Riverbank Instability

DRAFT Guide and Resources for NWT Communities

nwtac
NWT Association of Communities

NWT **RIVERBANK EROSION**
WORKSHOP 2025
DEC 2-4 | CHATEAU NOVA HOTEL | YELLOWKNIFE

Riverbank Instability: **A Draft Guide**

1 Recognize the Problem

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Identify when riverbank slope instability is threatening something in the community and understand what is driving change along the riverbank.

- Observe where instability is occurring, how the river behaves, and consider how that may impact important parts of the community.
- Talk to community members about how the area has changed over time.
- Look for early warning signs such as cracks, slumping, leaning trees, or exposed soils on slopes.
- Consider factors that may be contributing to riverbank instability like erosion, rainfall or surface water runoff, permafrost thaw, high water levels, shifting ice, and strong currents.

2 Manage the Threat Right Away

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Take steps to keep people and infrastructure safe while planning longer-term actions.

- Communicate with the community and reach out for expert advice (for example, through NWTAC or technical specialists).
- Check on the area regularly, especially after major weather events.
- Apply short-term fixes such as shoring up foundations, diverting overland flow from the bank, or restricting access to unstable slopes.
- Prepare a risk mitigation plan in case erosion occurs rapidly.

3 Gather and Assess Initial Information

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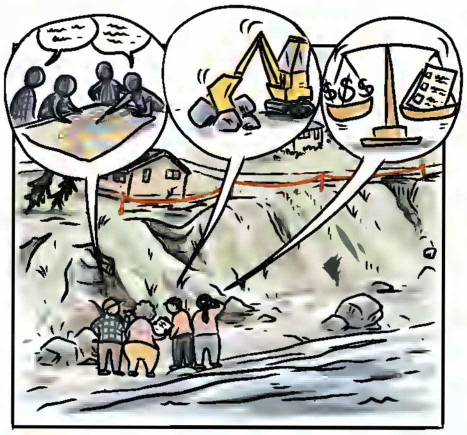
Work with technical specialists to better understand the problem and identify what information is needed to plan next steps.

- Hire the right kind of qualified specialists (geotechnical, hydrology, geomorphology, permafrost, or ecological).
- Review existing reports, maps, and photos, many of which can be found online; conduct field checks as needed.
- Receive an assessment report describing riverbank trends (erosion and instability), identifying risks, and recommending next steps.

Monitoring

Ongoing monitoring is part of every stage. It helps track changes, identify and address new risks early, and measure how well mitigation actions are working.

for Communities



4 Evaluate Options and Make a Plan

Compare potential solutions and develop a realistic, community-supported plan.

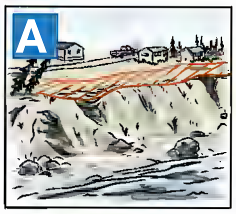
- Work with technical specialists and planners to sketch and evaluate possible actions and estimate approximate costs.
- Engage community members, property owners, and leadership to weigh options based on effectiveness, feasibility, cost, and environmental impact.
- Consult with regulators and funders to understand approvals and funding opportunities.
- Select a preferred option and begin planning how to implement it – preparing an initial conceptual design, securing funding, doing further assessments to refine actions, and beginning the work.

5 Take Action

Once your community has decided on a preferred approach, it's time to put the plan into motion. Every slope stability project is unique—what's required to stabilize a slope will differ from relocating a structure or reinforcing foundations—but most projects follow similar steps.

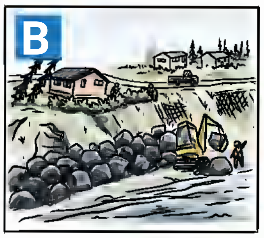
It will be important to think about how to connect these decisions to your community plan or zoning bylaws.

Most actions fall into one or more of the following categories:



Giving the River Space –

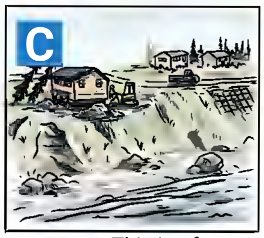
Avoiding development close to the riverbank so the river can move naturally. This may include setting setback lines or relocating buildings and infrastructure. In the long term, this is often the most effective and affordable approach.



Addressing the Issue –

Taking direct action on the riverbank or slope itself through one or more of the following:

- *Controlling erosion* – Installing measures to reduce impacts from flowing water and shifting ice.
  - *Direct (On-site):* Riprap, vegetation, or other materials applied at the erosion site.
  - *Indirect (Off-site):* Modifying river flow patterns, surface drainage, or sediment sources to reduce stress on the bank.
- *Stabilizing the slope* – Using retaining walls, gabion baskets, or other engineered structures to hold soil in place and prevent failure.
- *Managing permafrost thaw* – Using insulation, shading, rock embankments, or thermosyphons to help slow the thaw, or possibly flattening the slope.



Protecting Structures –

Reinforcing building foundations or stabilizing nearby ground to reduce damage from erosion or slope movement. This is often combined with other measures.

Combining Methods –

Most sites require a mix of approaches to address multiple issues such as thaw, slope movement, and erosion together.

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Riverbank Instability

DRAFT Guide and Resources for NWT Communities

This is a draft version of a guide to help communities and partners understand the different steps involved in addressing riverbank erosion and instability. Northwest Territories Association of Communities (NWTAC) worked with a group of specialists in geomorphology, engineering, and community planning to put together this draft guide to support the NWT Riverbank Erosion Workshop (Dec. 2-4, 2025). Alison McCreesh worked with this team to develop the illustrations. After the workshop, we will use what we learned together to update and improve these materials and then share them as a toolkit on the NWTAC website.

We welcome your feedback to ensure this guide works for you!

Send feedback to Miki at miki@nwtac.com or (867)873-8359

1

Recognize the Problem

Explaining Riverbank Instability

Draft

Caption:

What is riverbank instability?

Riverbank instability occurs when the soil or rock along a river's edge weakens and begins to move, slump, or collapse. It can be triggered by many factors, including erosion, thawing permafrost, or changes in water levels. While some movement is natural, instability becomes a problem when it threatens people, buildings, or infrastructure.

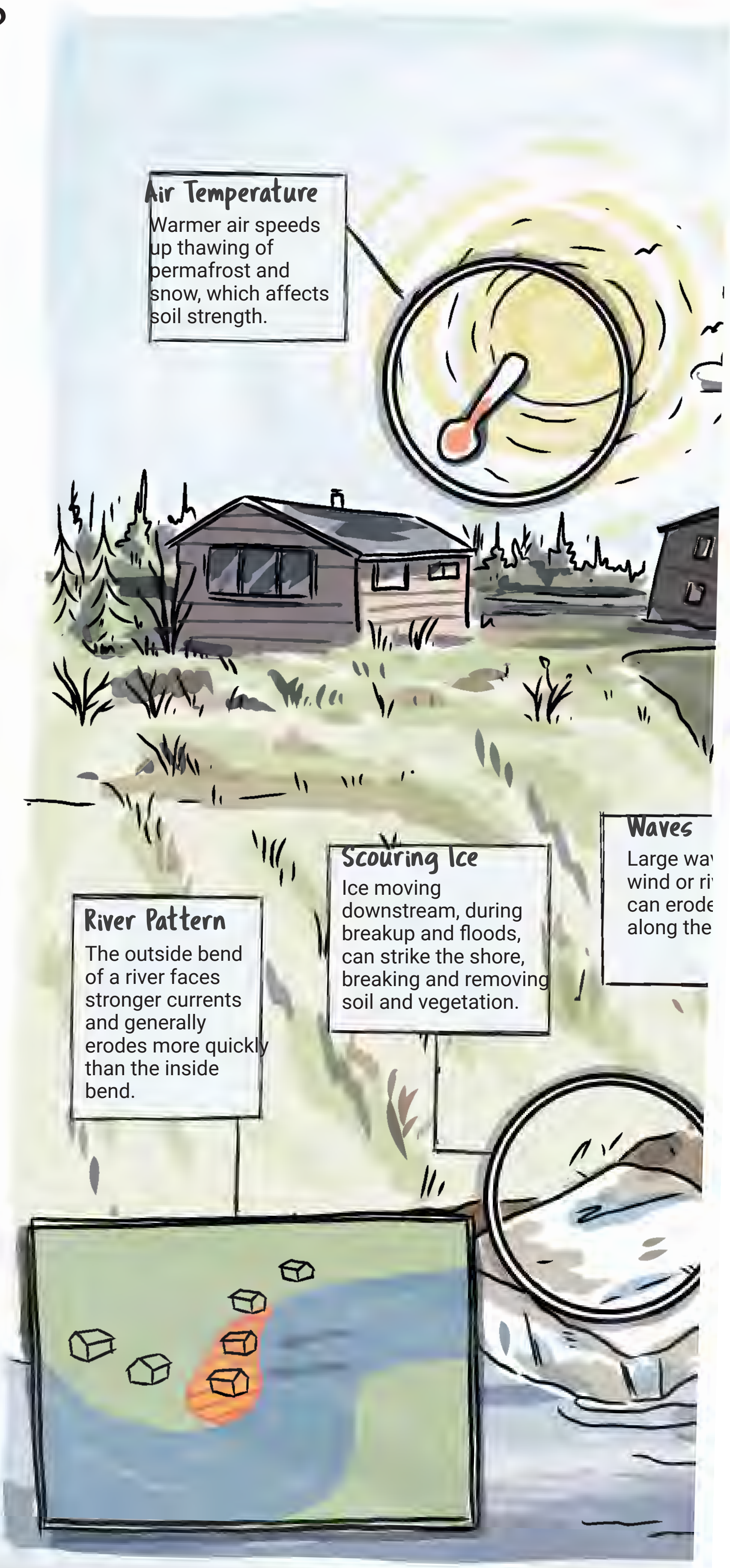
Along most rivers, the outside bends experience stronger water currents and tend to erode or fail more quickly, while inside bends usually build up sediment. In northern regions, once instability begins, it can progress rapidly and be difficult to stop—so recognizing early signs is important.

Why is the riverbank becoming unstable?

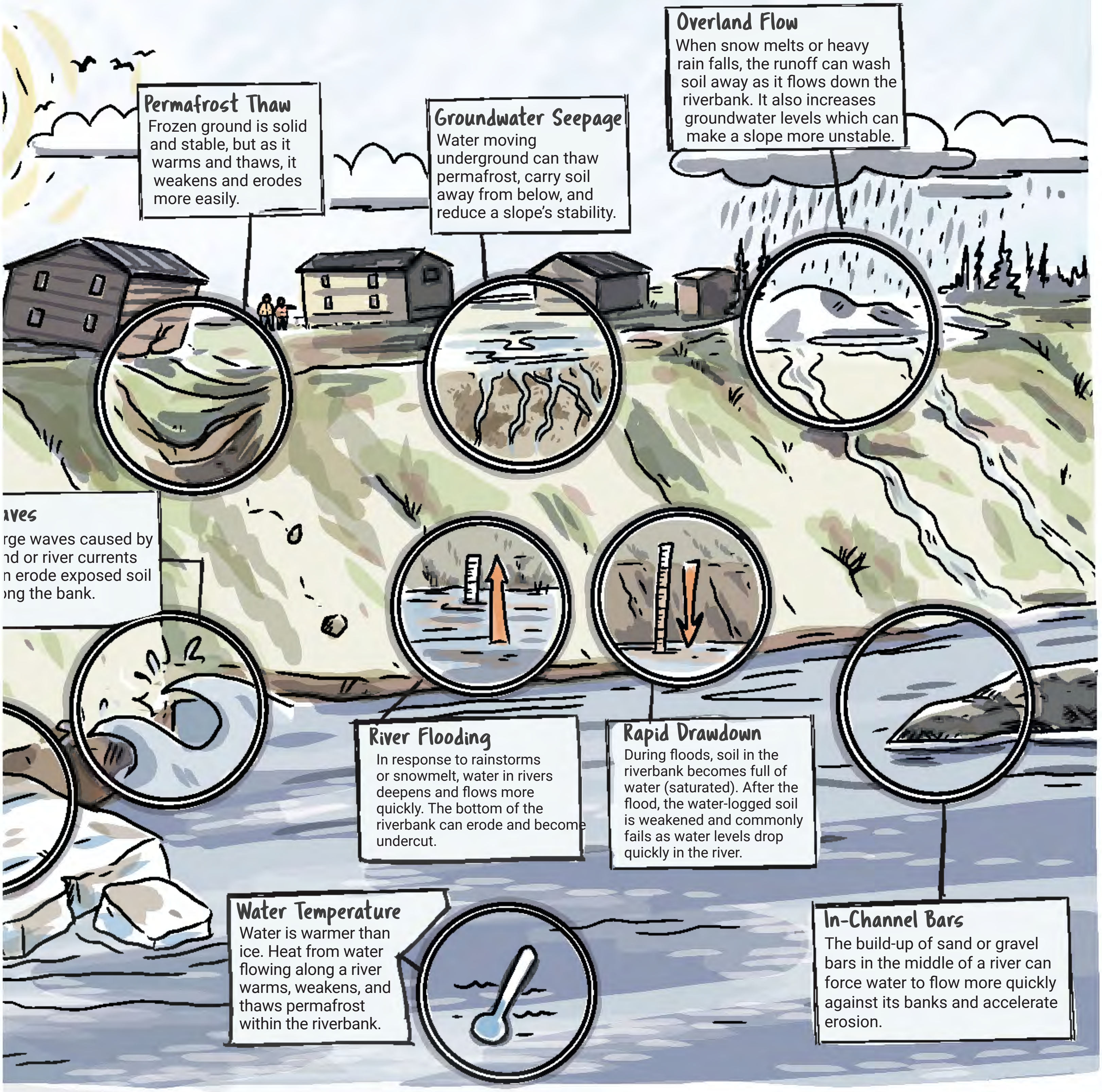
Riverbank stability is influenced by a combination of natural forces and local conditions. Erosion plays an important role, but so do changes in groundwater, temperature, and permafrost. These factors often interact—when one changes, others are affected. This diagram shows some of the common causes.

Climate change is increasing the risk of riverbank instability in many areas by:

- Causing more frequent and extreme weather events such as storms, floods, and droughts.
- Thawing permafrost, which weakens the ground and makes slopes less stable.
- Extending open-water seasons and reducing protective ice cover.
- Changing ice jam and flood behaviour, which can suddenly erode or undercut slopes.

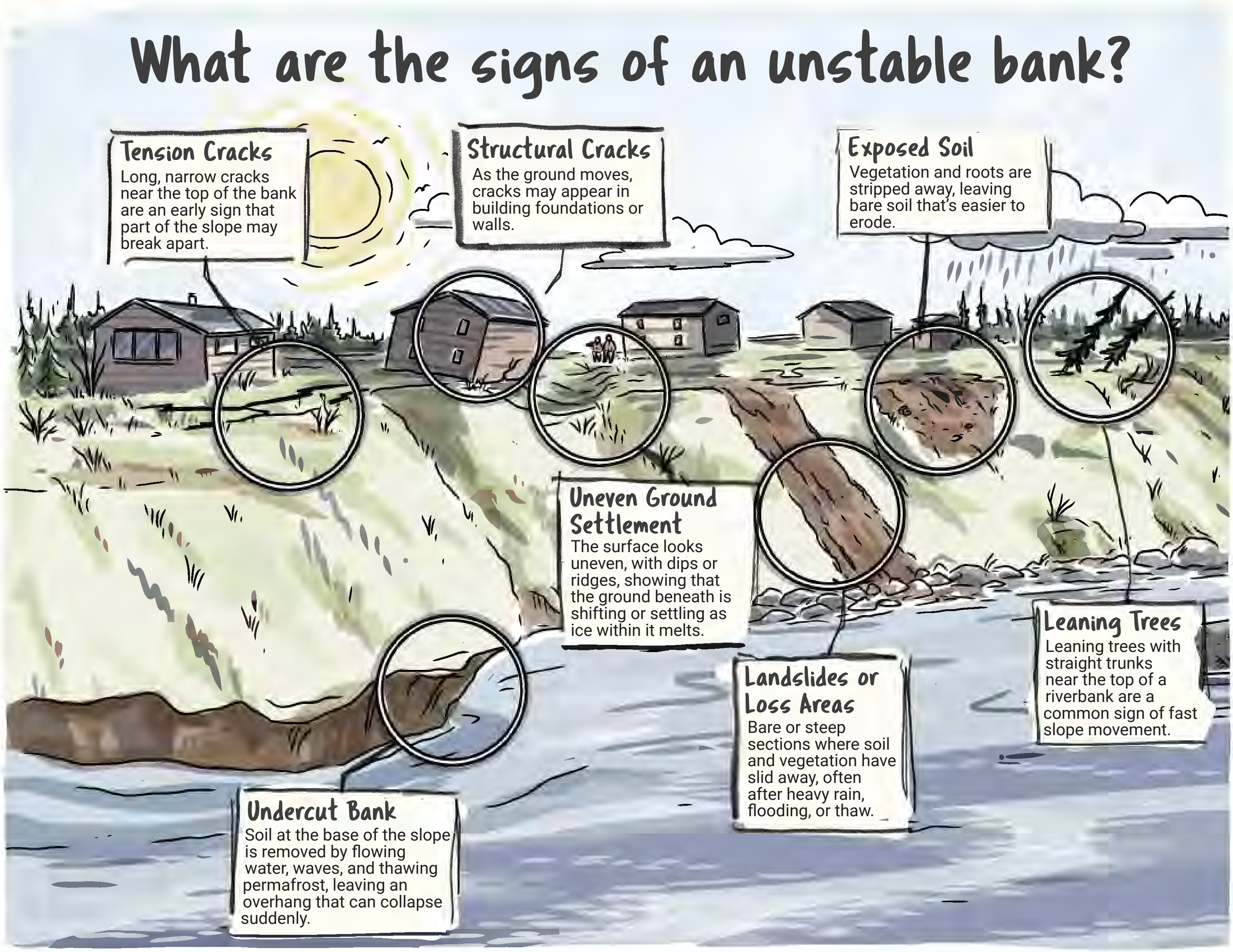


Why is the riverbank changing?



What are the signs of an unstable riverbank?

If a riverbank is becoming unstable, we might see clear signs like landslides, or more hidden ones like cracks in the ground or trees that start to lean over. This diagram highlights some of these factors.



2

Manage the Threat Right Away

Dealing with Riverbank Instability

Draft

What to do if you see signs of instability

- **Talk to people in your community.**

  Ask how the area has changed over the years. Has the riverbank moved? Have new cracks or slides appeared? Have buildings near the bank started cracking or showing other signs of movement? Local knowledge can help you understand whether stability is getting worse and how great the threat might be.

- **Take photos.**

  Use your phone to take a few quick photos of the site. These photos can help you share your concerns with others. They will also allow comparisons to be made as conditions change in the future, so those helping to find solutions can tell how quickly conditions are worsening..

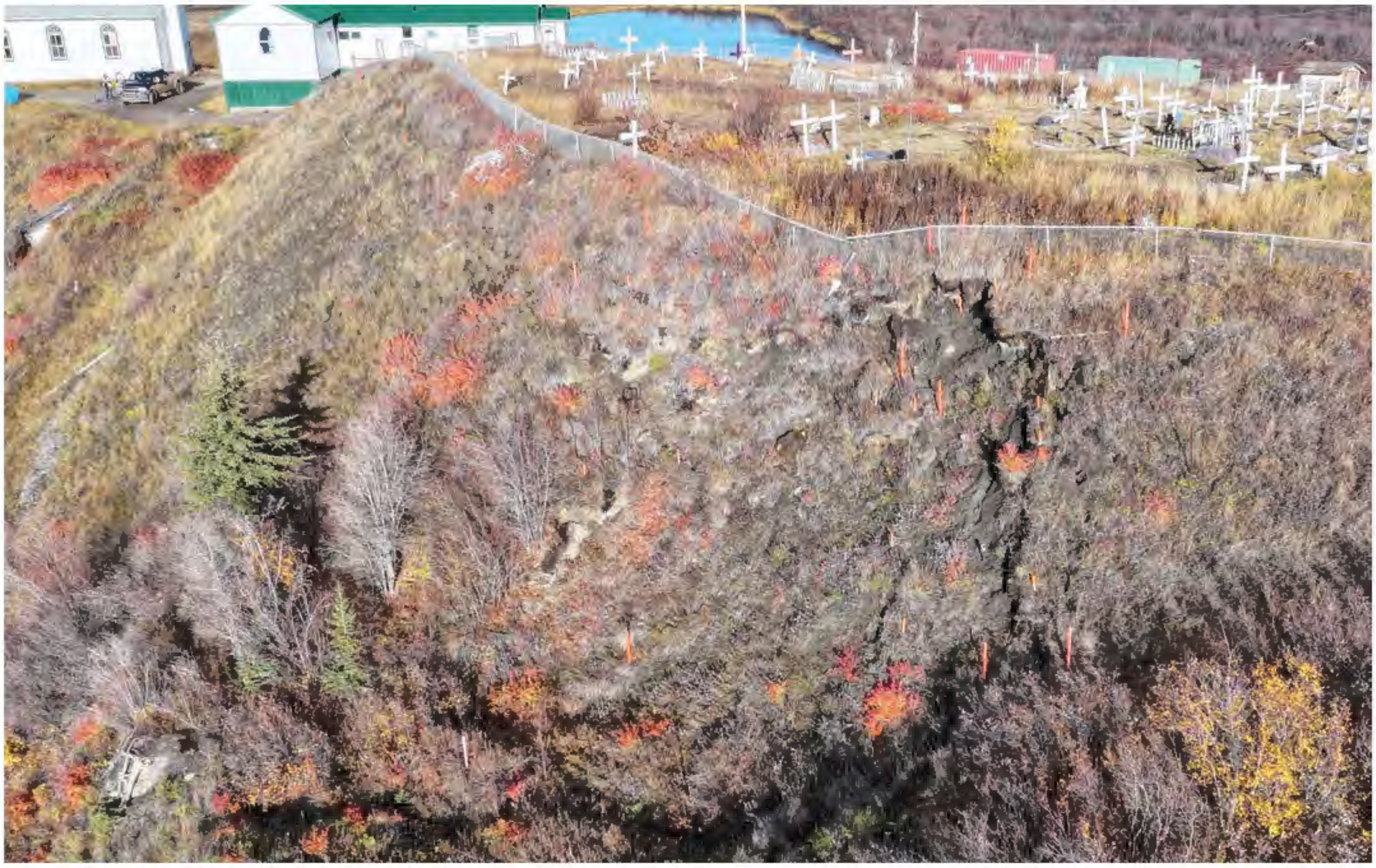
- **Reach out for advice.**

  Contact organizations that have experience with or responsibility for riverbank stability. The Government of the Northwest Territories' Department of Municipal and Community Affairs (MACA) should be one of your first points of contact. Regional offices have experience and knowledge of these issues. Other organizations such as the Northwest Territories Association of Communities (NWTAC) or technical specialists can offer guidance, connect you with specialists, and help you plan next steps.

Notes

One of the biggest problems communities have when dealing with riverbank erosion is that it takes a long time to be addressed and people involved tend to switch jobs. This means that valuable knowledge is lost and projects stall or work gets repeated.

That's why its so important to take notes, save your files, store any photos, and pass the information along to someone else! Because when you leave, you don't want all your hard work to go to waste.



Short-term actions to reduce risk

If you think there is a risk to people, property, or infrastructure, you can take steps right away to reduce the danger while longer-term solutions are developed.

- **Monitor the site.**

  Visit the area regularly, especially after heavy rain, flooding, or spring snowmelt. Take photos and notes to track changes over time — this helps you understand how serious and urgent the situation is.

- **Use temporary or "Band-Aid" solutions.**

  Take steps to stabilize the area and keep people safe. This might include:

  - Reinforcing or shoring up foundations in danger
  - Keeping people and vehicles away from the slope
  - Removing snow piles near the edge
  - Diverting surface runoff away from the bank
  - Filling tension cracks

- **Prepare a risk mitigation plan.**

  If there is a serious risk — for example, from an ice jam, potential flood, or heavy rain — have a clear response plan. Community Emergency Response Plans commonly do not provide the details needed for infrequent or seasonal issues like riverbank stability. In a mitigation plan, identify what triggers the plan (high water levels, extreme heat, etc.) and what steps need to be taken: increased monitoring, who to contact, what areas are most at risk, and what actions can be taken quickly to protect people, property, and infrastructure. *Be sure to also communicate the plan to the community! They need to know the risk and what to do!*

3

Gather and Assess Initial Information

Evaluating Riverbank Instability

Draft

Caption:

What is a preliminary assessment?

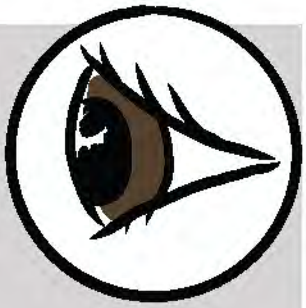
A preliminary assessment is usually completed by one or more technical specialists, such as geotechnical engineers, geomorphologists, water resource engineers, ecologists, or permafrost scientists.

Through this assessment, the specialists will:

- Review and analyze existing data and information to understand how the site has changed over time.
- Attempt to identify the main causes and patterns of instability.
- Estimate, where possible, how long it may take before a stability issue impacts people or infrastructure.

Notes

Technical specialists can often learn a lot without visiting the site. Old reports/studies, maps, aerial/satellite images, and photos provided by the community are all valuable sources of information. However, depending on the situation, a site visit may be needed to complete the assessment. If you are dealing with an erosion issue, a lot can be learned by looking at past changes in the river, but if it's a slope stability issue, it is often best to be physically present.



Collapse of undercut riverbank due to thawing and erosion of permafrost by high flows along Engineer Creek, Yukon

Who Does What: Understanding Technical Specialists

Different specialists bring different kinds of knowledge to an assessment. Depending on the situation, you may need one or more of the specialists listed below.

Geotechnical Engineers

These engineers study the stability and strength of soil and rock. They help determine how stable a slope is, how much it might move, and what kind of foundations or structures would be safe. They are often the lead specialists when erosion or slope failure threatens buildings or infrastructure.

Geomorphologists

Geomorphologists study how landscapes and riverbanks change over time. They can explain why erosion is happening, how quickly it might continue, and where the river could move in the future. Their work helps identify long-term trends and high-risk zones. Geomorphologists understand the movement of sediment in river systems and can help size riprap or other materials for erosion control.

Water Resource Engineers

These engineers focus on how water moves through developed and natural landscapes — including flow rates, floods, drainage, and ice. They are the right people to call if the main problem involves flooding, changes in river flow, or local drainage that is contributing to erosion. Water resources engineers also size riprap or other materials for erosion control.

Permafrost Specialists

These scientists study frozen ground and how it responds to warming, water, and disturbance. They can help determine where permafrost still exists, how fast it is thawing, and what can be done to keep the ground stable. They are especially important in areas where thawing permafrost is causing slumping or uneven ground.

Ecologists

Ecologists look at how plants, wildlife, and habitats interact with the land and water. They help identify areas with sensitive vegetation, fish habitat, or protected species that might be affected by erosion or by the work needed to control it. They also help recommend restoration and revegetation options and how and when to apply for permits.

How to contract a preliminary assessment

Before hiring technical specialists, you'll need to develop a scope of work — a short document that outlines what the assessment should include.

Developing a scope of work

- ❑ The scope of work helps everyone understand what will be done and ensures the specialists focus on your community's priorities.
- ❑ Keep it realistic. A smaller, focused assessment can save money and still give you useful results.
- ❑ Get advice from others who have done similar work. Reach out to:
  - GNWT's Department of Municipal and Community Affairs (MACA) Regional Offices
  - Other communities that have dealt with stability issues
  - The Northwest Territories Association of Communities (NWTAC)
  - Planning or engineering consultants experienced in northern stability projects

You can approach this in two ways:

1. Write a detailed scope of work yourself.

- Best if you already know what you need or have technical support.
- Clearly outline what tasks you want done and what information you need back.

2. Ask potential consultants to propose a scope of work.

- Explain your situation and ask:
  - What do you think should be done?
  - Why is that the best approach?
  - Can you do the work, by when, and how much will it cost?
- This approach lets you compare proposals and choose the best option.

Requesting Proposals from Consultants

Consultants and technical specialists regularly write proposals for projects prior to getting a contract and do not need to be paid for this work. Their business model expects that not all proposals will turn into paid work. Asking multiple potential consultants to prepare a proposal is okay!

Be upfront about your expectations, budget, and the process for evaluating proposals so they can choose whether to invest the time and effort in a proposal.

However, in the early stages of a project when the costs are relatively small and the scope is uncertain, it is often best to work directly with a trusted specialist.

Requesting proposals and awarding a contract

- Always request proposals from multiple consultants so you can compare costs, timelines, methods, and experience (especially in the North!).
- Keep in mind that the lowest bid is not necessarily the right bid for the challenge facing your community; be sure to consider other elements of the proposal as well.
- Outside support, such as the NWTAC or planning consultants can assist with reviewing proposals.
- It's often best to work step by step — completing smaller pieces of work as funding becomes available and plans become clearer, rather than trying to do everything at once.

What a preliminary assessment usually involves

A preliminary assessment focuses on reviewing existing data and, in some cases, gathering new information. It may include:

- A desktop review of reports, maps, and imagery.
- An analysis of apparent changes in riverbank position and character, as well as any changes in adjacent land use that may be contributing to instability.
- A site visit or inspection including:
  - Visual checks for signs of erosion or instability (such as tension cracks, slumping, or exposed soil).
  - Conversations with community members to collect historical and local knowledge about how the area has changed.
  - Possible installation of simple benchmarks (e.g. wooden stakes) from which community members can help monitor changes in ground elevation and bank retreat while potential solutions are being explored.

What you receive from an assessment

After the work is complete, the specialists will provide a report that includes:

- An assessment of erosion patterns and rates, along with initial attempts to identify what is driving instability.
- A preliminary evaluation of the level of risk the instability poses to people, property and infrastructure, and the urgency for mitigation.
- Initial recommendations for next steps (e.g., creating development setbacks and regular monitoring) and conceptual text-based mitigation and stabilization options.

How much information do you need from an assessment?

Undertaking site assessment work can be complicated and expensive. But how much information you need depends on what stage of the project you are at. Start simple (desktop reviews with existing data) and gather more as you need it. You may find you need more information later down the road, but you will have a better idea of what you need.

Budget and timing considerations

When planning a preliminary assessment, consider both budget and timing.

- **Budget:**
  - A desktop-only assessment does not need to be really expensive. Depending on the type and amount of background information available it can cost about **$10,000–$25,000.**
  - Adding a site visit usually adds **$10,000–$20,000,** depending on travel distance, field objectives, and the number of staff involved.

- **Timing:**
  - Desktop work can be done any time of year.
  - Site visits are best conducted in the early summer, when the riverbank and its surroundings are free of snow and ice and leafy shrubs or trees have not yet become established. This also tends to be the time when the effects of spring snowmelt, if any, are most obvious.

4

Evaluate Options and Make a Plan

Assessing Options to Address Riverbank Instability

Draft

Caption:

Keep working with your team

At this stage, you'll need to continue working with technical specialists to determine next steps. These might be the same specialists who completed the preliminary assessment, or you may need broader planning or more specialized technical support to help guide decision-making and preparation of funding applications.

Technical specialists can offer valuable knowledge about erosion and slope stability processes and potential solutions, but they may not always have experience with community engagement or long-term project planning. Make sure you have a team with a mix of skills, including technical, planning, and communication expertise.

Scoping and evaluating options

Working with your team, the first task is to define and compare the options for action. This usually includes:

- Developing descriptions of conceptual solutions, supported by simple sketches or diagrams.
- Preparing rough cost estimates for each potential action. Be sure the cost estimator is informed of what resources the community has available in the community (e.g. excavator).
- Identifying and comparing advantages and disadvantages of each option.
- Summarizing results in a clear, easy to understand format that can be shared with leadership and community members.

Sometimes you may find you need more information to evaluate options. More detailed site assessment work (as described in Step 5) may be identified at this point as the next step.

What do Community Planners do?

Work with technical specialists and community leadership to connect science with local goals and decision-making. They help integrate slope stability risk information into community plans, zoning bylaws, and land use decisions so that future development happens in safer areas.

Working with your community

Once options have been developed, work with your community and leadership to decide which approach makes the most sense. You know best how to reach and engage your community, but support is available if you need it.

When discussing the options, consider factors such as:

- **Risk level** – How severe is the threat to people, property, or infrastructure?
- **Community preferences and readiness** – Are people open to relocation or other major changes?
- **Effectiveness** – How confident is the team that the option will solve or reduce the problem?
- **Costs** – What are the up-front and long-term maintenance costs?
- **Logistical constraints** – How practical is the option given your local capacity and conditions? (e.g., how available is good quality rock for riprap)
- **Environmental impacts** – Will the option affect fish habitat, vegetation, or water quality?

You may also need to connect with regulators, funders, and territorial government departments to understand what permits and approvals may be required and what funding supports may be available.

Key reminders

Tip: Tables or worksheets can be useful when comparing different options. An example evaluation table is provided in the Appendix and can be adapted for your community's needs.

- **Request plain language communications.**

  Slope stability issues and engineering solutions can be highly technical. Ask your consultants to provide clear, plain-language explanations and summaries as part of their deliverables, even if there is a professional requirement to document complete technical details in their report. This ensures everyone can understand the findings and options being discussed.

- **Stay connected with property owners.**

  People who live or own property in the affected areas are often the most impacted. Keep them informed and involved throughout the process.

Active erosion along the outer bank of a meander of Engineer Creek, Yukon.

Captions:

Action planning

Once your community and leadership have selected a preferred option:

- Work with your technical and planning team to outline how this option will be implemented.
- Identify the steps, responsibilities, and timelines needed to move forward.
- Determine whether more technical or planning support is required based on the complexity of the chosen approach.

Securing funding

Most actions will require additional funding. Finding and applying for funding can take time, but it is much easier when you have a clear, well-organized plan. Results from the preliminary assessment can also help communicate the urgency of the problem to funders.

- Look for opportunities to fund the next stages of work — for example, more detailed design or risk assessments (as described in Step 5).
- Smaller, short-term funding can help move the project forward by allowing you to develop strong proposals with accurate budgets for future phases.
- Work with NWTAC, government departments, or funding program staff to identify suitable sources and ask for guidance.
- If risk mitigation work is not urgent, consider contacting a university to explore the possibility of involving a graduate student for the site investigation, which may save money.

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(Part 1 of 2)

Put the Plan into Motion

How to Implement Riverbank Instability Decisions

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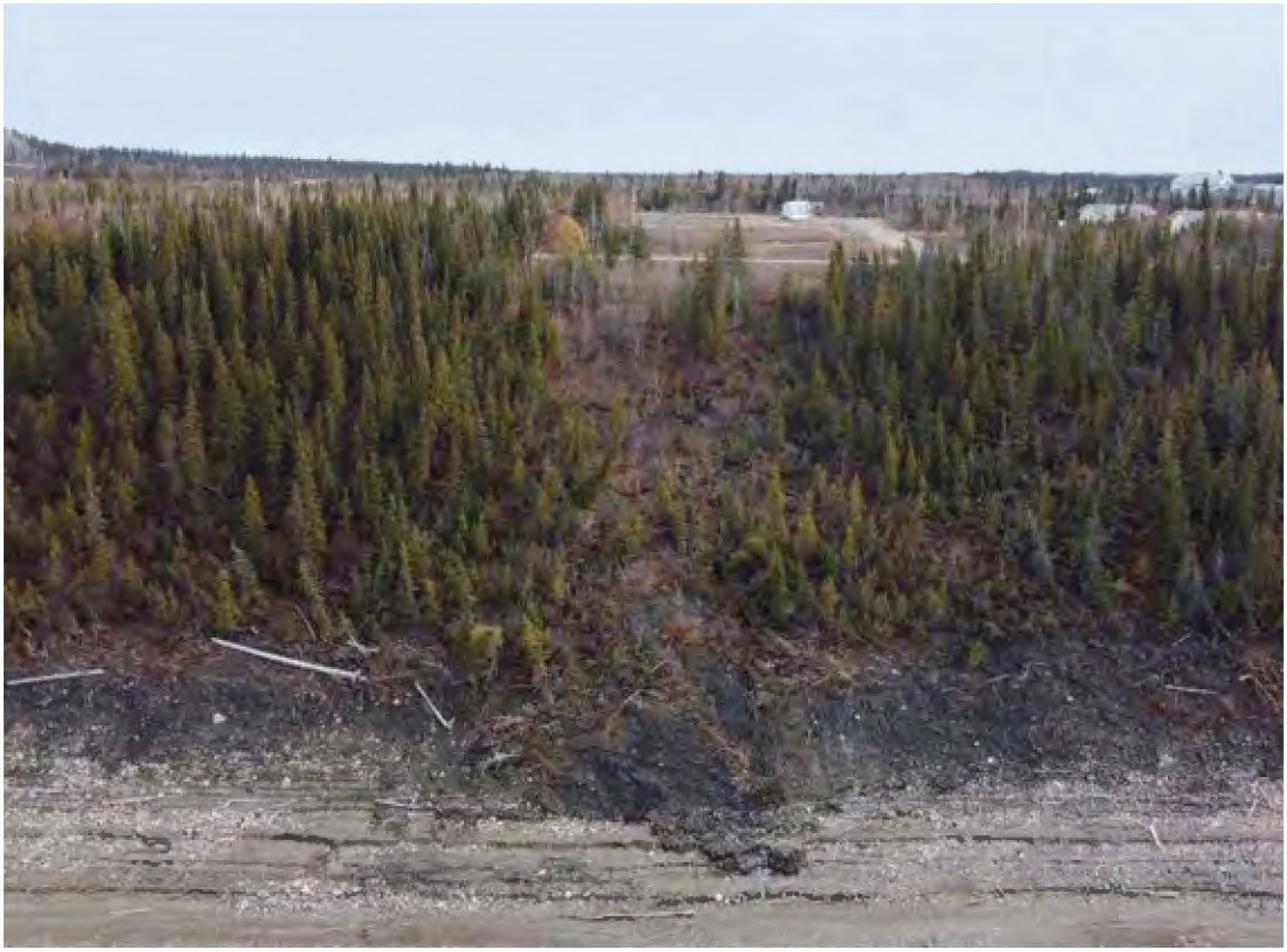


Captions:

Section 1 – How to Take Action

Every slope stability project is unique. The steps for stabilizing a slope, for example, will be very different from the steps for relocating a building or moving a road.

During **Step 4 (Evaluate Options and Make a Plan)**, your team will have developed a more specific action plan for your chosen approach. Even so, most projects will include the following general components:

Detailed Site Assessment

Before advancing designs or applying for funding, it's important to gather detailed information about the site. This will help develop the project design, improve cost estimates, and strengthen funding applications.

Note: Some of this work may need to happen during Step 4 to support funding applications and work planning.

Caption:

Depending on what was completed in earlier assessments, additional site work may include:

- **Visual inspections** for ongoing erosion and instability (for example, cracks, slumping, or leaning trees).
- **Drone surveys** to create detailed topographic maps (digital elevation models; DEMs) of the area. In some cases, a ground-based topographic survey (using GPS or total station equipment) may also be required.
- **Geotechnical drilling or test pits** to collect soil samples and assess ground ice. Laboratory testing helps determine soil type, strength, and chemical makeup — including whether there are any contamination concerns.
- **Install monitoring instruments,** such as piezometers (to measure water levels), inclinometers (to measure slope movements), or thermistors (to measure ground temperatures).
- **Geophysical surveys** (such as Ground Penetrating Radar or Electrical Resistivity Tomography) to better understand underground conditions. These can be useful for identifying bedrock or major layering in soils and the presence or extent of massive ice in permafrost.
- **River measurements or bathymetric surveys**, if the solution involves hydraulic (flood) modelling or placing materials (such as riprap) in or near the water.
- **Ecological Surveys** to document fish habitat and vegetation that may be impacted by the project, and to identify any opportunities for enhancement.

After collecting this information, all data should be compiled and analyzed to inform the design.

Design Preparation

Engineering design is the process of turning ideas into detailed plans that can be built safely and effectively.

- Designs are typically developed in stages:
  - **Concept design (about 30%)** – early sketches or layouts used to explore general approaches.
  - **Preliminary design (about 60%)** – includes more detail on materials, methods, and costs.
  - **Detailed design (90–100%)** – final drawings and specifications used for tendering and construction.

A detailed design is required before any construction can move forward but you may not always go to that extent right away. For example, you may decide to prepare concept designs to help apply for further funding or continue scoping a project.

Permitting

Depending on the type of work, permits and approvals may be required before starting construction.

For example, if the project involves adding materials below the normal high-water mark (such as riprap or fill), it may require a Fisheries Act Authorization. At a minimum, any proposed in-water works will require submitting a Request for Review to Fisheries and Oceans Canada (DFO). If DFO determines that the proposed works are likely to harm, disturb, or destroy fish habitat, additional permitting requirements will be needed such as offsetting the impacts by creating or enhancing fish habitat elsewhere.

Important:

Permitting processes can take a year or more and may increase planning and reporting costs. Build these timelines into your work plan early to avoid delays or costly surprises.

Implementation

Once you have:

- A final design,
- The necessary permits, and
- Funding in place,

...you can begin construction or other on-the-ground work.

At this stage, it's critical to ensure proper project oversight. Depending on the scale or complexity of the project, you may need dedicated construction administrator to coordinate consultants, track progress, and manage budgets. This should be included in your work plan and budget from the start.

At a minimum, a member of the design team should be on-site at key milestones over the course of construction to ensure works are built as designed. This also allows the lead designer to sign off on the work, once completed, which is a requirement of DFO and may also be a requirement of funders.

Caption:

Contracting Considerations

As with earlier steps, each project should begin with a clear scope of work. This ensures everyone understands what is expected, the schedule, deliverables, and responsibilities.

A carefully worded set of construction specifications helps:

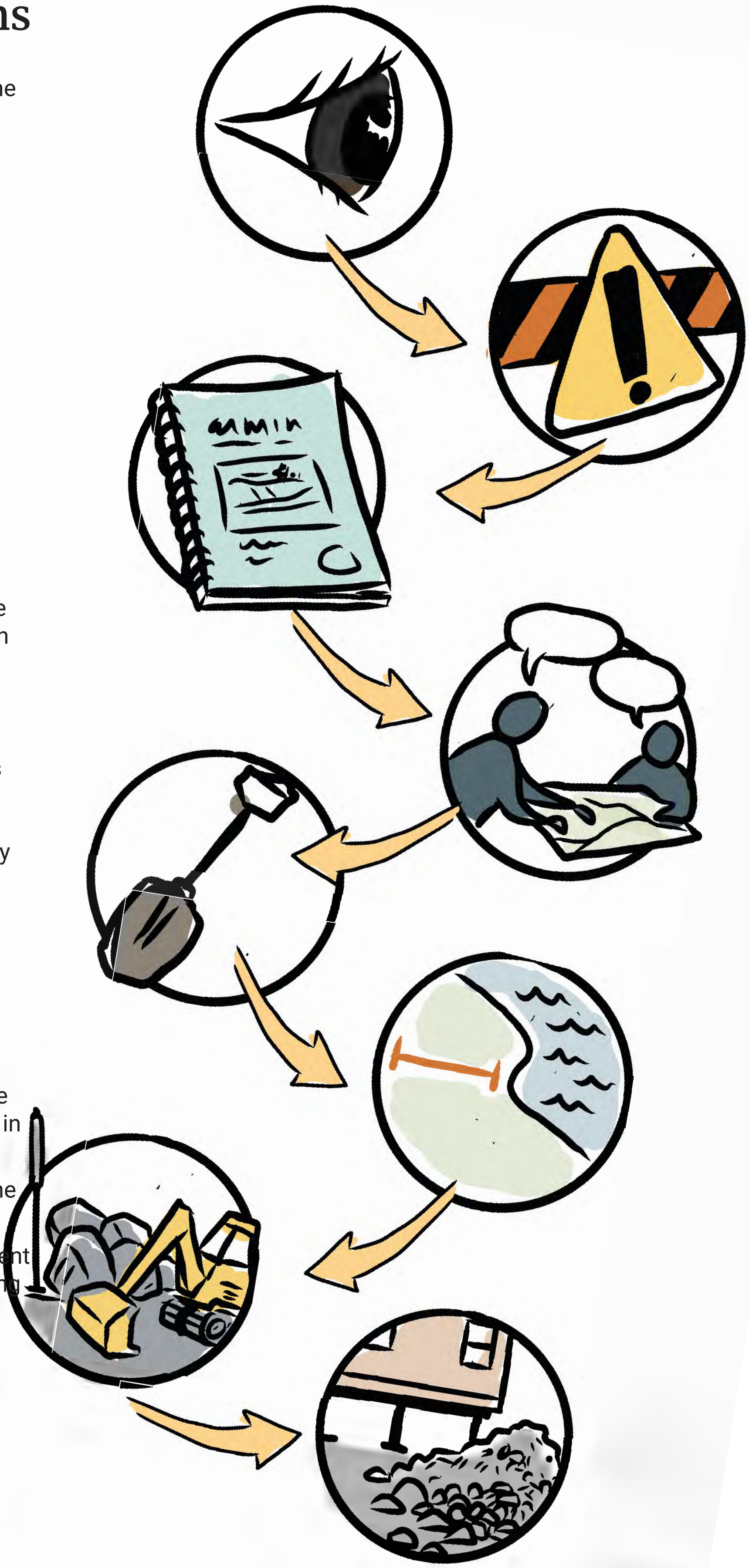
- Prevent confusion or cost overruns,
- Ensure quality control, and
- Keep the project on schedule.

Post-Construction

Before the work is completed, it's important to plan for how the project will be monitored and maintained over time.

Key activities may include:

- **Monitoring:**
  - Conduct repeat visual inspections and take photos from the same vantage points each time.
  - Use drones or satellite imagery to track ongoing changes along the riverbank.
  - Consider installing monitoring instruments to record movement, ground water levels, or ground temperature, if needed. Some may require data downloads by community members; others may be able to send data via satellite.
- **Maintenance:**
  - Plan for long-term access to the site (for example, through an easement). Avoid placement or reconstruction of structures within the hazard zone alongside the riverbank, where possible, in case there are failures that go unnoticed or unaddressed in the future.
  - Schedule regular maintenance to ensure the structures continue to work as planned.
  - Address any emerging issues early to prevent new problems from developing or becoming worse.



5b

(Part 2 of 2)

Types of Action

Approaches to Address Riverbank Instability

Draft

Captions:

1. Giving the River Space

Giving the river space means avoiding development or activity close to the riverbank, allowing the river to naturally erode and shift over time. This approach recognizes that rivers are dynamic — they move, bend, and reshape their banks.

In the long term, this is often the most sustainable and cost-effective way to deal with slope stability. It avoids ongoing costs for repairs or protection and lets the river "do its thing" safely, without threatening homes, infrastructure, or cultural sites.

Giving the river space can involve several different actions, depending on your community's situation and priorities.

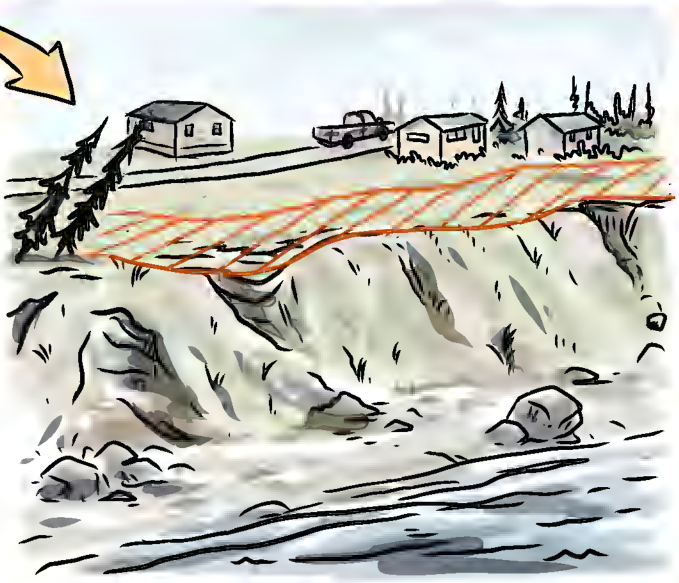
Creating Setback Lines

Setback lines are boundaries that show how close development can safely occur to the riverbank. They create a buffer zone that allows the river to move naturally without posing a risk to buildings or infrastructure.

Setting setback lines can help your community:

- Protect people, buildings, and infrastructure from long-term slope stability risks.
- Reduce the need for costly protection works or future relocation.
- Provide space for natural vegetation that can help stabilize the bank.

Developing setback lines usually involves input from technical specialists (to determine safe distances) and community decision-makers (to establish and apply the policy, locally).



Community Planning and Zoning Bylaws

Community plans and zoning bylaws (or land use plans, in the case of designated authorities) are one of the most powerful tools a community has to give the river space. These plans have the weight of law and determine where and how development can occur.

A community plan can set out a long-term vision for safe development and identify which areas are best left undeveloped due to slope stability or flood risk. Zoning bylaws then put that vision into action, using tools such as setback requirements or buffer zones along the river.

It's also important to think beyond short timeframes. In some communities, slope stability risks may mean rethinking altogether where future growth should happen. This could involve identifying new areas for housing or infrastructure outside hazard zones, rather than assuming that only minor adjustments are needed.

Moving Structures

In some cases, it may be more practical to move a structure than to try to stabilize a failing slope or address erosion below it. Relocation removes the risk entirely and provides a long-term solution.

Moving structures usually involves:

- **Selecting a new site** that is stable and safely away from slope stability risk. This may require some technical assessment to confirm ground conditions.
- **Conducting geotechnical investigations** to design appropriate new foundations.
- **Building new foundations** suitable for the local ground and climate.
- **Moving the structure** to the new location.
- **Reinstalling and finishing** the building on its new foundations.

Before moving a structure, it's important to confirm that it is able to be moved and that suitable relocation sites are available. This requires community input and a structural engineer's assessment.

Challenges may include:

- Building foundations in permafrost conditions, ensuring they will last and remain adaptable to climate change.
- Finding a qualified contractor with the equipment and experience to move structures safely.
- Potentially disassembling and reassembling buildings, which may require additional repair work.
- Cultural or historical considerations, such as opposition to moving buildings with strong emotional or traditional significance.

Despite these challenges, moving structures is a robust, long-term solution that removes the need for ongoing monitoring or costly slope stabilization.

Moving Infrastructure

It isn't only houses and buildings that may need to be moved. Communities may also need to plan for relocating infrastructure such as roads, water lines, or sewer systems that are located close to the river.

For example, a local road built within the riverside buffer may eventually need to be rerouted to protect it from washouts or slope collapse. In some areas, erosion has already exposed buried pipes or cables, creating additional maintenance and safety concerns.

Rethinking infrastructure layout can be complex, but it's an essential part of long-term planning. Coordinating with engineers, planners, and funding partners early in the process can help communities prepare for these changes in a planned and cost-effective way.

Caption:

Moving Cemeteries

In many communities, cemeteries located near riverbanks are at risk from slope stability. While moving a cemetery is extremely sensitive and complex, it may sometimes be the only realistic way to protect gravesites from being exposed or lost.

Key considerations include:

- **Identifying all gravesites**, including those unmarked or unknown. This may require geophysical surveys (such as ground-penetrating radar) and close consultation with the community.
- **Community acceptance,** as relocation of a cemetery is commonly an emotionally difficult process and should only be considered as a last resort.
- **Unidentified remains,** which may not be discovered during investigation, could be disturbed during excavation.
- **Cultural and spiritual impacts** associated with disturbing burial sites.

Although relocation can provide a permanent and stable solution, it must be approached with deep respect, care, and community leadership. The emotional impacts can be significant, even if the practical benefits are clear.

Caption:

Caption:

Abandon and Rebuild

Sometimes, retaining existing structures is not feasible. Buildings may be too old, damaged, or costly to protect or move. In these cases, it may make more sense to abandon at-risk sites and rebuild in a safer location.

This approach can:

- Provide new, more suitable facilities for long-term use.
- Eliminate the need for ongoing monitoring and repairs.
- Allow for updated design standards that better reflect climate and ground conditions.

While it may be difficult to leave behind familiar places, abandoning and rebuilding can offer a clean, cost-effective, and lasting solution for the community's safety and future development.

If structures or infrastructure are abandoned, you will need to consider costs for removal and clean-up of the site to ensure the area is free of contamination.

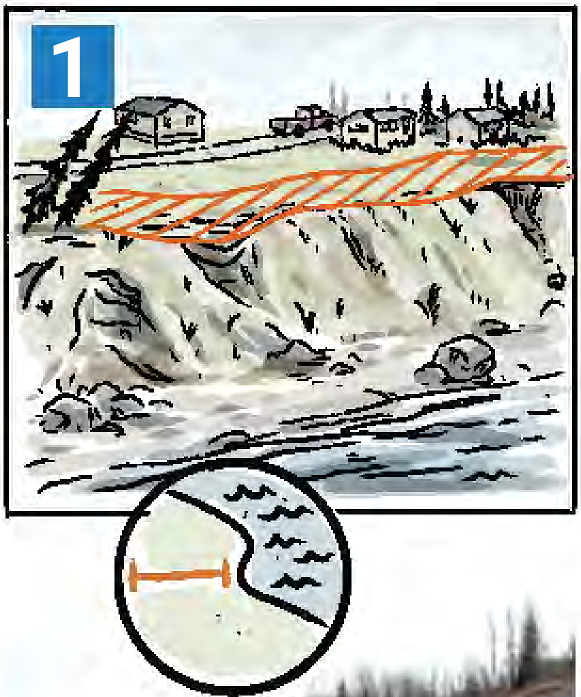
2. Addressing the Issue

Riverbank stability is a complex process. Determining the right course of action to stop or at least slow riverbank stability depends on the specific site conditions and the root causes of the problem. In many northern areas, slope stability is influenced by several interacting factors, including permafrost, slope stability, and river dynamics.

For this reason, actions to "fix" slope stability are grouped into three main categories:

1. **Controlling Erosion**
2. **Stabilizing the Slope**
3. **Managing Permafrost Degradation**

Often, more than one approach is needed to achieve long-term success.



Caption:

1. Controlling Erosion

Erosion control focuses on reducing the force of water, ice, and waves acting on the riverbank. These actions can take place directly at the site of erosion or indirectly by changing water flow patterns elsewhere.

Direct methods are usually more visible and commonly used, but they often only address the symptoms of erosion. Indirect methods tackle the underlying causes and can provide longer-term results, but they can be more expensive and possibly more difficult to get permitted.

i. Direct Approaches

Direct erosion control methods work at the specific location where erosion is happening. Direct erosion control involves increasing the resistance of banks to the erosional forces of flowing water. This is usually done by placing material on the bank that is too large or deep to be washed away. Direct erosion control also aims to slow the flow of water where it comes in contact with the bank, so it has less energy to erode materials.

Potential options include:

- **Planting and bioengineering** – Using vegetation, such as willows or deep-rooted plants, to stabilize the soil. Log structures, such as crib-walls or engineered logjams, can also be used where trees of sufficient trunk size are available. This approach can help in smaller streams or low-energy areas but may have limited success along large northern rivers or where infrastructure is at immediate risk.
- **Riprap** – Placing large rock or boulders along the riverbank to absorb the energy of waves and flowing water. Riprap is one of the most common methods because it provides immediate protection and is relatively straightforward to install. It can be combined with planting and bioengineering methods for added stability and benefits to aquatic habitat. Riprap is a more flexible or adaptable treatment than harder structures, such as concrete walls/slabs or rock walls (below), because the rocks can settle and adjust while remaining stable despite minor changes in underlying soil. Hydraulic calculations by a river engineer or geomorphologist are required to ensure riprap is sized appropriately for a given site. A geotextile (filter fabric) is commonly used as a filter layer beneath riprap, so fine sediments in the soil are not washed away among the stone. It is not uncommon to see the fabric flapping in the current after some areas of the riprap have slid off, but a sand-gravel filter bedding layer is now considered more appropriate.
- **Rock walls** – Layering relatively flat blocks of blast-rock to form a low, steep, terraced wall at the toe of a riverbank. Rock walls must be designed to be self-supporting, but they are more subject to undermining and collapse than riprap.
- **Sheet-pile walls** – Interlocking pre-made metal walls that are pounded into the ground to create a wall at the base of a slope to hold back soil.

Direct methods are often used as short- to medium-term solutions. While they can protect a bank from further damage, they do not fix the root causes of erosion and may need regular maintenance. Degrading permafrost in the bank can pose long-term challenges to the performance of direct methods.

Several important considerations must be given to the use of direct methods for erosion control:

- **Downstream energy transfer** – In most cases, direct methods result in 'hardening' of a riverbank that is otherwise made up of soils. Direct methods may also reduce bank roughness if natural hollows and bumps and vegetation are removed. Both have the effect of transferring energy downstream. As a result, it is common that erosion control in one area simply shifts the problem (downstream) to another area. The best way to combat this unintended effect is to build erosion control with rough areas.
- **Outflanking potential** – A common reason for at least partial failure of erosion control structures along riverbanks is outflanking. The structures must be placed far enough into the bank at their upstream or downstream ends so that water does not wash away soil and attack them from behind.
- **Embedment** – Another way erosion control structures commonly fail is by undermining. Water flows quickly along the base of hardened banks, and this can scour (erode) the bed. It is important for erosion control structures to be embedded, or founded, deeply enough that they are not at risk of being undermined.

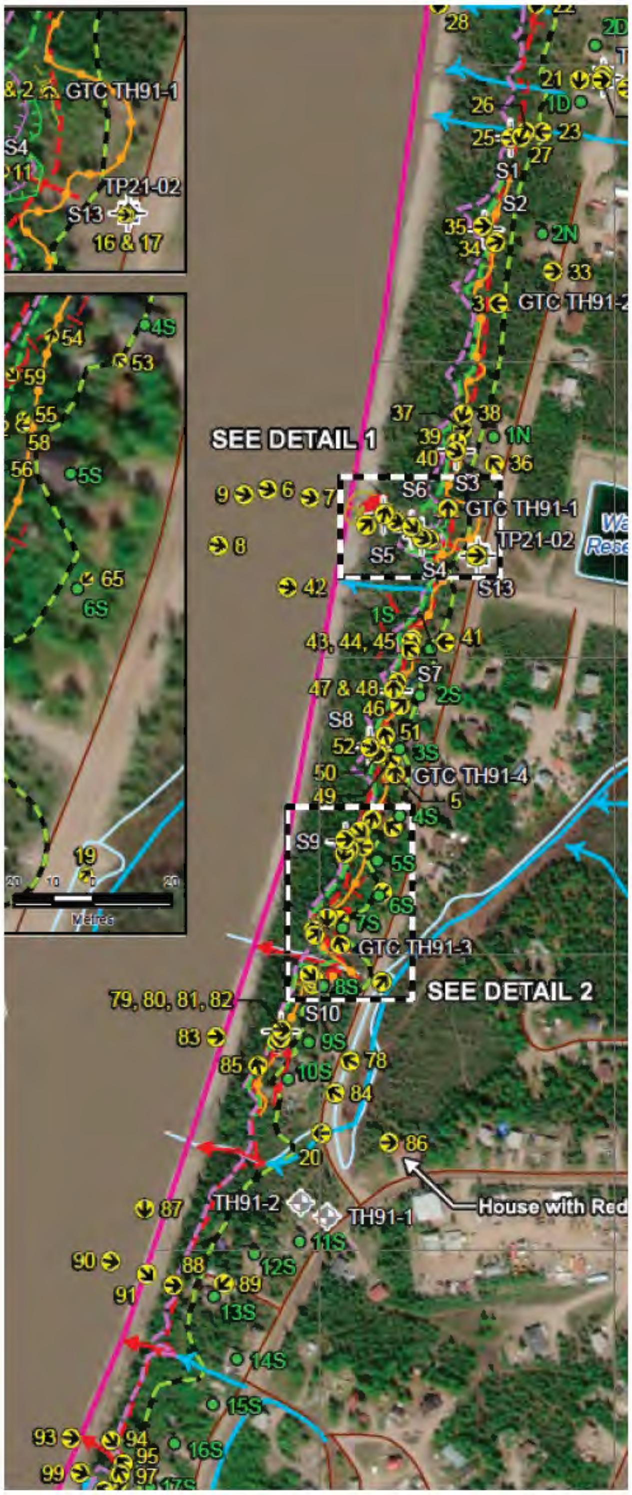
ii. Indirect Approaches

Indirect erosion control methods focus on changing how water moves near or along the site, often by addressing the drivers of erosion upstream or nearby. These approaches aim to reduce forces on the eroding bank itself.

Examples include:

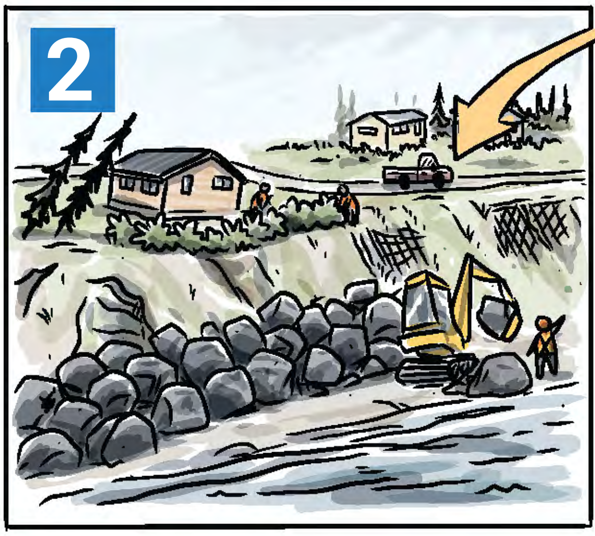
- **River training** – Building small rock or log structures (such as barbs or bendway weirs) to redirect the main river flow, or thalweg, away from the eroding bank. A series of small, engineered logjams could have a similar effect. These structures help shift the energy of the current and any scouring away from the eroding bank.
- **Channel realignment** – Modifying or redirecting smaller creeks or side channels that are causing local erosion. This option can provide a more permanent fix but usually requires significant design work and approval from regulators such as Fisheries and Oceans Canada (DFO).
- **Dredging sand/gravel bars** – Removing sections of sand/gravel bars that are forcing fast-moving water toward the bank. This can help redirect flow and reduce local erosion, especially if the bars are unlikely to reform quickly, but it may also not be viewed favourably by DFO.

Indirect methods can take longer to plan and implement because they will require more regulatory and permitting processes, but often offer more sustainable, long-term results than on-site protection alone.



Caption:

Note Work with technical specialists and community leadership to connect science with local goals and decision-making. They help integrate slope



Caption:

2. Stabilizing the Slope

Slope instability can develop when soil loses strength, permafrost thaws, or the river erodes the base of the bank. One way to manage these problems is to use slope-retaining structures — engineered systems designed to hold soil in place and prevent it from sliding or collapsing.

While these structures can help maintain permafrost in some cases, they do not depend on it. Slope retaining structures are widely used in both northern and southern regions to stabilize slopes and protect infrastructure such as roads, buildings, or utilities.

Because many erosion problems in northern communities involve both permafrost and riverbank processes, it's important to consider how the chosen structure will interact with the local ground and climate conditions.

Key Design Considerations

When planning a slope-retaining structure, several factors need to be considered:

- **Type of structure** – Different systems work in different situations depending on soil type, slope height, and available materials.
- **Drainage** – Water must be directed safely away from the back and base of the structure to prevent pressure buildup or erosion.
- **Foundation depth** – The structure must be set deep enough to stay stable, even if river scour removes soil at the toe of the slope.
- **Upstream and downstream limits** – A common reason for failure of retaining structures along riverbanks is outflanking at their upstream or downstream end.
- **Access for construction** – The site must be reachable by equipment without causing further damage or instability.

Advantages

- Provides a durable, long-term solution that does not rely on keeping permafrost frozen.
- Can often use local materials, such as rock-filled (gabion) baskets or modular blocks.
- Helps hold back unstable soil and protect structures located upslope.
- Suitable for areas that need the most robust and permanent mitigation.

Limitations

- Must have a strong and stable foundation, which may require deep piles or anchoring into bedrock. This can be expensive and may need specialized equipment and expertise.
- Generally more costly to design and build than other methods.

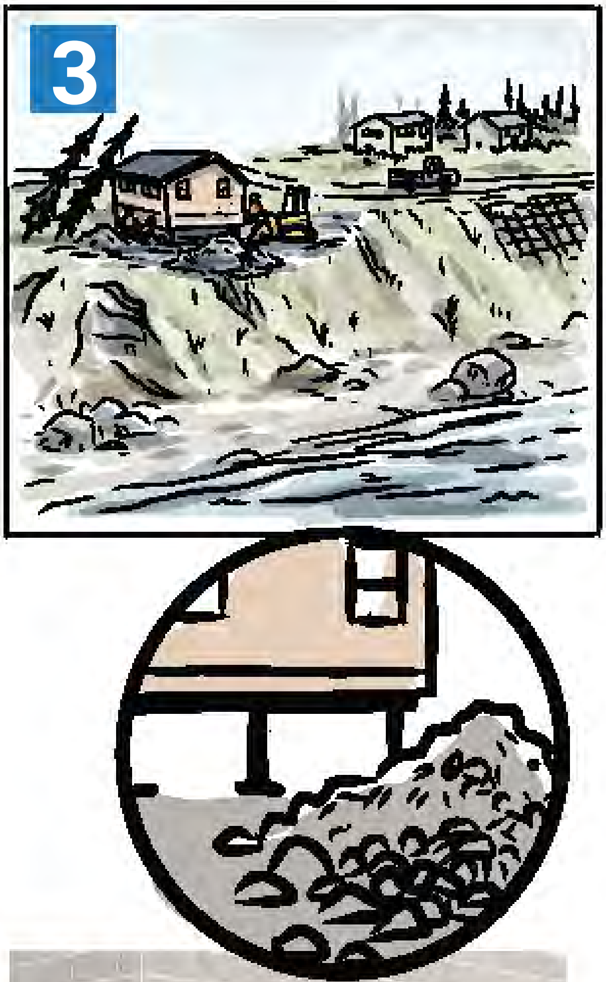
- Requires construction access along the slope for equipment and materials, which can be challenging in steep or sensitive areas.
- In some cases, winter construction is preferred to minimize disturbance, which can increase cost and planning requirements.

Common Types of Slope-Retaining Structures

Several types of systems can be used to stabilize slopes, depending on local conditions and available resources:

- **Mechanically Stabilized Earth (MSE)** – Uses layers of reinforcing materials (such as metal strips or geogrids) within compacted soil to create a stable, self-supporting structure.
- **Sheet-pile Walls** – Vertical steel or composite panels driven deep into the ground to hold back soil and prevent erosion along steep banks.
- **Gabion Structures** – Wire mesh baskets filled with rock or soil, stacked to form a wall. These are flexible, allow drainage, and can be built using local materials. They are best reserved for locations not directly in contact with the river, because fluctuating water levels accelerate rusting and failure of the wire mesh and the release and erosion of the stones from within it.
- **Lock-block Walls** – Interlocking concrete blocks that can be assembled in layers to create strong, durable retaining walls. The walls can be up to about 3 m tall without more reinforcement.
- **Toe Berms** – A toe berm is a layer of rock or gravel placed at the base (toe) of a slope to add support to the soil above.
- **Flattening the Slope** – Reducing the steepness of a slope spreads the weight of soil over a larger area, lowering the potential for slumping or collapse.

Caption:



Caption:

3. Managing Permafrost Thaw

In many northern communities, permafrost is one of the reasons that riverbanks stay stable – they're frozen in place! That is why permafrost thaw is one of the main drivers of riverbank instability. Permafrost degradation occurs naturally along many riverbanks, but climate change is increasing its rate and extent. As permafrost warms and thaws, the ground weakens, water moves more freely through the soil, and slopes can begin to slump or slide. Managing permafrost degradation is about slowing down thawing and keeping the ground cold and stable.

Below are several methods that can help reduce permafrost thaw and protect vulnerable slopes.

i. Insulating Materials

Insulating materials can be used to reduce heat reaching the ground surface and underlying permafrost. These materials can be natural, such as wood chips or soil stabilization mats, or synthetic, such as expanded or extruded polystyrene (Styrofoam) insulation.

Surface treatments like wood chips or mats provide shade, reduce water infiltration, and allow vegetation to regrow. Buried insulation layers can further reduce summer heat and help maintain more stable ground temperatures.

Advantages:

- Reduces solar heating and water infiltration, keeping slopes cooler and drier in summer.
- Can often be installed and maintained by local labour with minimal training.
- Soil stabilization mats support natural revegetation, helping slopes blend back into the environment.
- Materials are lightweight, reducing added stress on unstable slopes.
- Generally a low-cost, low-tech option for moderate-risk sites.

Limitations:

- Effectiveness is limited on steep slopes, where major thaw slumps or slides are already active, or below high-water levels where they will be washed away.
- Insulating materials can also trap heat in winter, slowing natural ground cooling. To reduce this risk, installation should happen in spring before thawing begins.
- Organic materials can decay and release heat, while dry materials may increase fire risk.
- Materials need to be secured in place using fencing, ground pins, or other methods and require regular maintenance.
- Often a short- to medium-term solution, best used to slow thawing while planning longer-term actions or relocations.

In areas, of warm, degrading permafrost, insulation will usually do more harm than good.

ii. Air Convection Embankments

Air convection embankments, or ACEs, are large layers of rock placed on a slope to help keep the ground cold. They work by allowing cold air to move through the spaces among the rocks in winter while trapping that cold air in summer. This process helps remove heat from the ground, slowing or stopping permafrost thaw.

In addition to cooling the ground, the weight and structure of the rock layer can help hold the soil in place and make the slope more stable.

Advantages:

- Helps cool and preserve permafrost over long periods.
- May provide extra stability for slopes that are already moving.
- Can use locally available rock and community labour for construction.
- Offers a long-term, durable solution if designed and built properly.

Limitations:

- Requires a large amount of big rock and heavy equipment, making it one of the more expensive options.
- Needs good access for hauling and placing rock along the slope.
- Works best when shaded or combined with other methods, such as shade boards.
- If snow or fine soil fills the spaces among rocks, the cooling effect is reduced, so periodic inspection and maintenance are needed.
- The slope must be stabilized otherwise the weight of the rock blanket may cause additional stability issues.

Overall, air convection embankments are a strong, long-lasting solution where budgets and access allow, but they may not be practical for all sites including many riverbanks where frequently inundated by sediment-rich floodwater.

Captions:

iii. Thermosyphons

Thermosyphons are metal pipes installed in the ground that help move heat out of the soil and release it into the air. They contain a pressurized carbon dioxide that circulates naturally between the ground and the cooler air above. In winter, the system draws heat out of the soil and helps the ground stay frozen.

Thermosyphons are commonly used in northern infrastructure, such as under buildings or roads, to keep the ground cold and prevent damage from thawing. They are often used in combination with insulation, which stops heat penetration in the summer while the thermosyphons remove heat in the winter.

Advantages:

- Actively cool and refreeze the ground, helping preserve permafrost.
- Can reduce the risk of slope movement and thaw slumps.
- Work well over long periods, even as the climate warms.
- Can be connected to refrigeration systems for additional cooling if needed.

Limitations:

- Does not address erosion, which may compromise the installation.
- Installation may require drilling, which can be expensive and difficult on steep slopes.
- Multiple units are needed to protect large areas, increasing cost.
- Above-ground pipes are visible and may not be preferred in prominent community locations.
- Installation may disturb the slope and require additional erosion control or landscaping afterwards.
- In some cases, added freezing can cause frost heave, which could affect nearby structures.

Thermosyphons are best suited for protecting high-value or critical sites where long-term ground stability is essential and where the risk of the riverbank collapsing can be addressed.

3. Protecting Structures

Sometimes, it may be possible to protect or reinforce the foundations of existing structures to make them more resilient to erosion or slope movement.

This approach can help extend the lifespan of buildings or facilities, but it has important limitations. Protection methods do not stop the river from eroding or the ground from shifting, so they may not be suitable where the riverbank is expected to continue moving toward the site.

In many cases, protection works should be combined with other measures that address the underlying erosion or slope instability.

When to Use Protection Measures

Protection approaches may be worth considering when:

- The structure is of high importance or cultural value.
- The building is in good condition and can be safely reinforced.
- The erosion risk is moderate or progressing slowly. Or if erosion control actions are in place or being planned.
- Space or community preference makes relocation difficult.

If the riverbank is moving quickly or the slope is highly unstable, protection measures may only delay the inevitable and will likely cost as much as — or more than — relocation.

Common Protection Methods

Underpinning a Foundation

Underpinning strengthens or reinforces an existing foundation that is no longer fully supporting a building. This method is used when the soil beneath the foundation has weakened or shifted, causing cracks or settlement.

It typically involves:

- Lifting the building slightly off its foundation.
- Installing new piers, piles, or supports that extend deeper into stable ground or bedrock.
- Reconnecting the structure to the new supports to stabilize it.

Underpinning can be complex and expensive. In particular, the ability of the new foundation to resist sideways movement of the soil will need to be

Caption:

considered. It may be appropriate for key buildings that cannot be moved, but costs are often comparable to relocation.

Building a Raft Slab Foundation

A raft slab (also called a mat foundation) spreads the building's weight across a large area of soil. It is a reinforced concrete slab, either solid or grid-like, that helps the structure move more evenly if the ground shifts.

A raft slab does not stop the whole building from moving (downslope, side-to-side etc.) unless it is anchored to bedrock. However, it can reduce cracking and differential settlement by allowing the structure and foundation to move together as a single unit.

Even with these benefits, if soil movement is significant, damage can still occur, and repairs may be impractical or too costly.

Stabilizing the Immediate Area

In some cases, measures can be taken to make the ground around a building more stable, including:

- **Retaining walls** to support soil and prevent further slope movement.
- **Thermosyphons**, which remove heat from the ground to help keep permafrost frozen and stable.

These techniques can help reduce localized instability but do not solve the broader erosion problem.

Caption:

Weighing the Options

Because foundation reinforcement and slope stabilization are often expensive and complex, communities should carefully weigh these options against moving structures to a safer location.

In most cases, underpinning or raft slab construction will cost about the same as relocation — and relocation provides a longer-term, more secure solution.

Combining Methods

- In most cases, no single action is enough to stop riverbank erosion or slope failure. Slopes are often affected by several issues at once—such as permafrost thaw, ground movement, and erosion from water or ice.
- Because of this, the most effective approach is to combine different methods that address each part of the problem. For example, improving drainage can help reduce permafrost thaw, while riprap or vegetation can protect the slope surface. Using a mix of techniques can create a stronger, longer lasting, and more cost-effective solution overall.
- This is why having a good team with different specialities is very helpful!

Monitoring

Monitoring is an important part of managing riverbank slope stability, no matter how serious the problem or what type of actions are being taken. Ongoing observation helps track how quickly a slope is changing, identify early warning signs of failure, and guide when and where further action is needed.

Regular monitoring allows communities to:

- Understand how fast the riverbank is eroding or settling.
- Detect new cracks, slumps, or other signs of instability early.
- Measure how effective existing mitigation measures are.
- Plan for maintenance or additional protection before larger problems occur.

What Monitoring Can Include

Monitoring can range from simple community-based observations to advanced instruments that collect continuous data transmitted by satellite. The right approach depends on the level of risk, available resources, and technical support.

Common community-based monitoring activities include:

- **Installing monitoring equipment** to track changes such as:
  - Slope or riverbank movement.
  - Ground temperature (to detect permafrost thaw).
  - Surface water and groundwater seepage.
  - Movement of structure foundations.
  - Growth of tension cracks or other signs of instability.
- **Taking repeat photographs** from fixed locations to visually track changes over time.
- **Recording field notes or using GPS** to mark locations where erosion or slumping is observed.
- **Periodic site visits** by trained community staff or qualified professionals to review slope conditions, interpret monitoring data, and recommend next steps. The appropriate frequency of these visits will depend on site conditions and the type of monitoring.

Building Community Capacity

Many monitoring tasks can be done locally. Training community staff to take photographs, measure ground temperatures, or record visible changes can provide valuable information between professional inspections. Using local knowledge and consistent record-keeping helps build a clear picture of how the slope is changing over time.

See Appendix for an example of a riverbank slope stability monitoring framework.

NOTES

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