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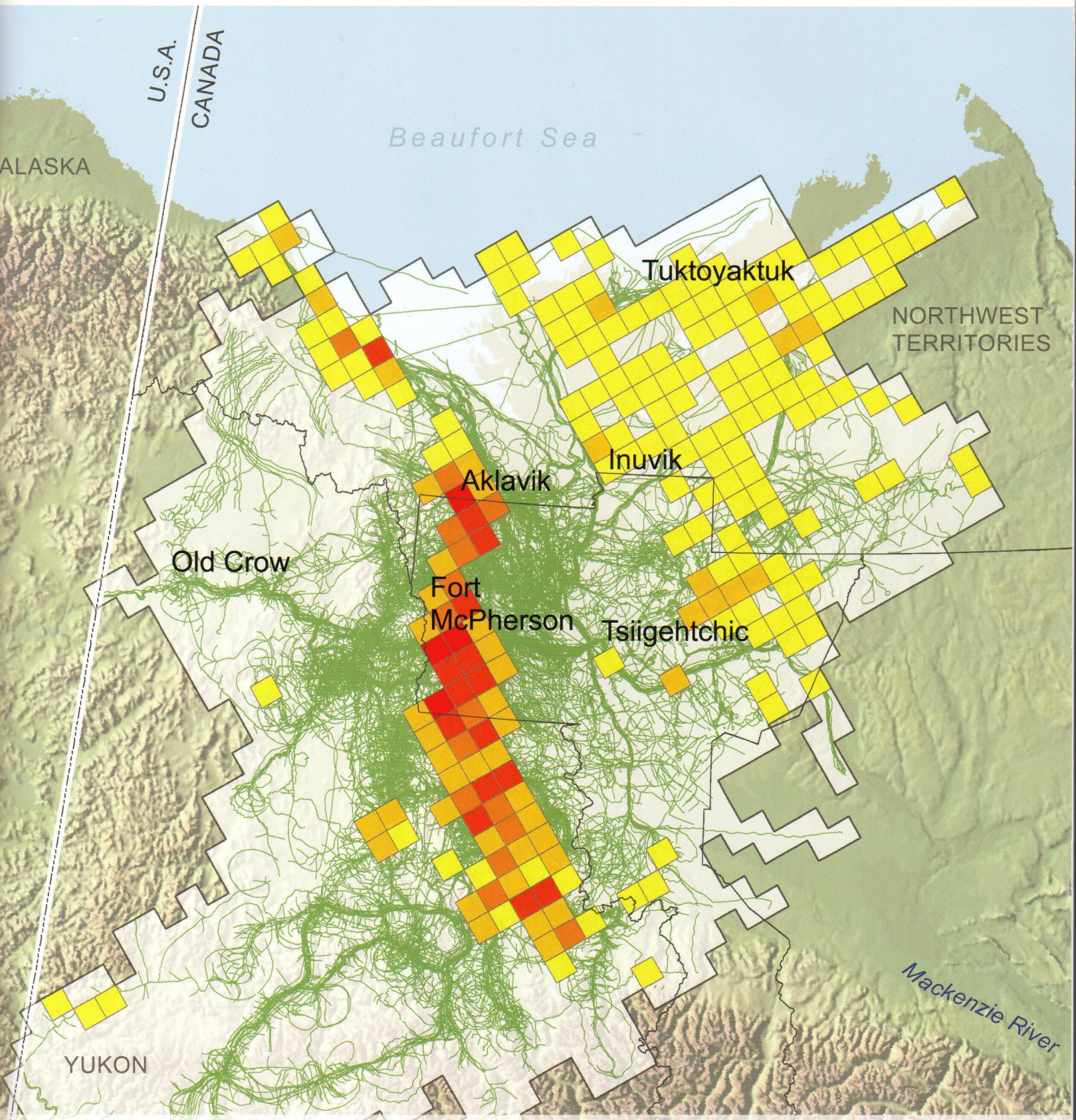

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Cover: Risk rating based on integration of Gwich'in traditional trail and thaw-slump distribution data. Courtesy of J. Buysse, GNWT.

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SPECIAL ISSUE ON CLIMATE CHANGE AND PRESERVATION TECHNOLOGY

Permafrost Thaw and Aboriginal Cultural Landscapes in the Gwich'in Region, Canada

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Steven V. Kokelj
Glen MacKay
Julie Buysse
Ingrid Kritsch
Alestine Andre
Trevor Lantz

Fig. 1. A large retrogressive thaw slump and debris tongue deposit in the Ramparts Plateau, Northwest Territories, 2015. Photograph by T. D. Andrews, Government of the Northwest Territories (GNWT).

GIS-based heritage risk assessment can help protect fragile cultural resources in the Yukon and Northwest Territories.

In Canada's Northwest Territories, where continuous or discontinuous permafrost underlies close to 80 percent of the landscape and air temperatures are increasing at a rate significantly greater than the global average, cultural-resource managers are faced with the enormous challenge of predicting and managing the impacts of climate change on cultural sites and landscapes.[1]

Climate-change-induced impacts to cultural resources in the Northwest Territories (NWT) are geographically widespread and can frequently be catastrophic. Coastal erosion — exacerbated by increases in the frequency of storm surges, eustatic sea-level rise, loss of sea ice, and isostatic subsidence — is actively destroying the rich archaeological record of the Arctic coast and impacting sites used today by traditional harvesters.[2] In the mountains, permanent alpine ice patches, which contain a well-preserved record of ancient hunting activities, are melting at an alarming rate as summer air temperatures increase.[3] Throughout northwestern Canada, the thawing of ice-rich permafrost is leading to significant terrain alteration.[4] These processes are almost

certainly impacting archaeological deposits lying in or above ice-rich soils, and traditional harvesters have observed impacts to their trapping areas and the removal of important landmarks along travel routes due to landscape collapse.[5] While the thawing of ice-rich permafrost can result in a number of characteristic landscape modifications (referred to as thermokarst features), retrogressive thaw slumps are the form of thermokarst erosion with the largest impact on landscape structure and sediment transport and are of particular concern to cultural-resource managers (Fig. 1).

Common throughout glaciated terrain in the western Canadian Arctic, retrogressive thaw slumps are disturbances that form in sloping terrain underlain by ice-rich permafrost; they are especially prevalent along coastlines and the shorelines of lakes, rivers, and streams.[6] They have a characteristic morphology, consisting of a crescent-shaped, ice-rich headwall, a scar area containing saturated mineral soils, and, in some cases, a debris tongue. Once initiated, the headwalls of active slumps can advance upslope at rates ranging from about 1 to 10 meters per year, with some slumps remaining active for decades.[7] While thaw slumps vary in size, it is common for them to impact several hectares of land, with the largest slumps achieving tens of hectares in area. Importantly, studies in the western Canadian Arctic indicate that the rate of thaw-slumping activity is accelerating as the climate warms and summer rainfall intensifies and that this process is impacting terrestrial and aquatic ecosystems as massive amounts of sediment are released into water bodies.[8] Cultural resources in this region are often located at slope breaks or near water bodies and thus are also at risk of direct impact from thaw-slumping activity. As thaw slumps occur over a vast and remote geographic area of the NWT, cultural-resource managers are in need of a way to identify areas where the risks to cultural resources from thaw-slumping and other forms of landscape change are greatest. This information will assist managers in using limited financial resources more effectively, while ensuring that the archaeological or other cultural sites most at risk are documented on a priority basis, especially when dealing with impacts in other cultural-landscape settings.

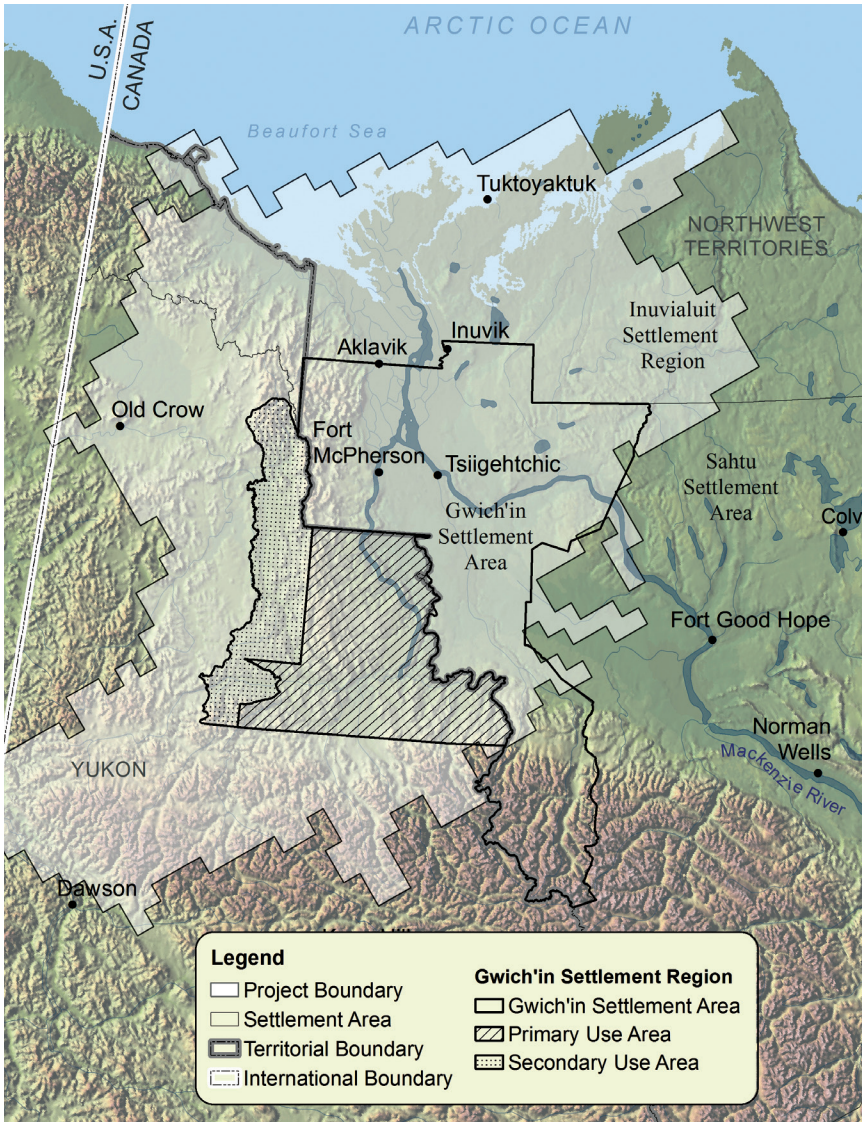

Fig. 2. Map of the Gwich'in region and study area. Courtesy of J. Buysse, GNWT.

The goal of this paper is to describe a risk-assessment tool that integrates traditional land-use data with data on the density of retrogressive thaw slumps in order to predict the risk that permafrost thaw poses to cultural resources in the northwest area of the NWT. The study area for this project is the Gwich'in cultural landscape (Fig. 2), which is defined for the purposes of this paper as the geographic extent of the trails recorded by Gwich'in harvesters in the NWTdurring the Dene Mapping Project.[9]

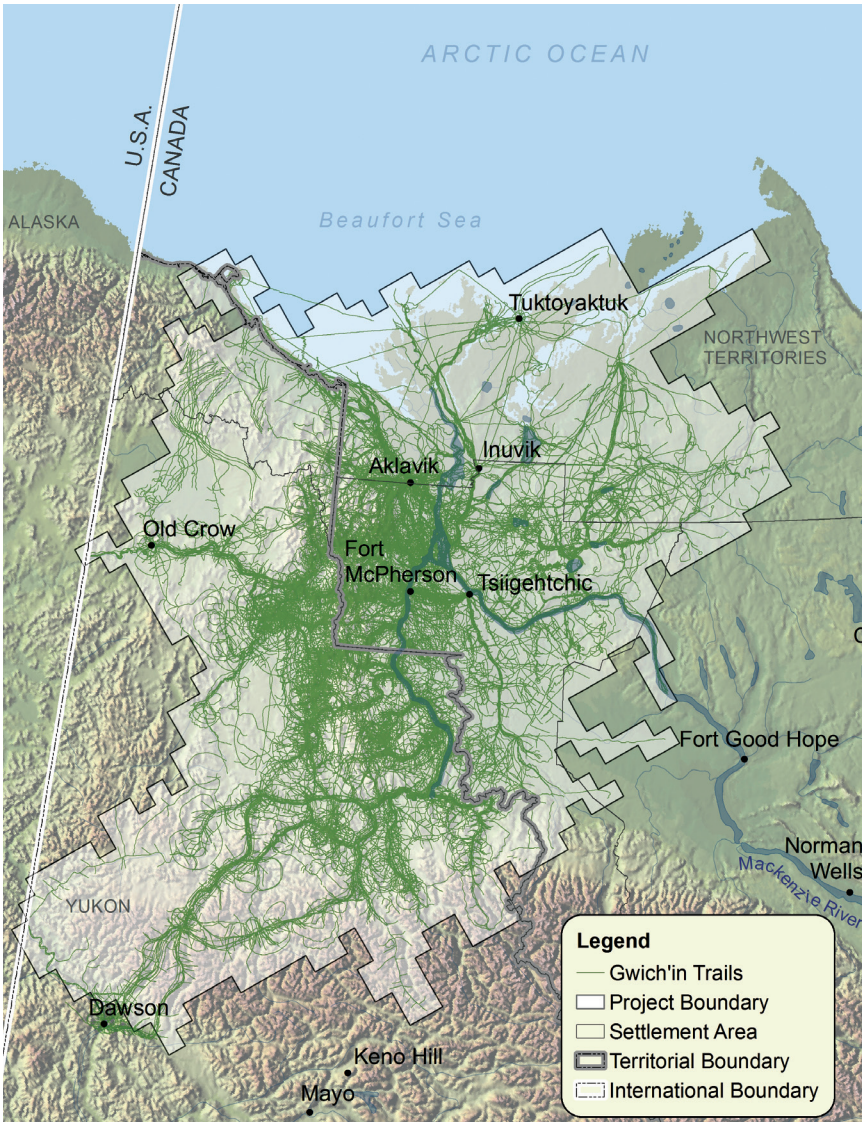

Fig. 3. Study area, showing Gwich'in traditional trails. Courtesy of J. Buysse, GNWT.

This cultural landscape is the product of many generations of Gwich'in making a living on the land as mobile hunter-gatherers and is embodied in the place names and the oral traditions associated with thousands of landscape features.[10] The Gwich'in, speaking a language from the Athapaskan family of languages, are one of several Dene peoples occupying the northwestern parts of Canada. Other regional Gwich'in bands occupy parts of Alaska and the northern Yukon, but their land-use information is not included in this study.[11] The practical engagement of the Gwich'in with the landscape has left many physical traces, including burial sites, camps, cabins, harvesting areas, trails, and sacred places where ritual offerings are made and has resulted in a rich cultural and archaeological record that often lies just underfoot of the traditional subsistence activities that continue in these places today. The landscape is also imbued with intangible cultural values linked to Gwich'in cosmology, spirituality, and the relationships between humans, animals, and other-than-human entities that inhabit the landscape. Trails link the tangible and intangible, which together comprise Gwich'in cultural resources.

Following the completion of the Gwich'in Comprehensive Land Claim in 1992, the Gwich'in Tribal Council formed the Gwich'in Social and Cultural Institute (GSCI). This organization was given the mandate to work with four Gwich'in communities in the NWT (Aklavik, Inuvik, Fort McPherson, and Tsiigehtchic) to document, preserve, and promote the practice of Gwich'in culture, language, traditional knowledge, and values.[12] The GSCI works closely with the Government of the Northwest Territories (GNWT) and the Yukon Government (YG) on the protection and management of heritage resources in the Gwich'in Settlement Region (GSR). The risk-assessment tool described in this paper was intended to assist cultural-resource managers of the GSCI, GNWT, and YG in their efforts to predict and manage the impacts of climate-change-related landscape disturbances on heritage values and contemporary land use in the Gwich'in cultural landscape.

Data and Methods

Two spatial datasets were employed in creating the risk-assessment tool: traditional harvester trail data from the Dene Mapping Project and a polygon grid describing the density of retrogressive thaw slumping within 15-by-15 km blocks. Overlaying the datasets provides a view of potential risk to Gwich'in heritage.

Retrogressive Thaw Slumps

Spatial data on the distribution of retrogressive thaw slumps was derived from a broad-scale mapping project undertaken jointly by the GNWT and the University of Victoria.[13] The densities of

active retrogressive thaw slumps were mapped for a large area (1,274,625 square km) of the Yukon, NWT, and Nunavut, using a constructed grid system of cells measuring 15-by-15 km. Trained technicians assessed each grid cell by viewing the geo-referenced SPOT 5 and SPOT 4 orthomosaics (2005-2010). They recorded slump density, along with other data on slump characteristics, including disturbance context. The SPOT imagery had a pixel size of 10 m, was viewed at a scale of between 1:20,000 and 1:30,000, and allowed mappers to identify slumps as small as 0.75 hectares. Slump surfaces that had been colonized by vegetation were not mapped in this exercise. This approach resulted in a map product (compiled in ArcGIS 10.0-10.2) consisting of 15-by-15 km grid cells ranked into five classes based on slump density: none (0 slumps), low (<5 slumps), medium (5-14 slumps), high (>15 slumps), and not applicable (cells covered entirely by water). For this study, the density of slumping occurring in each grid cell was given a number rank of one through three, based on their original classified values of low, medium, and high. Cells classified as "none" and "not applicable" were removed from the analysis, as they were deemed to have a very low or no-risk rating. The slump study covered the entire Gwich'in land-use region except for a small region in the southern Yukon of less than 900 square km (Fig. 4). Given that this area lies in a permafrost-free zone and represents only 0.004 percent of the entire risk-assessment study area of 232,424 square km, its exclusion is regarded as insignificant.

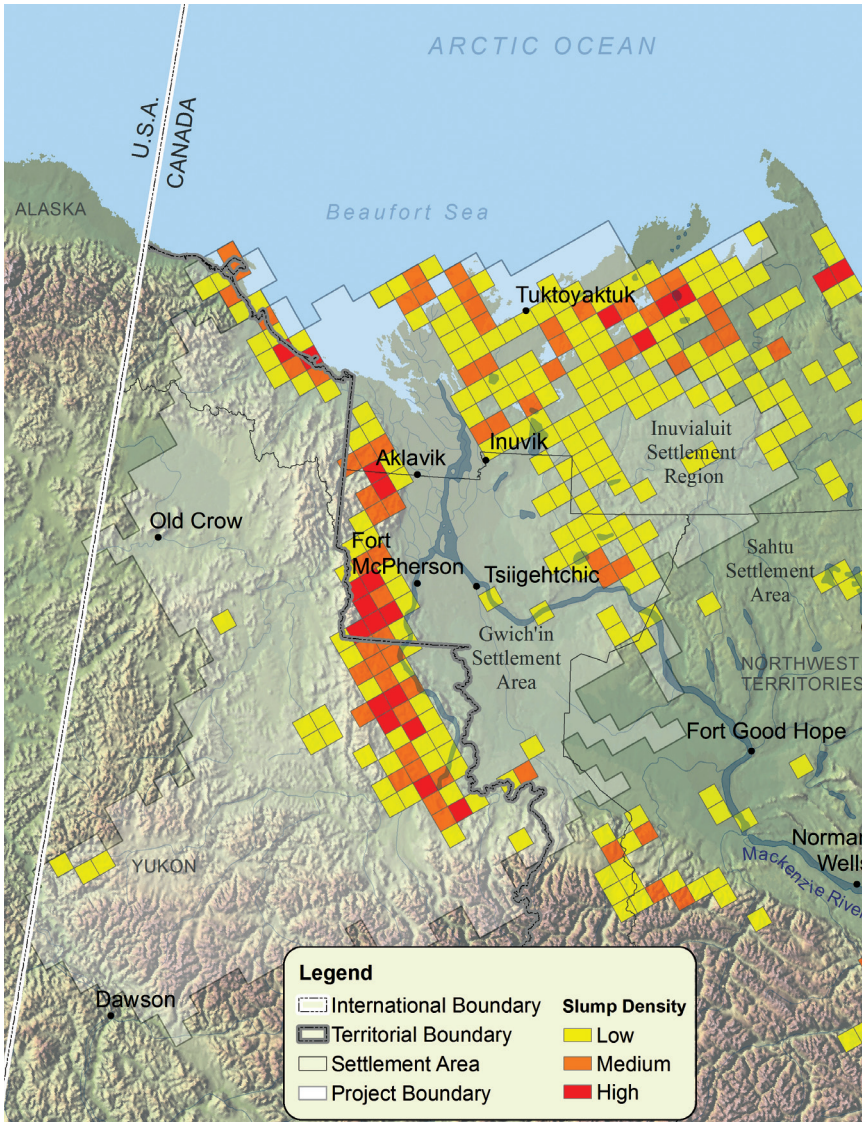

Fig. 4. Thaw slump heat map for the study area. Courtesy of J. Buysse, GNWT.

Trail Data in the Dene Mapping Project

For the purposes of this study, traditional land-use data was extracted for the four Gwich'in communities from the Dene Mapping Project dataset. This proprietary dataset was created between 1972 and 1983 to support the Dene Nation's negotiation of a comprehensive land claim with the Canadian government. The spatial data comprises traditional trails representing historical land use based on interviews with 30 percent of the active hunters and trappers living in the NWT.[14] In total, 600 individuals from 27 communities were interviewed (Fig. 3). Hunters were asked to draw their life's history of trail use using a colored pencil, tracing them on 154 mosaics constructed from 1:250,000 scale National Topographic System map sheets. The land use represented the time period from the late 1800s to the late 1970s. Since more than one hunter was represented on any given mosaic, multiple lines were drawn adjacent to each other on the map, indicating that the same trail was used by many individuals and families. This mapping method provides important information on the density of land use.

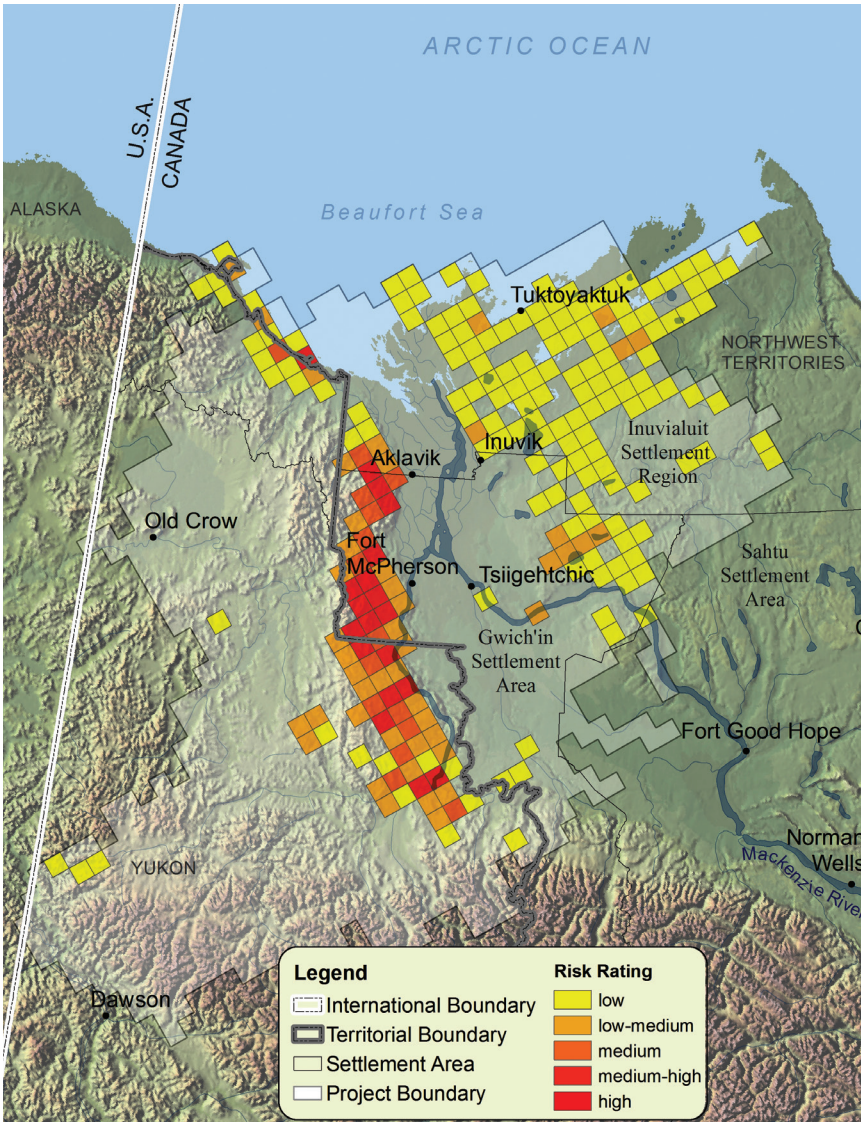

Fig. 5. Results map showing risk rating based on integration of Gwich'in traditional trail and thaw-slump distribution data. Courtesy of J. Buysse, GNWT.

In 1980 the mosaic maps were transferred to the University of Alberta to be digitized. Using the mainframe computing facility and a purpose-built geographic information system designed by Christopher Gold (Government of Alberta) and Robert Engly (University of Alberta), the trails were digitized and organized into a spatial database to which land-use information was appended. In the early 1990s the spatial data was transferred from a mainframe to a PC platform and is currently compiled in ESRI's geodatabase format.[15] A total of 127 hunters and trappers were interviewed in the four Gwich'in communities (61 in Fort McPherson, 21 in Tsiigehtchic, 35 in Aklavik, and 10 in Inuvik), and the maximum areal extent represented by this body of land use comprises the study area for this project.

Risk Assessment

Using ArcGIS 10.1 software, an overlay of the datasets was performed using the "Spatial Join" tool in order to determine the number of trails that fell within each 15-by-15 km grid cell. The resulting trail count was appended to the polygon grid table, with values ranging from 0 to 296, representing each individual line segment or portion of trail that fell within each cell. Where a null value existed, indicating that there was no overlap of traditional trails and slump activity, the record was removed from the dataset. Using the Jenks natural breaks classification method, the trail count was divided into five possible classes and assigned a rating value of one through five.

The GIS analysis was conducted using the line dataset of Gwich'in traditional trails and the retrogressive thaw-slump classification as described above. The numeric fields for thaw-slump density one through three and trail density one through five were multiplied by each other to derive a value that corresponds to risk. Using the Jenks method, the numeric risk value was divided into five classes and symbolized accordingly.

Results

The analysis indicates that of the 1,033 15-by-15 km blocks in the study area, 804 have no risk of impact to Gwich'in cultural resources from thaw-slumping activity, 148 blocks have low risk, 47 blocks have low-medium risk, 15 blocks have medium risk, 15 blocks have medium-high risk, and 4 blocks have high risk. The greatest risk to Gwich'in cultural resources occurs along the western border of the Gwich'in Settlement Area in the general area of the Peel Plateau, where 10 adjoining blocks to the west of Fort McPherson have medium-high or high risk. This area of higher risk extends south into the Yukon Territory, with several medium-high-risk grid cells results lying adjacent to the Peel River. This pattern reflects the high incidence of thaw-slump activity in the Peel Pla-

teau combined with intensive traditional land use, especially near Fort McPherson. There is also a small pocket of elevated risk along the Arctic coast to the west of the Mackenzie Delta (Fig. 5).

In contrast, most blocks in the broad area adjacent to the Mackenzie River (including much of the Mackenzie Delta) and the Arctic Red River were rated as posing no risk to Gwich'in cultural resources; this rating reflects the near absence of thaw-slumping activity in this area. The large area to the north and east of the Mackenzie River is largely classified as low risk, with a few pockets of low-medium risk. While there are some hotspots for thaw-slump activity in this area, Gwich'in land use is generally less dense, especially nearer to the coast. Though beyond the scope of this study, including overlapping traditional land use of neighboring Aboriginal groups would change the risk values in areas closer to the coast and into the Mackenzie River corridor, providing a more accurate assessment.

Discussion

In the vast and largely remote circumpolar North, landscape-scale risk-assessment tools are likely the only cost-effective way to prioritize actions for managing the impacts of climate-change-induced landscape disturbance on cultural resources. A central challenge in the development of these kinds of tools is having accurate spatial data on the full distribution of cultural resources across the landscape. This need is especially true where resources have been surveyed or mapped in detail in some areas but not in others. The value of the Dene Mapping Project trail data for developing this risk-assessment tool is that it provides a reasonably systematic view of Gwich'in land use in the study area. Landscape units with a higher density of trails are also likely to have a higher density of cultural places related to Gwich'in land use.[16] However, some caution is required in extending this relationship into the deeper past, as precontact Gwich'in land-use patterns may have been different from those captured by the Dene Mapping Project in the 1970s, and very little is known about the archaeological record of large portions of the study area. Generally speaking, archaeologists working in both Arctic and subarctic contexts in the NWT have established that there is a high degree of continuity between the distribution of late precontact archaeological sites and traditional land use.[17] As such, the risk-assessment tool described above provides a reasonable approximation of risk to late precontact Gwich'in archaeological sites. It is important to note that the risk-assessment tool is specific to past and present Gwich'in land use and cannot be used to predict impacts to the cultural values of neighboring cultural groups; for example, there is likely a much larger number of cultural resources linked to Inuvialuit land use at risk of impact from thaw slumping in the Inuvialuit Settlement Region that are not captured in this risk model. While the distribution of Gwich'in heritage sites is determined by a combination of cultural and landscape factors, the action of thaw slumps has enormous potential to remove entire sites from the environment, especially where traditional land uses are associated with littoral areas or changes in slope.

> Thaw slumping is a dominant process driving landscape change in ice-rich glacial environments.

Thaw slumping is a dominant process driving landscape change in ice-rich glacial environments. Slope and sediment type are controls on terrain stability, but the development of large retrogressive thaw slumps requires the presence of thick layers of ice-rich permafrost. There is growing evidence indicating that these disturbances are most prominent in ice-rich moraine environments. For example, the Peel Plateau is comprised of predominantly ice-rich moraine deposits that demarcate the western limit of the Laurentide ice sheet. Fluvial incision of the ice-rich plateau provides relative relief to accommodate the development of very large thaw slumps. Ice-rich moraine deposits are also common throughout the region west of the Mackenzie Delta, but the lake-rich environment has a more subdued topography, and generally the disturbances are smaller than on the Peel Plateau. It should be noted that the mapping method that generated the slump inventory data may be less effective at capturing smaller, rapidly revegetating shoreline disturbances that are more common in the lake-rich regions to the west of the Mackenzie River and Delta.[18]

This study also highlights the value of developing landscape-scale inventories of thermokarst disturbances. While these data are coarse grained, they provide a good indication of the relative susceptibility of different landscape areas to thaw-slumping activity and enable researchers to focus archaeological fieldwork on the 15-by-15 km blocks where the frequency of thaw slumping will likely accelerate as the climate warms. In this way, the risk-assessment tool cannot be used to determine where and when a specific Gwich'in cultural feature will be impacted by a thaw slump, but it does indicate in which blocks this is most likely to happen. Areas identified as having low slump count are in part a product of having used coarse-scale imagery and a conservative mapping strategy. This remote-sensing tool is not particularly effective at identifying small slump features where vegetation is not completely evacuated from the scar zone. Consequently, there may be cells with small, stable slumps that were mapped as "low slumps" or "no slumps." As such, the mapping is not particularly effective in mapping small, lakeside slumps, and even if there were many of these small slumps present, mapping methodology precluded the mappers from identifying them. In the future, a nested approach should be used, including the broad-scale techniques used here coupled with change detection, fine-scale mapping, and, where possible, low-level airborne inspections.[19]

This information is useful to cultural-resource managers in a number of ways. It can be used to prioritize areas for finer-grained map analysis of the interactions between thaw slumps and cultural resources. For example, detailed mapping of thaw slumps and their landscape associations for a given area could be used to identify known cultural places that are located in terrain susceptible to thaw-slumping activity. This information could be used to design management plans for specific sites and to select important cultural places that would benefit from community-based monitoring. The risk map can also be used to prioritize ongoing efforts to inventory cultural resources in the Gwich'in cultural landscape, in areas where cultural values have been identified through map-based studies but not recorded on the ground.

The risk map may also be useful to land-management bodies in the Gwich'in region. The Gwich'in Land Use Planning Board (GLUPB) is currently exploring cultural-resource management approaches for a network of conservation areas in the GSA. The risk map described here will facilitate the inclusion of management issues related to climate change in the GLUPB planning process. The risk map could also be used to evaluate the potential for cumulative impacts to cultural resources from industrial development activities and thermokarst disturbances in proposed development areas. The risk map can be used to ensure that Gwich'in residents carrying out traditional activities, including subsistence harvesting, are aware of threats to travel safety resulting from areas of high slump activity. For example, the Northwest Territories Geological Survey used the slump data to issue a geohazard advisory for travelers in the Husky Lake area of the Peel Plateau.

Updating the slump inventory and making available fine-scaled disturbance mapping products on a regular basis will provide cultural-resource managers with current assessment data, while adding other heritage information, such as archaeological sites, sacred locations, named places, critical harvesting sites, locations of burials, and overlapping land use of neighboring Aboriginal groups. This process will bring greater precision to management of heritage resources. Finally, the techniques employed here will have application in circumpolar settings where thermokarst erosion threatens cultural landscapes.

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Trevor Lantz *is an associate professor with the School of Environmental Studies at the University of Victoria. His work focuses on the impacts of global change on ecocultural landscapes in western North America. An ecologist and ethnobiologist, he has conducted research that employs local knowledge of ecosystems, as well as observational and experimental approaches. He may be reached at tlantz@uvic.ca.*

Dedication

This paper is dedicated to the memory of the late Susan Buggey. Susan was a friend and colleague whose work in helping to define and document Aboriginal cultural landscapes has inspired many and will continue to do so. Through her work, she helped further the understanding that the key aspect of Aboriginal cultural landscapes is that they are living landscapes, "constructed" through the daily practice of life, layered and made complex by the sweep of generational time. In the process of developing these ideas, Susan became an ally to many Canadian Aboriginal groups interested in finding ways of commemorating their landscapes, and her work in the Northwest Territories is remembered fondly and with respect.

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