - Talk with shoreline residents
- Observe and measure the length and height of these deposits in the areas of sedimentation (inside banks of meanders).(*)
- Asses the flow velocity. Is the water flowing slowly or quickly?

Information to be obtained from shoreline residents

- Water depth during flooding
- Changes in flow rate over time

(*) Note: These two indicators are used to determine the height of the protection required for the toe of the bank (normal peak level).

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