Image credit: Benjamin Jones, USGS.

EXECUTIVE SUMMARY

Climate heating is disproportionately affecting northern regions, with average temperatures in Canada's North rising roughly four times faster than the global average. This heating is disrupting vast ecosystems across the Arctic and threatening the lives, livelihoods, and cultures of Northerners. It is also creating profound impacts below the surface, in ways that will accelerate, and may imperil, our efforts to limit further heating.

This is because surface warming is seeping into the *permafrost*—the massive deposits of long-frozen soil buried beneath the surface—causing the permafrost to thaw. Permafrost thaw changes the local landscape, for example by draining existing lakes or creating new ones (Wilcox et al., 2020), or by causing ground to shift, damaging roads, buildings, and other infrastructure.

Permafrost thaw also leads to significant releases of the heat-trapping gases that cause climate change, as the thawed organic material in the permafrost begins to decay. Such emissions are rapidly growing, as the warming climate thaws more and more permafrost. Permafrost regions are now releasing more carbon than they absorb (Natali et al., 2024; Noor, 2024). And as global temperatures rise, the rate at which permafrost releases carbon dioxide and methane will accelerate.

The vast amount of carbon locked up in permafrost—an estimated 1,500-1,700 gigatons, roughly twice the amount currently in the atmosphere—means that runaway permafrost thaw could eventually become a devastating emissions source. Such an outcome would seriously challenge efforts to keep atmospheric temperatures within a range that can support complex life as we know it.

Unlike emissions from fossil fuels or agricultural activity, which we can reduce or eliminate by switching to other energy sources or by changing agricultural practices, there is no simple fix for permafrost emissions. Once permafrost thaws, emissions will continue for centuries (*Country of Permafrost*, 2022)—an unstoppable climate-cooking cascade. Thus, even if we succeed in curtailing human-sourced climate pollution, the planet's temperature may continue rising, driven by a pernicious permafrost feedback loop.

> *There are ways for the North to take action, leveraging growing knowledge of the mechanisms causing permafrost thaw and emissions and emerging ideas of what can be done about these threats.*

However, there are ways for the North to take action, leveraging growing knowledge of the mechanisms causing permafrost thaw and emissions and emerging ideas of what can be done about these threats.

For example, recent work, summarized in this report, has identified 13 potential interventions that can slow or stop thaw and reduce or delay resulting emissions (Table A). These interventions would help preserve Arctic ecosystems and buy time for the world to reach net zero, arresting any further rise in temperature before permafrost thaw becomes unmanageable.

So far, only three of these interventions—wildfire management, caribou herding, and conservation or restoration of peatlands and wetlands—are already commonly practised, though not yet in ways designed to specifically prevent or slow permafrost thaw. Work on the other 10 is at very early stages. Intervention proponents will need to achieve significant advances if they are to be available in time to be useful.

Meanwhile, Northern rights holders, alongside scientists, practitioners, governments, and permafrost research institutes, are starting to think through the many political, legal, social, scientific, technological, and other issues associated with testing, deploying, and managing such interventions.

TABLE A:

Overview of the assessed interventions

UArctic ID	Intervention	Tech readiness	Scalability	Timeliness	Termination shock risk
1. Interventions with local impact					
44	Enhanced permafrost freezing with air pipes				
-	Snow compaction in winter				
-	Draining of thermokarst lakes/regions				
41	Conservation and restoration of peatlands and wetlands in taiga and tundra				
2. Interventions with regional impact					
37	Wildfire management				
39	Caribou herding				
40	Rewilding of permafrost regions				
-	Engineered methanotrophs				
49	Methane flaring (not industrial)				
3. Interventions with global impact					
20	Arctic winter stratospheric aerosol injection				
21	Cirrus cloud thinning				
22	Mixed-phase regime cloud thinning				
24	Space-based solar radiation management				

Summary of assessments for the 13 potential interventions discussed in the paper. See Section 3 for details.

Indeed, identifying effective interventions addresses only part of the challenge of permafrost thaw. Any program to reduce thaw and preserve Arctic ecosystems will need to advance five linked initiatives:

- **Improve understanding of the science of thaw and associated emissions.** To slow or stop thaw, we need to better understand and be able to predict how, where, and why thaw and the resulting emissions are happening.
- **Gather better data about permafrost regions.** Researchers need more and better long-term data to effectively answer questions related to thaw, emissions, and mitigation.
- **Develop high-quality permafrost thaw models.** Better models of the North can tell us where, when, and how thaw (and emissions) will happen, and where (and which) actions may be needed.
- **Craft thaw-mitigation and emissions-mitigation strategies.** Researchers will need to develop and test interventions that can slow or stop thaw and reduce or stop the consequent release of heat-trapping gasses. This work will take time, substantial resources, and deep community support.
- **Develop and deploy an operating model for governance and decision making.** All thaw mitigation work should be framed under a governance model that engages with and has the support of stakeholders, particularly local populations and communities.

Of course, these five initiatives are no substitute for global efforts to reduce the release of heat-trapping gases. Indeed, if we are unsuccessful at achieving such reductions, the resulting warming will eventually overwhelm the permafrost thaw interventions explored here.

Canada has more permafrost than any country but Russia and has the deep science-and-technology foundation and industrial base needed. And with strong working relationships with other Arctic nations, Canada is well-positioned to play a leadership role in a global effort to tackle this problem, for the benefit of all.

Indeed, given the current challenges in Russia and the United States, we feel Canada can take a global leadership role in permafrost emissions reduction work by spearheading the establishment of a global framework for measuring, monitoring, and mitigating permafrost thaw emissions.

Faced with this challenge and opportunity, the Canadian federal government, with the central involvement of Northern community leaders, should establish a permafrost thaw mitigation task force that brings together key Canadian political and community leaders, permafrost science experts, and other stakeholders to develop a permafrost thaw mitigation strategy. Such a task force could be chartered to come up with:

- a clear and compelling problem statement around the value of permafrost thaw mitigation to Canadians and the world, including desired outcomes;
- an assessment of key risks, opportunities, strengths, and gaps;
- a program governance model, including a strategy for stakeholder engagement;
- high-level goals, success metrics, and potential intermediate milestones; and
- an initial program budget, structure, and operating model.

Given the magnitude of the challenge, such a program will need to run over decades and will need to be adaptable to changing circumstances. It will thus be critical to have broad public support and a flexible operating model.

This report seeks to inform Canadian Northern community leaders and policymakers of the permafrost problem and of emerging ideas for addressing it. However, the analysis and recommendations presented here should apply to all permafrost countries and be of interest to any stakeholder trying to address permafrost thaw.