Inuvialuit Land Administration

Permafrost Workshop Report

February 24-27, 2025

Inuvik, Northwest Territories, Canada

Permafrost Workshop in-person participants, 16:00, 24 February 2025. Full participant list and identifications in photo are in Appendix 2. Credit: Inuvialuit Regional Corporation.

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Credit: Inuvialuit Regional Corporation (left), and Lynda Orman, Polar Knowledge Canada (right).

Executive Summary

The Inuvialuit Land Administration (ILA) held a Permafrost Workshop in Inuvik, N.W.T., from 24–27 February 2025. It was attended by about 70 people in person and a few dozen more online. The workshop was organized by Hans Lennie of the Inuvialuit Land Administration (ILA), supported by Jennifer Humphries of Aurora Research Institute (ARI), and Tim Ensom, Steve Kokelj, and Kumari Karunaratne of the Government of Northwest Territories (GNWT). The main purpose of the workshop was to understand the views and perspectives of those interested in permafrost across the Inuvialuit Settlement Region (ISR) in order to help permafrost research and monitoring better serve Inuvialuit needs. The ISR is an area where much visible change in the permafrost environment is apparent to many people, especially in coastal erosion and the development of thaw slumps. The threats to coastal communities' infrastructure and the quality of the landscape and freshwater are front of mind for many in the region. The legacies of petroleum exploration, represented by the ~223 drilling waste sumps in the ISR, were a concern for participants and an ILA management priority.

The workshop was attended by many Inuvialuit representatives of boards and committees in the ISR. The workshop began with activities designed to help participants get to know each other and break the ice. Soon the room was buzzing with conversation. Then followed some overview talks and a panel discussion to set the scene and provide scientific and administrative context for the meeting. The second day was dominated by presentations on activities by researchers and agencies that indicated the need for permafrost knowledge. One key comment that day was: "We don't want to forget what we already know." It is so easy to forget the results of past research when people are caught up in present activities and administration. The third day was focused on discerning the important areas where activity and work are needed in the short term, and the fourth to assigning relative priority to these tasks. Two key conclusions were (1) that long-term working relationships with Inuvialuit have been essential to understanding regional permafrost change, and there is an important opportunity for expanded investment in the wide range of available Inuvialuit support; and (2) a holistic approach to the permafrost environment is needed to address the priorities of land users, which may not be the same as for individual scientists. In particular, to understand effects on the ability of streams to sustain fisheries and on the land to support habitat for caribou, moose, and other species harvested as part of the Inuvialuit way of life.

The workshop included plenty of time for discussion in small groups. It was an enjoyable and stimulating meeting for all attendees and will likely be repeated in a year or two, as part of the ILA's activities. The workshop was sponsored by several agencies, especially Polar Knowledge Canada, the ILA, Natural Resources Canada, GNWT, Aurora College, and PermafrostNet.

1. Introduction

As we learn more about the impacts of permafrost thaw across the Arctic, the concern about permafrost grows. It is a topic that crosses disciplines and scales and implicates a wide range of parties - from northern governments, regulators, and industry to communities and land users who depend on the foundation it provides. The Inuvialuit Settlement Region (ISR) is one of the world's most climate-sensitive permafrost regions, and the Beaufort Delta Region hosts the highest density of road, community, and historical oil and gas infrastructure in Arctic Canada. Permafrost capacity and collaboration are critical to support resilient northern communities facing climate change. This workshop brought together a diverse group of individuals and organizations with interests in permafrost, including Inuvialuit, decision-makers, planners, land managers, industry, and researchers, to share their perspectives, needs, and knowledge about permafrost and explore how to work together in co-developing permafrost projects that support northern interests. This workshop builds on past workshops in the ISR to foster a collaborative community of permafrost partners who work to support Inuvialuit interests.

2. Agenda and Activities

Day 1 of the workshop brought together those who live on and think about permafrost, specifically the “permafrost community of the Inuvialuit Settlement region,” to make connections and learn about the perspectives participants brought to the meeting. The day also served as an opportunity to begin understanding the diverse needs and interests of the permafrost community in the ISR. A round table kicked off the meeting. Chris Burn set the stage for the day with a presentation on “Why do we care about permafrost”, which was followed by a presentation from Mykola Sokurenko on the challenges and priorities of permafrost thaw from an Inuvialuit land management perspective. Northwest Territories information from an NWT Permafrost Map and permafrost depth profile across the territory, along with an infographic summarizing climate change and permafrost thaw effects in the western Arctic (Polar Knowledge Canada) provided relevant background information to workshop participants (Appendix 3, 4). Panel 1 centred on learning about the perspectives of a range of individuals in the permafrost community. The rest of the day centred on two activities. For activity 1, attendees were grouped by function, such as researchers, regulators, and environmental monitors. Activity 1 prompted reflection on (1) why they are interested in permafrost, (2) what the topics of concern and interest are, and (3) is there anything you’d like others to understand about your perspective and where you’re coming from? For Activity 2, groups were mixed up, and participants were asked to revise a list of permafrost interests by adding, removing, and marking the highest priorities.

Sharing information was the focus of Day 2 – covering the research, activities, projects, and landscape changes being observed. The program consisted of a selection of presentations and a panel. The morning session consisted of overview presentations on three research

programs (a collection of projects) by the Northwest Territories Geological Survey, Aurora Research Institute, and Natural Resources Canada/Hamlet of Tuktoyaktuk. This was followed by a session and a discussion on drilling waste sumps in the ISR. In the afternoon, land users, including Jim Elias, David Anikina, Borge Arey, Max Kotokak and Douglas Esagok, joined Jen Lam for a conversation on the importance of stories, bridging research and community, and some of the changes they are seeing. The rest of the afternoon consisted of presentations on Tuktoyaktuk coastal and permafrost issues, permafrost engineering research on the Inuvik-Tuktoyaktuk Highway, the NSERC PermafrostNet LEAP field school, and work in Paulatuk; the day closed with seven 3-min project pitches on smaller-scale research projects in the region.

Day 3 built off the understanding gained on the breadth of motivations and interests that brought participants to the meeting, and updates on the permafrost work that is happening in the ISR during the first two days, and asked, "What have we learned about collaborating on research and what can we do better?" The day started with two overview presentations on the ways we monitor permafrost and how data is used for modelling. This was followed by a panel led by Kumari Karunaratne (NTGS) with individuals who each play unique roles in the research system – from researchers and directors who support the co-management, to program managers and funders (Dustin Whalen, Dean Arey, Kirt Ruben, Lynda Orman). The rest of the day was dedicated to a series of progressive activities that worked towards understanding where we can go in the future, by asking groups to (1) reflect on what things make a project good or bad, (2) brainstorm on what we are doing well already that can be built off of and conversely what are things that need to be addressed, and finally (3) generate a list of potential actions that could be taken after this workshop.

The list of potential actions produced in the final activity of Day 3 was used on Day 4 for an IMPACT vs. EFFORT grid – potential actions were presented back to workshop participants, and the room collectively worked to decide where to place them and their relative priorities.

Discussion during Panel 1. Credit: Inuvialuit Regional Corporation.

3. Interests, challenges, and needs of the permafrost community in the ISR

The interests and needs of the permafrost community in the ISR were explored in the presentations, panel, and activities of Day 1, and reinforced throughout the activities in the days that followed. The workshop drew upon a wide range of individuals who live or work in permafrost regions. It was recognized that people bring a wide range of experience to their current roles, and that the diversity and equity of voices in a workshop setting were invaluable. Panel 1 was hosted by Kumari Karunaratne (NTGS), with Jason MacNeil (GNWT Infrastructure), Peter Clarkson (Mayor, Town of Inuvik), Charles Klengenberg (Hamlet of Tuktoyaktuk), Lennie Emaghok (Imaryuk Monitor), and Don Arey (GNWT Env. and Climate Change) as panellists. Participants were able to get a snapshot of the diversity of perspectives and needs of those who think about permafrost (Figure 1).

Figure 1. Graphic summary of Panel 1: understanding the needs and interests of those in the permafrost community. Credit: Rae Landriau.

Activity 1 broke the workshop participants into "functional groups" based on those with similar roles or functions in the ISR permafrost community, including environmental monitors (local practitioners), researchers (local or non-local), regulators, development (industry and infrastructure), research funders (federal or territorial representatives who support research activities), local and regional organizations, and representatives of the co-management system (including Inuvialuit organizations and co-management boards). Group discussions reflected the variety of participants and their interests during Activities 1 and 2, but three themes emerged during Activity 1 when participants were asked, "***Why do people care about permafrost?***":

1. Permafrost is tied to land and livelihood—the impact of permafrost thaw on participants' everyday lives. People in the region are experiencing the impacts of permafrost thaw firsthand. The idea that the permafrost landscape of the ISR is the home of the Inuvialuit and residents of the region, and, as such, is related to their livelihood, culture, traditional knowledge, health, food availability, and storage, was strongly reinforced.
2. Environmental and landscape change. These landscape changes raise specific questions related to permafrost, such as slumps and coastline changes, as well as how they impact the interconnected system, including habitat, water, and health.
3. Impact on infrastructure. The effects of infrastructure on the environment, and vice versa. This includes new infrastructure and the long-term effects of past disturbance and development.

In Activity 2, when groups were asked, "***What topics are of interest or concern***?" three broad categories came out during the discussion:

1. Environmental and landscape change, e.g., climate change in the north, permafrost degradation, plants, lakes, fish, hazards, impacts on food and water, shoreline erosion, parasites.
2. Concerns or problems related to health, heritage and community (human life and infrastructure) that need to be addressed, e.g., community adaptation and relocation planning, preservation of heritage and burial sites, infrastructure maintenance, drilling waste sumps, and impacts on travel over land for traditional activities, safety and quality of country foods.
3. Concepts or specific areas where things could be improved, e.g., the need for knowledge transfer (more communication, better communication between organizations, passing on knowledge, etc.), updating old policies and regulations, developing study design and data standards, data interoperability, an overall strategic and comprehensive permafrost management plan to include collaborative research, monitoring, mitigation, and the need for more northern education and training (particularly for youth), long-term funding, communication, and data accessibility.

4. A snapshot of permafrost work in the ISR

There is a long history of permafrost research in the western Canadian Arctic, in part because of the number of communities, the history of resource and infrastructure development projects, local research institutions, and Inuvialuit leadership. Understanding the effects of rapid climate warming has been a more recent driver of research. Day 2 showcased community members' observations of change and the activities and results of several permafrost research programs in the ISR. Panel 2 was chaired by Jennifer Lam (Joint Secretariat), with Jim Elias (Inuvialuit Game Council), David Anikina (ILA Monitor), Borge Arey and Max Kotokak Sr. (Imaryuk Monitors), and Douglas Esagok as panellists. The focus of the panel was to hear from harvesters and land-users about what they are observing (Figure 2). The rest of this section provides a brief summary of the presentations from Day 2, which cover a range of permafrost-related programs and activities happening in the ISR.

Permafrost mapping (A Wilson presentation) is important because it can help us understand how permafrost developed and, therefore, the ground materials that make up permafrost. This is important for predicting how permafrost in specific places will respond to the changing climate, or to development/disturbance. Mapping is often done at different scales, ranging from a community to the whole ISR or NWT, and common mapping methods include aerial photos, satellite photos, and, increasingly, drones. The NWT Geological Survey and several partner organizations lead this mapping.

The Aurora Research Institute's Western Arctic Research Centre (WARC), in Inuvik, supports a range of permafrost research (J Humphries and C Ferguson). These include long-term ground temperature monitoring at sites in the Mackenzie Delta, the Dempster Highway, and ITH, and long-term water quality monitoring to understand how permafrost and landscape change affect water quality. WARC also collaborates to understand coastal erosion and conducts outreach in schools and communities.

Research on coastal change has been led by the Hamlet of Tuktoyaktuk, Natural Resources Canada, and other partners (D Whalen and D Pokiak). This work integrates community-based monitoring, knowledge co-development, and knowledge transfer to describe how coastal erosion is occurring and anticipate the impacts of permafrost thaw, enabling decisions about which parts of the community to plan to repair, replace, or maintain. Shoreline erosion in Tuktoyaktuk (C Klengenberg) has been most effective when large concrete slabs and non-fractured rock were used, however Tuk Island is eroding rapidly which is of concern for Tuk Harbour. Terrain mapping around Tuktoyaktuk by research partners is assisting land-use planning. In Paulatuk, concerns over environmental change include but are not limited to sea ice, coastal and riverbank erosion, and changes in water quality. Mapping and monitoring are important tools for Paulatuk, and the community welcomes support from researchers.

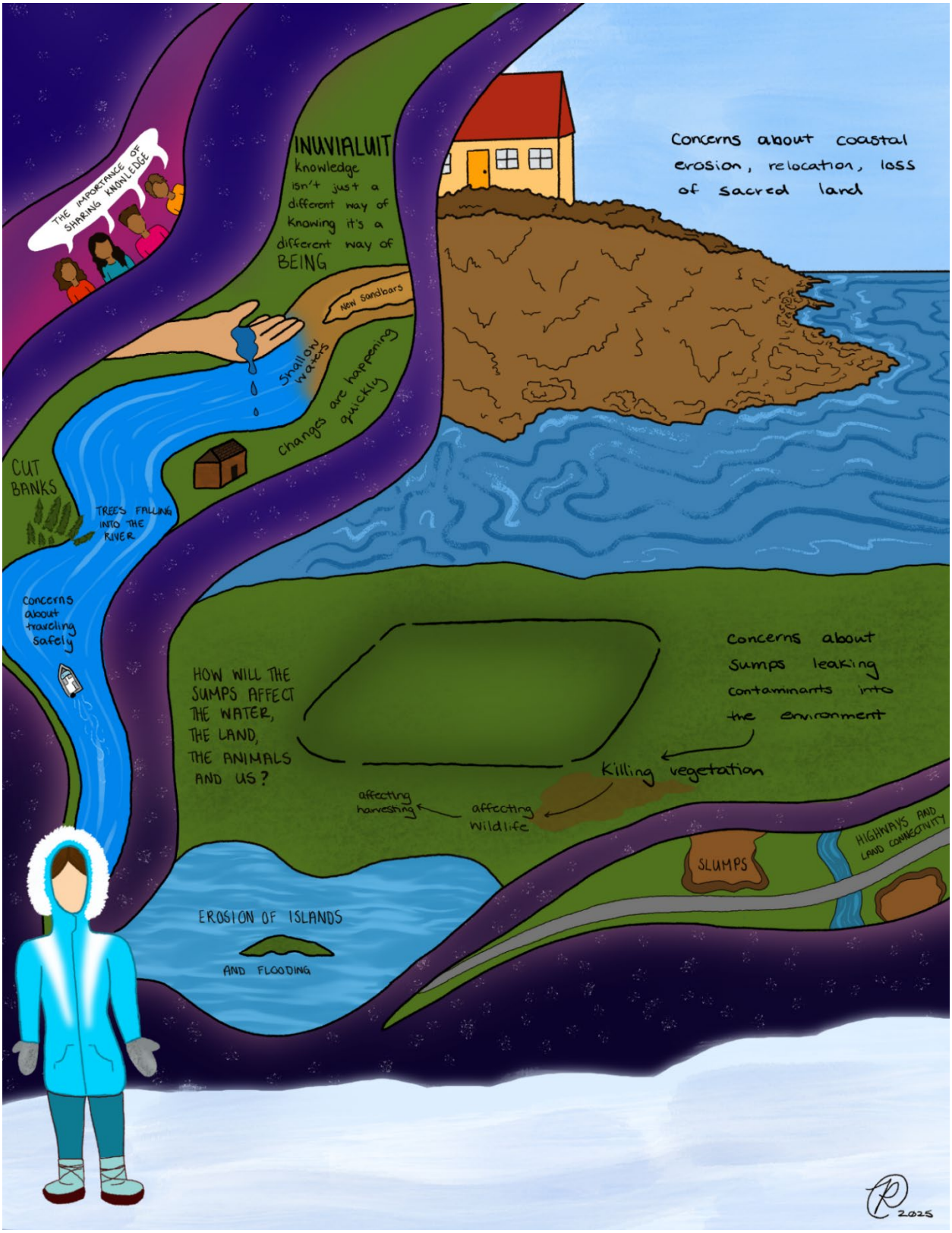


Figure 2. Graphic summary of panel 2: Community observations of change. Credit: Rae Landriau.

Understanding and managing sites disturbed by past oil and gas exploration that rely on permafrost for contaminant storage is a priority for the ILA. Over 230 drilling waste storage sumps are present in the ISR. Permafrost research at these sites over several decades has shown that local permafrost conditions and sump construction methods influence sump performance (i.e., waste containment), and that consistent monitoring is essential for understanding environmental risk (T Ensom). There is ongoing monitoring of certain sumps by the companies that own them and others (P Barnes), yet increasing evidence of sump failure in association with climate change, and interest by the ILA in updating and formalizing the land use authorizations at these sites (M Sokurenko).

Field data collection, coupled with computer modelling, is an approach used by engineers and permafrost scientists to estimate how infrastructure will perform in a warming climate (R Beddoe). This is being done to assess how well the pilings under the Gunghi Creek concrete arch will continue to perform. Monitoring snow depth and underlying ground temperature for several years at sites along the ITH has shown how compacting snow keeps the ground colder. Models that use this field data can then tell us how much site management (e.g., snow compaction) gives us a good return on investment. The ITH has therefore helped us better understand permafrost management and how roads affect permafrost, streams, vegetation, snow, and other parts of the environment.

Several underlying messages about research and monitoring emerged during workshop discussions on Day 2:

- Local observations can prompt research projects that are very insightful, e.g., D. Esagok and outer delta vegetation die-off.
- Research tells us about landscape change processes and what characteristics make them more likely, but it is hard to predict what will happen at a specific location.
- It is important to invest in a long-term presence in a place that people care about.
- The connection between data and the people who collected it is important. Timely data release is important for preserving data context and for data repatriation.
- Long multi-year data sets that incorporate field manipulation/disturbance are important for understanding processes, and also for understanding how the environment responds to different levels of management effort and for helping us project the future, e.g., Illisarvik (Burn), snow compaction/modelling (Wilson/Beddoe), veg. regrowth after fire (Cornette).
- Similarly, long-term monitoring and checking up on past research locations helps us understand if what we thought would happen indeed happens (hypothesis testing), and helps us understand if a solution or policy we tried actually worked.
- Harvester presence on the land is inherently important, and distinctive from environmental monitoring, with respect to what it can teach about landscape change.
- More research is welcomed by Paulatuk and other areas outside of the ITH corridor.

5. Approaches for collaboration and co-development

The morning of Day 3 began with three presentations, including two on different methods for generating knowledge (E Street, N Brown, A Alvarez, and S Gruber) and an overview of the Pathways Approach to better research programs (S Kokelj). See Pathway to Better Monitoring in Canada's North – A Step-by-Step Guide, developed by NWT Cumulative Impact Monitoring Program, for more details on the Pathways Approach. A panel, moderated by Kumari Karunaratne (NTGS), and panellists: Kirt Ruben (Joint Secretariat), Dustin Whalen (Natural Resources Canada), Don Arey (Inuvialuit Game Council), and Lynda Orman (Polar Knowledge Canada), asked those with experience for their reflections on what goes into building better programs (Figure 3). After the panel, participants then reflected on their own experiences of research or work in the ISR and developed two lists based on the following discussion questions:

1. What are the characteristics of "good" research and monitoring programs?
2. What are some common errors or problems that can arise in research and monitoring programs that make them less effective/relevant/useful?

Clear themes emerged from discussions during Activity 3. Practices that support "good" projects in the ISR included a focus on communication, well-thought-out projects, clear community influence, and opportunities for collaboration and capacity development. See below for more detailed suggestions and thoughts on characteristics of good monitoring programs.

- Communication:
    - Early (i.e., before the project begins), sustained communication.
    - Researchers with long-term ties to a region that come up frequently, develop trust, and can assist communities by making sense of their observations.
    - Providing feedback to the community in a way that's accessible (plain language).
    - Sharing and reporting on the data and project outcomes.
    - Sharing information with relevant HTCs and community corporations, and looking for new ways to engage (school visits, elders).
    - Establishing a point of contact in the community.
    - Recognize that the *story* is a very advanced and effective way of sharing knowledge, as identified in Panel 2.
- Project management:
    - Appropriate resources (funding, capacity, timelines, etc.), and flexible multi-year funding.
    - Clear questions.
    - Solutions-based projects that involve the community.
    - Finding the "why" for the project; understanding the real-world context or consequences of the research and the value of the work.
    - Time spent understanding and learning about the region (place names, people, relevant organizations, key issues, cultural sensitivity).
    - Time spent understanding what work has already been done to avoid duplication and ensure relevance.

- Community influence: Clear and mutual benefit to the community (equity), community-driven, opportunity for feedback, and co-developed projects. Deva-Lynn Pokiak encouraged community members to engage scientists to turn community concerns or observations into proposals, and to set up projects that require leadership and training by and for the community.
- Collaboration and multi-disciplinary research: integration and respect for local and traditional knowledge, working with environmental monitors and guardians, and mentorship.
- Capacity development: It is important to develop northern capacity, integrate training opportunities (particularly for youth), find the right people, and enable students from the north to study in the north. Ensuring that participants are engaged and invested in a project, rather than serving as field assistants, enables them to communicate and interpret the project results to better manage the land.

Challenges or common problems included:

- Communication: Lack of communication, using science jargon, the sensationalism of research and the damage it can cause, treating all communities the same, siloed projects, not sharing results or data.
- Project management: Projects with tight timelines, lack of resources, scope creep, incomplete projects, and difficulty in ensuring continuity of resources (programs, funding, people).
- Institutional structures such as funding, budget, and timelines that can impede good practices, for example, short timelines that make collaboration difficult, or a lack of funding at the end of a project for dissemination.
- Community: Lack of compensation and respect for local knowledge.
- People: ego, lack of information on a region before visiting, coming at the wrong time, and duplicating work.
- Capacity: The capacity to do the work is an ongoing challenge, and there is a lack of administrative support.

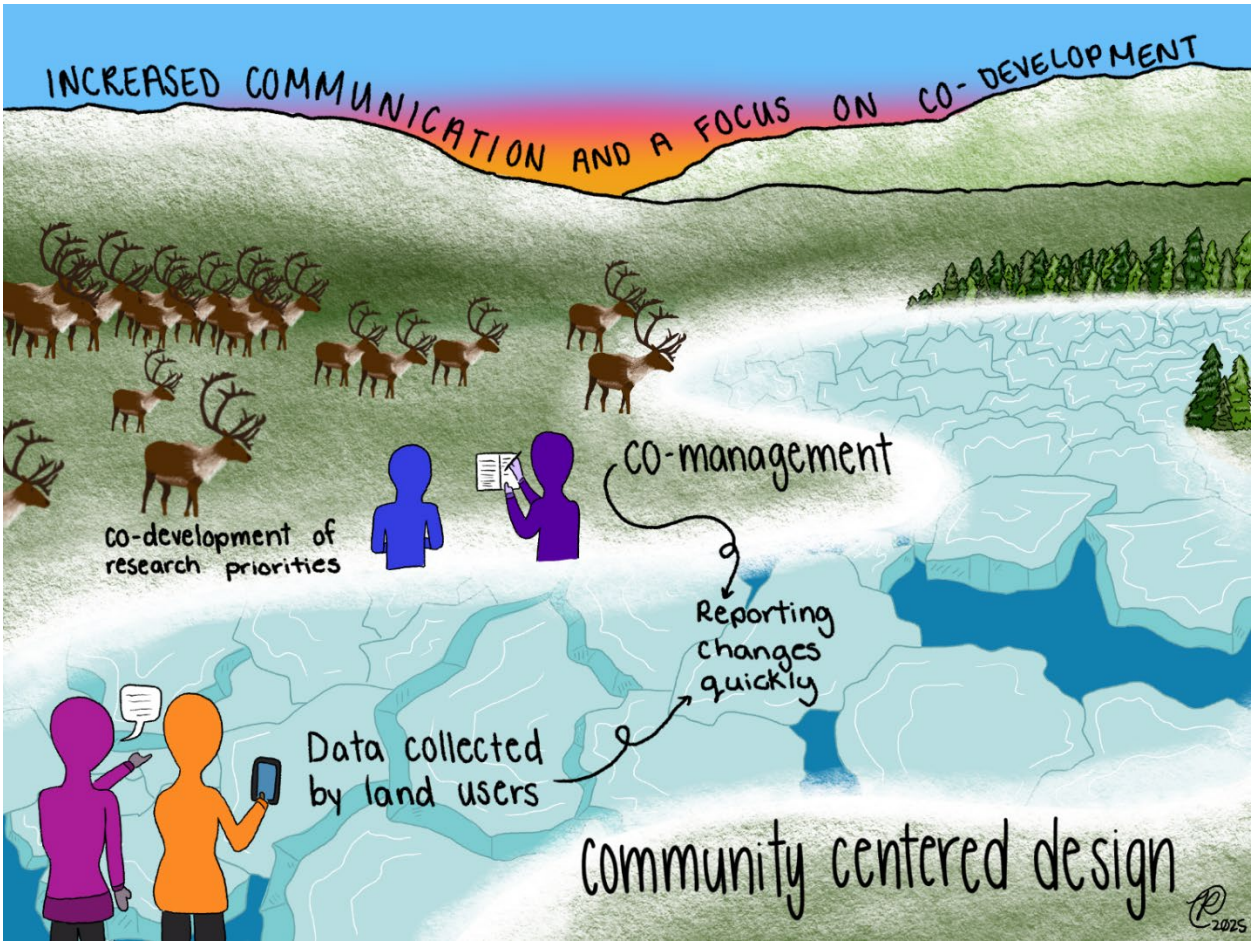


Figure 3. Graphic summary of Panel 3: Reflections on building better permafrost monitoring and research programs. Credit: Rae Landriau.

6. Critical issues and next steps

In the afternoon of Day 3, participants shifted their focus to what needs attention in ISR (activity 4) and then identified potential actions (activity 5). In activity 4, participants used a structured brainstorming process to identify what can be built on, changed or improved to allow us to design and implement permafrost programs that will work well and respond to the needs of the Inuvialuit and residents of the ISR. These ideas were then sorted into four categories: **resources and capacity development, relationships, methods and tools, and knowledge**. What emerged from the discussion was a picture of what future permafrost research and activities could focus on in the ISR. Specific ideas for each of the categories are shown below:

What needs attention?

Resources and Capacity Development

- Supporting future leaders (training and leadership opportunities for youth)
- Desire for community-led and driven training for locals
- Lack of office space and equipment
- Community capacity is still stretch, despite the capacity for permafrost research growing a lot in recent years within the ILA, students, ARI, and industry
- Funding is a big challenge (lack of core funding, burdensome application and reporting requirements)

Relationships

- Building relationships is critical, and finding ways to bridge that communication gap between researchers and community members
- Long-lasting relationships with researchers are valued
- Desire for data and results to be reported in a timely manner
- Finding the right team is both a challenge and an opportunity, and requires talking with lots of people
- Would like to see more collaboration between projects
- Would like to see more outreach in remote communities and schools

Methods and Tools

- Need for updated best practices, standards and policies
- Better data sharing – need for standards on collecting and sharing environmental data properly (e.g., adheres to OCAP, decolonizing data)
- It is a challenge to get funding for positions to support building data capacity
- Desire for clearer licensing process and communication expectations
- Relevant deliverables; prioritizing projects that are of interest to and benefit the community

Knowledge

- Multidisciplinary (holistic) and solutions-oriented research
- Desired outputs: community hazard maps, accessible baseline data, more sharing of information and data
- Topics of interest include: trails, infrastructure, drilling mud sumps, water quality, invasive species, health concerns

Credit: Inuvialuit Regional Corporation.

Activity 5 was titled **"Where do we go from here?"** and asked groups to use the points that came out of activity 4, and come up with potential initiatives and actions that could be taken. **Data** was such a large part of the discussion that it became a fifth category, along with the original four: **resources and capacity development, relationships, methods and tools, and knowledge**. During the discussion throughout the afternoon, there was a suggested need for a strategic, integrated, and comprehensive NWT Permafrost Management Plan that includes collaborative permafrost planning, coordinated research, monitoring, and mitigation, and is codeveloped with the Inuvialuit Regional Corporation and the Inuvialuit Land Administration.

Specific initiatives and actions that could be taken related to **resources and capacity**:

- Important to invest in the training of youth and environmental monitors (giving respect and opportunities to community members who could lead projects).
- Cultural training for researchers.
- More infrastructure to support research and training, such as storage and office space.
- Communities can identify people to mentor and invest in as part of their leadership of projects.

Specific initiatives and actions that could be taken related to **relationships**:

- Time and engagement require appropriate funding for researchers and community members to be in the field together and build relationships.
- Outreach, communication throughout the project.

- Community-based project representatives could serve as liaisons, with full-time funding and proper resources (equipment and workspace).
- Informing community elders and students in schools about work being done.
- Researchers should educate themselves about the culture they will work in.

Specific initiatives and actions that could be taken related to **methods and tools**:

- Safety plans, standards, manuals and guidelines, e.g., a how-to guide for monitoring permafrost.
- Contribution agreements and contracts could be co-developed to ensure there is a written understanding of expectations, and these agreements need not always involve a government partner.
- Develop Inuvialuit community-led researcher training and certifications that recognize field experience, and are recognized as credit towards higher degrees.
- Inuvialuit-owned databases could provide easier access to data by Inuvialuit co-management bodies, and would require staff /capacity.

Specific initiatives and actions that could be taken related to **knowledge**:

- Develop multidisciplinary research projects.
- Leadership could be by a Permafrost Management Board.
- Products like community hazard maps are produced in part at the community level through funding and capacity development.
- Products that can allow information holders (including industry) to share information, and land users to see information and report problems, for example, about drilling waste sumps.

Specific initiatives or actions that could be taken related to **data**:

- Metadata available for projects, permits and activities in the ISR.
- Develop a plan for long-term strategic and responsive monitoring.
- Envision and build local capacity and training.
- Plan for data storage, simulation, and interoperability.
- Build a data working group.
- Identify existing data and databases.
- Develop and maintain a database.

To determine next steps (Activity 6), the potential actions and initiatives generated in Activity 5 were plotted on an impact vs. effort grid into 4 groups, i.e., high effort/low impact, high effort/high impact, low effort/low impact, and low effort/high impact, so participants could discuss and prioritize actions collectively. Low impact and low effort, for example, indicate small improvements that would be easy to do. The outputs of the impact vs. effort grid are shown below.

Small improvements that would be easy to do: a map of regional permafrost projects, bringing elders to outreach or engagement events.

Big improvements that would be easy to do: improved communication between researchers and regional organizations, identifying knowledge gaps, ensuring community voices are represented, and engaging youth.

Big improvements that would be hard to do: training and growing local capacity to bridge science and IK, such as Douglas Esagok; procuring funding; developing data-sharing tools; and developing Inuvialuit-led certifications that leverage existing training programs.

7. Evaluation and Feedback

A short survey was made available on the final day for participants to provide feedback. Thirty-five participants provided their thoughts on how the workshop went, when the next workshop should run, who else should be invited, and what components (such as panels, presentations, activities and unstructured time to network) worked and what could be added for next time. Response to the workshop was positive; 33 out of the 35 respondents (95%) felt happy or very happy about their time at the workshop. Participants were asked when the next ILA Permafrost Workshop should be held. Two years from now (2027), three years (2028), four years (2029), or not sure. There was consensus (89%) that another workshop should be held as soon as possible, in two years. The notion that we don't want to 'lose momentum' was mentioned in the feedback by a handful of respondents. A recurring theme throughout the workshop and feedback was the desire to involve youth and elders. Thirty-two of the 35 responses noted that youth should be involved in the next meeting, and 21 noted that more elders should be involved. Respondents also indicated that fieldtrips (23), school visits and time with youth (22), and training (12) would be good additions to the program in the future, and that the combination of panels, presentations, activities, and unstructured time worked well for this gathering. Suggestions for other groups to include at the next meeting include: land users, international scientists, other organizations such as research groups, regional organizations in the ISR, industry, and representation from funding programs and land-use planners.

8. Responses to IRC Leadership

This section provides responses to the six topics identified by IRC Leadership as priorities for the Permafrost Workshop.

1) *Develop a network for all to feed regular updated data from their activities and research*

The workshop participants expressed interest in having permafrost workshops like this one, or similar events, every couple of years. These would be venues where data and research programs would be interpreted in plain-language, which was identified as very important by workshop participants. Such community-based reporting is already required by the NWT Research Licencing process and also as part of the EISC review process. There was interest in more frequent research interaction and reporting to the Inuvialuit Game Council. These more frequent reporting activities within the ISR also contribute to a permafrost network. A network is in essence a community of people that communicate often. Polar Knowledge Canada (POLAR) recognized a desire among workshop participants for a strategic, integrated and comprehensive permafrost management plan for the NWT and ISR that includes collaborative and holistic research, permafrost monitoring, management and mitigation. POLAR sees potential for this plan to be scaled up to comprise a national plan in collaboration with the Director Generals Permafrost Working Group. This could involve Environment and Climate Change Canada, Natural Resources Canada, Polar Knowledge Canada, Northwest Territories Geological Survey, Government of the Northwest Territories, Aurora Research Institute, Inuvialuit Regional Corporation, Inuvialuit Lands Administration, Carleton University and other academic institutions and researchers, industry, among others.

2) *Develop a map showing where research is conducted, including any passive data like community observations*

During workshop discussions, some participants commented that it would be better to work with existing methods of disseminating information than developing a whole new 'infrastructure'. Examples of existing platforms that show information on a map, or that maintain lists of projects or manage information about field observations in the ISR, include but are not limited to the following:

- Aurora Research Institute: http://www.nwtresearch.com/
- Environmental Impact Screening Committee: https://eisc.azurewebsites.net/
- GNWT Department of Education, Culture and Employment: https://data.researchlicensing.ece.gov.nt.ca/
- SIKU: https://siku.org/
    - SmartIce (Including SmartBUOY and SmartQAMUTIK) are available through SIKU
- Imaryuk Program

Building connections between these programs, including links in online platforms, is a valuable opportunity. A single map may not be able to represent research programs as effectively or inclusively as good linkages between online resources.

3) *Historical maps showing past images of where the permafrost was*

The ISR is a region of continuous permafrost, where permafrost is underneath most of the land (Appendix 3). An important message in the workshop was that permafrost is so thick in this region (often over 100 metres), that it will take hundreds or thousands of years for the permafrost layer to be absent in many places. Observations of erosion, slumping, ponding, and other change near the ground surface tells us that the top of the permafrost layer is likely thawing. Comparing historical images of the land surface with recent images tells us about the places and the kinds of terrain where permafrost is thawing the fastest. Having a mapping system that provides users with links to images of this change, and to explanations of what is causing the change and names of people who are learning why it is happening, is a valuable opportunity that might address this priority.

4) *A breakdown of coastal research and delta research, as well as other like the 5 universities studying the permafrost on the ITH*

During the workshop there were several presentations on coastal research (Klengenberg, Pokiak, Whalen, Ruben, Chiasson), two presentations related to the ITH (Beddoe, Wilson), and a mention of Delta research (Burn, Landriau, Ensom). There is a long history of permafrost research along the coast and the Delta, and also some work along the ITH corridor even before road construction. Coastal permafrost research has considered what kinds of coastal terrain and locations are most vulnerable to erosion, how fast erosion is happening, where is the permafrost along the coast and under the ocean near the coast, and where and how thick is sea ice. Research in the Delta has included descriptions of how the channels change over time, how this affects vegetation and therefore permafrost, where there are gaps in permafrost, how water moves, how storm surge affects the environment, and many other topics. Permafrost research along the ITH has included looking at permafrost drill cores (from construction) to better understand how the landscape evolved over thousands of years, understanding ground temperature in the main types of natural terrain, understanding how borrow pits in permafrost change over time, and understanding how the road affects ground temperature, water movement, and snow. Identification of these three key regions of interest for the IRC is valuable, and can help connect knowledge holders in different fields working in the same settings, and guide future events for this permafrost network.

5) *Recognition of impacts our communities are observing and hopefully reporting through team Jenn has, and a commitment of academia and governments to engage and support*

The workshop included extensive discussions of environmental change and impacts on communities and land use in the ISR. Jennifer Lam (EISC) was very helpful in supporting these discussions, in ensuring that impacts and concerns experienced by communities were

articulated, and in ensuring that the system of communicating knowledge through stories was seen as equal to western scientific approaches to communication. The impacts of change on communities were well communicated to the participants from government (territorial and federal) and academia. These participants were generally very interested in continued engagement and support based on their participation during the workshop and closing statements.

6) *A commitment to develop a long-term database that maybe IRC /IISCC would administer*

Participants were generally interested in information being available in a database, as described under IRC priority 2 above. A specific purpose for an initial/trial database could be historic oil and gas exploration sites and their associated sumps and other infrastructure. IRC IISC, with the leadership of Sam Dyck and the ISR Sumps Technical Working Group, has begun to develop this type of database, with a map interface, focusing on drilling sumps. This database if successful could be an option for compiling information on other sites of interest, and could include links to other spatial data repositories described in item 2 above.

Appendix 1: Participant Agenda

Inuvialuit Land Administration Permafrost Workshop
Agenda

Inuvik, NT
Ingamo Hall Friendship Centre, 20 Mackenzie Road, Inuvik, NT
February 24-27, 2025

This project is funded in part by a grant from Polar Knowledge Canada. We also thank the Natural Resources Canada GEM GeoNorth Program, the Department of Municipal and Community Affairs (Government of Northwest Territories) Climate Resilient Northern Coastal Communities Project, and NSERC PermafrostNet for their financial support.

Inuvialuit Land Administration Permafrost Workshop

Location: Ingamo Hall Friendship Centre, 20 Mackenzie Road, Inuvik, NT
Date and Time: February 24-27 (Day 1 from 8:30-4:00, Day 2 from 8:30-4:30, Day 3 from 8:30-4:00 and Day 4 from 8:30-12:00)

Organizers: Hans Lennie, Inuvialuit Land Administration
With support from: Tim Ensom, GNWT Environment and Climate Change, Jen Humphries, Aurora Research Institute, Steve Kokelj & Kumari Karunaratne, Northwest Territories Geological Survey (NTGS)
Facilitator: Jen Humphries

Context:
Permafrost issues are growing priorities for northern governments, regulators, communities, and industry as they plan for, mitigate, and adapt to the effects of climate change in the North. The Inuvialuit Settlement Region (ISR) is one of the world's most climate-sensitive permafrost regions, and the Beaufort Delta Region hosts the highest density of road, community, and historical oil and gas infrastructure in Arctic Canada. Permafrost capacity and collaboration to generate permafrost information, data stewardship, and knowledge application are critical to support resilient northern communities facing climate change. This workshop brings together a diverse group of individuals and organizations with interests in permafrost, including Inuvialuit, decision-makers, planners, land managers, industry, and researchers, to share their perspectives, needs, and knowledge about permafrost and explore how to work together in co-developing permafrost projects that support northern interests. This workshop builds on past permafrost and monitoring workshops in the ISR, often led by the Inuvialuit Land Administration, to foster a collaborative community of permafrost partners that work to support Inuvialuit interests.

Purpose:
This 4-day meeting is to better understand the perspectives of those interested in permafrost (permafrost partners and stakeholders) in the ISR, share permafrost monitoring and research approaches and some of the findings, and explore how we can collaborate and co-develop projects and programs that better serve a broad range of Inuvialuit and permafrost stakeholder needs. This meeting and discussions provide a foundation for working together and determining the next steps.

Objectives:
The objectives of this meeting are to:

- Better understand permafrost conditions in the ISR and the interests and needs of different permafrost partners and stakeholders. Specifically, we will discuss who is interested in permafrost (*partners and stakeholders), w*hy they are interested (*motivations),* and their respective roles;
- Identify interests and needs and similarities, potential synergies and gaps;
- Share information on permafrost research and monitoring in the ISR;
- Explore approaches for co-developing and applying permafrost knowledge that addresses the needs of Inuvialuit and other permafrost stakeholders and;
- Plan for the next steps.

Outputs:

The main output of this meeting is a report that will include (1) a meeting summary, (2) an inventory of permafrost partners and stakeholders in the ISR, (3) a summary of partner and stakeholder interests, challenges, and needs, (4) a synthesis of approaches for collaboration and co-developing permafrost projects, and (5) identification of the critical issues and next steps.

Day 1: Setting the Context – understanding the interests and needs of permafrost stakeholders

Time	Item	Details
8:30 am	Breakfast *(30 mins)*	Arrive, settle-in
9:00 am *(30 mins)*	Welcome	Welcome, opening remarks, opening prayer, agenda review, and housekeeping
9:30 am *(30 mins)*	Icebreaker	Participants will have a chance to get to know the people at their table a bit better
10:00 am *(30 mins)*	Presentation 1: Why Permafrost?	Presentation by Chris Burn (Carleton University)
10:30 am	Break *(15 min)*	
10:45 am *(15 mins)*	Presentation 2: Inuvialuit Land Management perspectives on challenges and priorities arising from permafrost changes	Presentation by Mykola Sokurenko (Inuvialuit Land Administration)
11:00 am *(1 hr)*	Panel 1: Understanding the needs and interests of different permafrost partners and stakeholders	Panel will provide diverse perspectives from: municipal and local decision-makers, environmental monitors, territorial government, and more. Panelists: • Jason MacNeil, Regional Airport Manager, GNWT Dept. Infrastructure • Peter Clarkson, Mayor of Inuvik • Charles Klengenberg, Projects Manager, Hamlet of Tuktoyaktuk • Lennie Emaghok, Imaryuk Monitor • Don Arey, Regional Superintendent, GNWT Dept. Environment and Climate Change Moderator: Kumari Karunaratne, Director, NTGS
12:00 pm	Lunch *(1 hour)*	
1:00 pm *(1 hr 30 mins)*	Activity 1: Getting to know the permafrost community in the ISR	Participants will break into discussion groups based on having similar functions or roles, followed by a debrief to the larger group. Discussion questions:

Time	Item	Details
		1. Why are you interested in permafrost? What does permafrost mean to you? 2. What permafrost topics are you concerned about and or interested in, and why? 3. Is there anything you'd like other people in the ISR permafrost community to understand about your perspective and where you're coming from? (For example do you have one topic that is your focus, is there one thing you really need information on, is there a particular challenge you have, etc.)
2:30 pm	Break *(15 min)*	
2:45 pm *(1 hr)*	Activity 2: Permafrost partner and stakeholder Insights	Refining the interests and needs of the permafrost community. Participants will work in small groups, based on a draft list of permafrost "interests" to refine it, and if possible, start to prioritize interests. (Interests can be points of concern, issues, topics of focus, etc.) Discussion questions: 1. Is there anything you think is an important permafrost concern or topic that isn't on the lists? (and should be added to the list) 2. Is there anything you think isn't actually an important permafrost topic or concern? (and should be removed from the list) 3. What do you think are the most important points from the lists?
3:45 pm *(15 mins)*	Wrap up and look ahead	Facilitator will review the day and preview the agenda for Day 2.
4:00 pm	End of day	

Day 2: Knowledge sharing – a snapshot of permafrost work in the ISR

Time	Item	Details
8:30 am	Breakfast *(30 mins)*	Arrive, settle-in
9:00 am *(15 mins)*	Welcome	Welcome, highlights from Day 1, agenda review for Day 2 and housekeeping
9:15 am *(1 hr 15 mins)*	Presentations 3: Permafrost mapping in the Western Arctic	Presentation by Alice Wilson (Northwest Territories Geological Survey)
	Presentation 4: Permafrost Research at the Aurora Research Institute	Presentation by Jen Humphries and Celtie Ferguson (Aurora Research Institute)
	Presentation 5: An approach to solution-oriented research in the coastal community of Tuktoyaktuk, Canada	Presentation by Dustin Whalen (Natural Resources Canada) and Deva-Lynn Pokiak (Hamlet of Tuktoyaktuk)
10:30 am	Break *(15 mins)*	
10:45 am *(1 hr 15 mins)*	Presentations related to sumps	
	Presentations 6: "Drilling Waste Sumps"- Synthesis on sumps and research activity	Presentation by Tim Ensom (GNWT Environment and Climate Change / NTGS)
	Presentation 8: Leaking Sumps in ISR – Permafrost Change has Surfaced the Colonial Past	Presentation by Mykola Sokurenko (Inuvialuit Land Administration)
	Presentation 7: Program update on sumps work from industry "Industry Sumps Management Update"	Presentation by Paul Barnes (Canadian Association of Petroleum Producers) *Due to technical issues this was presented after Mykola's presentation*
	Sumps discussion	Time for Q&A and discussion
12:00 pm	Lunch *(1 hour)*	

Time	Item	Details
1:00 pm *(1 hr)*	Panel 2: Community observations of change	An opportunity to hear from community and land users on the changes they're noticing in the region Panelists: • Jim Elias, Director, Inuvialuit Game Council • David (Obie) Anikina, ILA Environmental Monitor • Borge Arey and Max Kotokak Sr., Imaryuk Monitors • Douglas Esagok Moderator: Jen Lam, Joint Secretariat
2:00 pm	Break (15 mins)	
2:15 pm *(1 hr 15 mins)*	Updates on a variety of permafrost programs	
	Presentations 9: Tuktoyaktuk coastal and permafrost issues	Presentation by Charles Klengenberg (Hamlet of Tuktoyaktuk)
	Presentation 10: Engineering Research Along the ITH	Presentation by Ryley Beddoe (Royal Military College)
	Presentation 11: NSERC Create Leap Field School	Presentation by Alejandro Alvarez (University of Alberta)
	Presentation 12: Permafrost dynamics in Paulatuk and along the coast of the Anguniaqvia Niqiqyuam Marine Protected Area (AN MPA)	Presentation by Lawrence Ruben (Inuvialuit Game Council) and Dustin Whalen (Natural Resources Canada)

Time	Item	Details
3:30 pm *(45 mins)*	Project Pitches	3-minute pitches on projects and outcomes of permafrost work relevant to the ISR P1 “Sumps”: Rae Landriau, Carleton University P2 “Mapping ice-rich permafrost in the Mackenzie Delta Region”: Alejandro Alvarez, University of Alberta P3 “Fires”: Lea Cornette, University of Montreal P4 “Ice wedge cracking and northern housing review”: Gabriel Karam, Carleton University P5 “Exploring Traditional Knowledge of Permafrost in the Inuvialuit Settlement Region and Gwich’in Settlement Area”: Emma Street, University of Victoria P6 “Mapping of Surficial Geology and Permafrost Conditions for Communities: Why Fine-scale Mapping and Field Investigations Matter”: Alexandre Chiasson, Northwest Territories Geological Survey P7 “Polar Knowledge Canada Permafrost Workshop”: Lynda Orman, Polar Knowledge Canada
4:15 pm *(15 mins)*	Wrap up and look ahead	Facilitator will review the day and preview the agenda for Day 3.
4:30 pm	End of day	

Day 3: Collaboration and Co-development – what works, and what can we improve?

Time	Item	Details
8:30 am	Breakfast *(30 mins)*	Arrive, settle-in
9:00 am *(15 mins)*	Welcome	Welcome, highlights from Day 2, agenda review for Day 3 and housekeeping
9:15 am *(45 mins)*	Presentations on different methods used to generate knowledge	
	Presentations 13: How to we learn about permafrost	Presentation by Emma Street (University of Victoria), Nick Brown (Carleton University) and Alejandro Alvarez (University of Alberta)
	Presentation 14: Permafrost modelling and simulation	Presentation by Stephan Gruber (Carleton University)
10:00 am	Break *(15 mins)*	
10:15 am *(15 mins)*	Presentation 15: Pathways to permafrost collaboration	Presentation by Steve Kokelj (Northwest Territories Geological Survey)
10:30 am *(45 mins)*	Panel 3: Reflections on building better permafrost monitoring and research programs	Panelists have experience with building permafrost monitoring programs and will share thoughts on how the programs developed, the challenges and successes they encountered, what worked and what didn't. Panelists: • Kirt Ruben, Community Based Monitoring Program Manager, Joint Secretariat • Dustin Whalen, Physical Scientist, Natural Resources Canada • Dean Arey, Chair, Inuvialuit Game Council • Lynda Orman, Manager, Polar Knowledge Canada Moderator: Kumari Karunaratne, Director, NTGS
11:15 am *(45 mins)*	Activity 3: Learning from our experiences: What makes a good program?	Participants reflect on their own experiences of research or work in the ISR and develop two lists based on the following discussion questions:

		List #1: What are the characteristics of "good" research and monitoring programs? *For example: What works about their approach? What do they do well? Who do they involve and how?* List #2: What are some common errors or problems that can arise in research and monitoring programs that make them less effective/relevant/useful? What could be changed or improved to address that issue? Some time will be allotted to share highlights of the discussion from each group.
12:00 pm	Lunch *(1 hour)*	
1:00 pm *(1 hr 30 mins)*	Activity 4: What needs attention?	Participants will work in groups using a structured brainstorming process to bring some analysis the discussions over the past 2-3 days to identify what can be built on, changed or improved to allow us to design and implement permafrost programs that will work well and respond to the needs of the Inuvialuit and residents of the ISR. Discussion questions: 1. What good things are already happening that we should build on or do more of? 2. What are the challenges or obstacles that we will need to address or overcome? 3. What are we not doing or not doing enough of? What are the critical gaps we need to address? As part of the debrief, the group will sort ideas into categories for further discussion.
2:30 pm	Break *(15 mins)*	
2:45 pm *(1 hr)*	Activity 5: Where do we go from here? (Part 1)	Building on Activity 4 and using a worksheet to guide their discussion, participants will draw insights and conclusions for each

		category and identify potential pathways for action.
3:45 pm *(15 mins)*	Wrap up and look ahead	Facilitator will review the day and preview the agenda for Day 4.
4:00 pm	End of day	

Day 4: Where do we go from here – next steps

Time	Item	Details
8:30 am	Breakfast *(30 mins)*	Arrive, settle-in
9:00 am *(15 mins)*	Welcome	Welcome, highlights from Day 3, agenda review for Day 4 and housekeeping
9:15 am (1 hr and 30 mins)	Activity 6: Where do we go from here? (Part 2)	Based on the outcomes of Activity 5, the facilitator and "connectors" will present the range of potential actions/initiatives and plot them on a grid based on their anticipated impact and level of effort Time for discussion and further prioritization of actions/initiatives by participants.
10:45 am	Break *(15 mins)*	
11:00 am *(1 hr)*	Activity 7: Summary and final thoughts	Wrap up discussion and closing thoughts
12:00 pm	End of day	

Appendix 2: Participant List

ID numbers are typically shown on the shoulder or chest of the person they identify. If space is limited, especially in the back row, numbers may appear above the person's head.

In-person Attendees

Name (ID in above photo)	Affiliation
Hans Lennie (56)	Inuvialuit Land Administration (IRC)
Jennifer Humphries (21)	Aurora Research Institute (Aurora College)
Tim Ensom (31)	GNWT Environment and Climate Change
Kirt Ruben (5)	Joint Secretariat
David Anikina (12)	Inuvialuit Land Administration (IRC)
Sheila Nasogaluak (24)	Wildlife Management Advisory Council
Chris Burn (46)	Carleton University
Stephan Gruber (49)	Carleton University
Rae Landriau (27)	Carleton University
Dustin Whalen (35)	Natural Resources Canada
Steve Kokelj (37)	Northwest Territories Geological Survey (GNWT)
Alice Wilson (22)	Northwest Territories Geological Survey (GNWT)
Alexandre Chiasson (15)	Northwest Territories Geological Survey (GNWT)
Kumari Karunaratne (28)	Northwest Territories Geological Survey (GNWT)
Patrick Gordon	Aklavik Hunters and Trappers Committee
James Keevik	Tuktoyaktuk Hunters and Trappers Committee
Deva-Lynn Pokiak (29)	Hamlet of Tuktoyaktuk
Emma Street (20)	University of Victoria
Trent Kuptana (2)	Ulukhaktok Hunters and Trappers Committee
Patrick Akhiatak (9)	Ulukhaktok Hunters and Trappers Committee
Karla Kuptana (4)	Inuvialuit Regional Corporation
Lynda Orman (33)	Polar Knowledge Canada
Ryley Beddoe (42)	Royal Military College

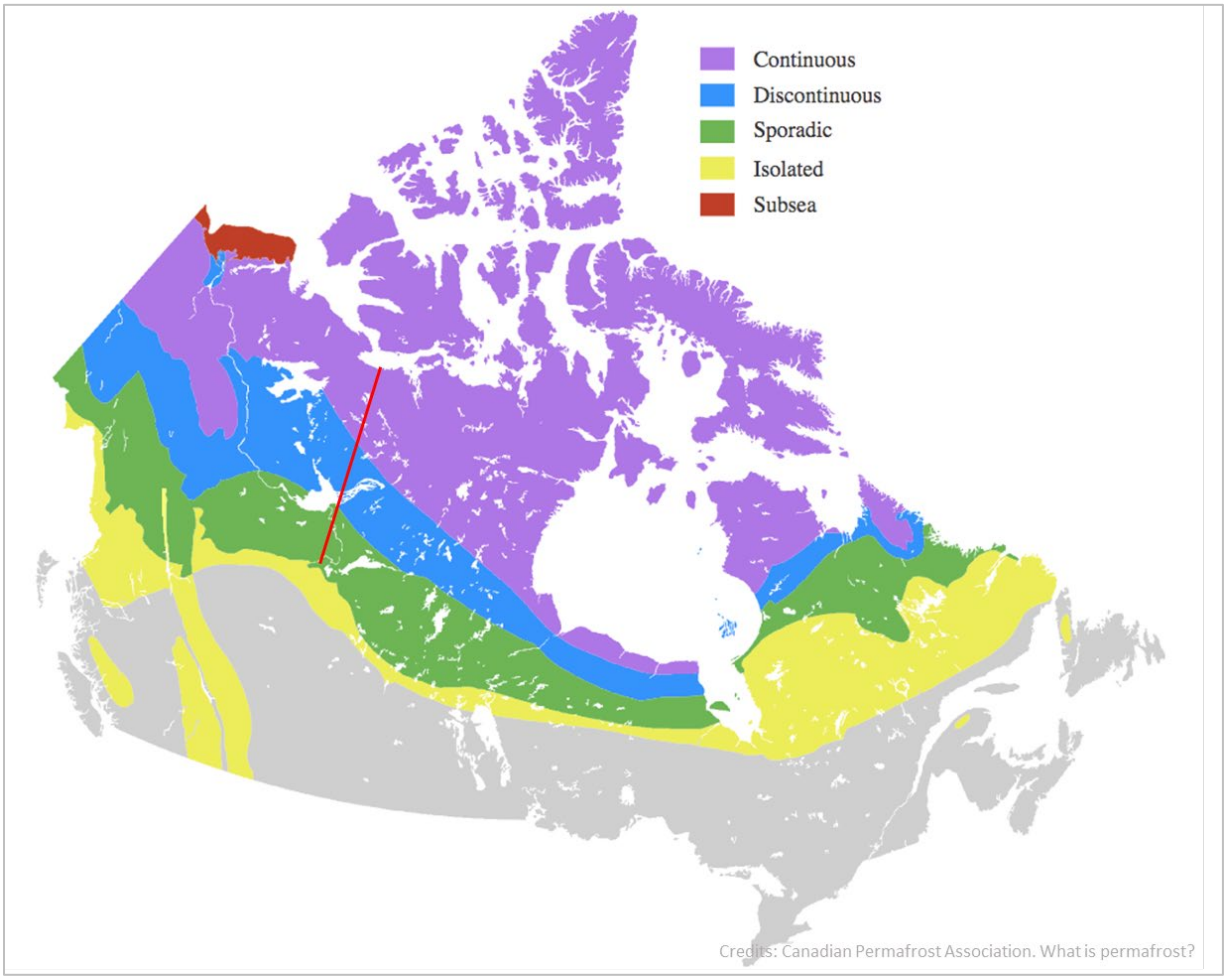
Jen Lam	Joint Secretariat
Vernon Amos (17)	Environmental Impact Screening Committee
Patricia Sung (3)	Environmental Impact Screening Committee
Douglas Esagok (1)	Independent
Nolan Rainville	Gwich'in Tribal Council
Danny Gordon Jr. (51)	Aullaviat Anguniarvik Working Group
Samuel McLeod (53)	Aullaviat Anguniarvik Working Group
Mykola Sokurenko (39)	Inuvialuit Land Administration (IRC)
Paden Lennie	Inuvik Hunters and Trappers Committee
Nicolas Ouellette (8)	Crown-Indigenous Relations and Northern Affairs Canada
Stanley Felix (23)	Inuvialuit Land Administration (IRC)
Denise Atter (19)	Nautchiuk
Alejandro Alvarez (48)	University of Alberta
Charles Klengenberg (34)	Hamlet of Tuktoyaktuk
Nick Brown (36)	Carleton University, NSERC PermafrostNet
Gabriel Karam (55)	Carleton University, NSERC PermafrostNet
Olivier Piraux (7)	Ookpik Stantec
Lea Cornette (47)	Universite de Montreal, NSERC PermafrostNet
Christopher Ruben (44)	Paulatuk Community Corporation
Bobby Ruben Sr. (14)	Paulatuk Community Corporation
Lennie Emaghok (10)	Imaryuk Monitor
Max Kotokak Sr. (11)	Imaryuk Monitor
Kevin (Borge) Arey (52)	Imaryuk Monitor
Elizabeth Kolb	Inuvialuit Regional Corporation
Allen Kogiak (16)	Inuvialuit Land Administration (IRC)
Candace Ruben (26)	Paulatuk Hunters and Trappers Committee
Brandon Green (18)	Paulatuk Hunters and Trappers Committee
Lawrence Rogers (38)	Inuvik Hunters and Trappers Committee
Dean Arey	Inuvialuit Game Council
Jim Elias (30)	Inuvialuit Game Council
Lawrence Ruben (6)	Inuvialuit Game Council
Peter Clarkson	Town of Inuvik
Jacqueline Menzies (54)	Parks Canada
Michael Fabijan (13)	Kavik Stantec
Donna Ruben (25)	Hamlet of Paulatuk
Alan McDonald (50)	Inuvialuit Energy Security Project (IRC)
Jason MacNeil	GNWT Infrastructure
Don Arey	GNWT Environment and Climate Change
Chris Hewitt	GNWT Municipal and Community Affairs
Mesbahul Alam (40)	GNWT Municipal and Community Affairs
Andrew Leung (43)	Polar Knowledge Canada
Howard Cody Felix (45)	Sachs Harbour Hunters and Trappers Committee

Sam Dyck	Inuvialuit Regional Corporation
Mathieu Lamontagne-Cumiford	University of Manchester
Travis Balaski	Inuvialuit Energy Security Project (IRC)
Celtie Ferguson (32)	Aurora Research Institute (Aurora College)
Howie McLeod (41)	Polar PA
Andy Sharpe	Parks Canada
Viola Arey	Hiku Drilling Tools Corporation
Duane Smith	Inuvialuit Regional Corporation
Trudy Kogiak	Aklavik Hunters and Trappers Committee

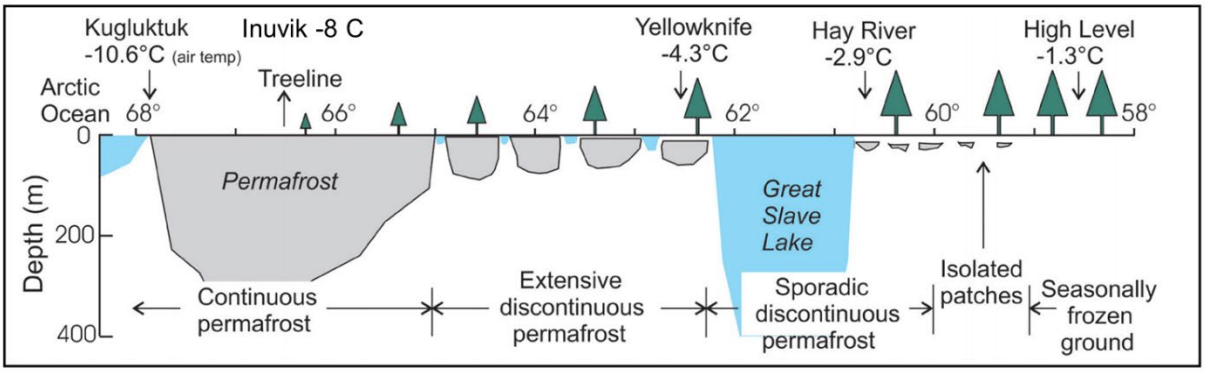
Online Attendees

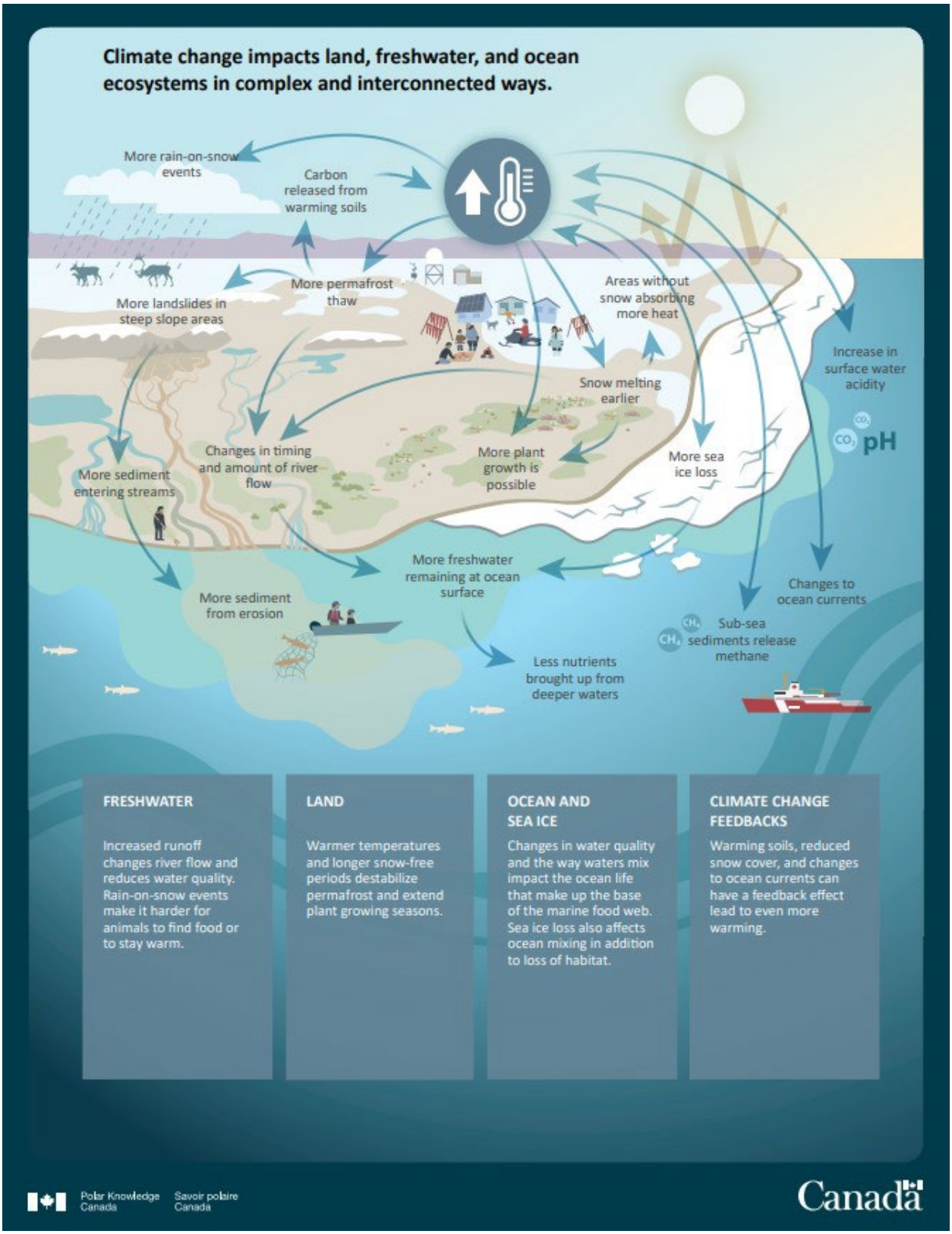
Cate Hydeman	ConoccoPhilips, ISR Sump Technical Working Group
Ed Grozic	Kiggiak-EBA
Lukas Arenson	BGC Engineering
Sidney Conlon	Imperial Oil, ISR Sump Technical Working Group
Peter Morse	Geological Survey of Canada
Merran Smith	Indigenous Services Canada
Alicia McRae	GNWT Environment and Climate Change
Camellia Gray	Independent
Joseph Carpenter	Sachs Harbour Hunters and Trappers Committee
Lenz Haderlein	WSP
Ron Wallace	Environmental Impact Screening Committee
Brendan O'Neill	Geological Survey of Canada
Moritz Langer	Alfred Wegener Institute
Sofia Antonova	Alfred Wegener Institute
Paul Overduin	Alfred Wegener Institute
Dara Schmidt	Suncor, ISR Sump Technical Working Group
Michael O'Rourke	GNWT Prince of Wales Northern Heritage Centre
June Skeeter	Natural Resources Canada
Johnnie T Storr	Aklavik Community Corporation
Igor Egorov	National Research Council
Paul Barnes	Canadian Association of Petroleum Producers, ISR Sump Technical Working Group

Appendix 3: Graphics on Permafrost Distribution in the Northwest Territories and Canada



General permafrost distribution in Canada. Red line corresponds with thickness profile below. From Canadian Permafrost Association. https://canadianpermafrostassociation.ca/What-is-Permafrost.htm.



Simplified permafrost thickness in northwestern Canada. From Kokelj and Wolfe, 2018, Fig. 2. Northwest Territories Geological Survey – Permafrost 101.

Appendix 4: Climate change factors affecting permafrost thaw infographic