OUR RECENT PILOT PROJECT IN TUKTOYAKTUK AND NORMAN WELLS...

The Geological Survey of Canada is examining sensitivity of permafrost degradation under climate warming, using a community approach. A pilot study was conducted in two communities in the Mackenzie Valley, Norman Wells and Tuktoyaktuk (Couture *et al.* 2000; Robinson *et al.* 2001; Couture *et al.* 2001).

Crack developed in pavement due to frost heave in road foundation.

Continuous permafrost and cold ground temperatures characterize Tuktoyaktuk, whereas discontinuous permafrost and warmer ground temperatures occur in Norman Wells (see Figure 3). The pilot study focused on surficial geology, permafrost distribution and conditions, frozen ground temperature, geotechnical properties of frozen materials, and infrastructure and foundation systems and their performance history. Geotechnical data from 432 boreholes for Norman Wells and 342 boreholes for Tuktoyaktuk, including physical, mechanical, and geotechnical properties, were compiled (Chartand *et al.* 2001) and analyzed.

Degradation of polygonal ice wedges threatening the integrity of the abandoned airstrip at a DEW-line site.

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In addition, types of infrastructure and foundation systems were identified and classified, and the performance of past and existing infrastructure was examined. Ground temperatures have been measured at several sites, and data shows the warming effects of ground clearance (see Figures 6 and 7). Thermal modelling was conducted to evaluate the response of currently disturbed and undisturbed ground to climate warming scenarios and to assess the associated impacts on infrastructure. Reports and databases will assist communities and authorities responsible for the design, construction, and maintenance of infrastructure to develop plans that incorporate anticipated climate changes.

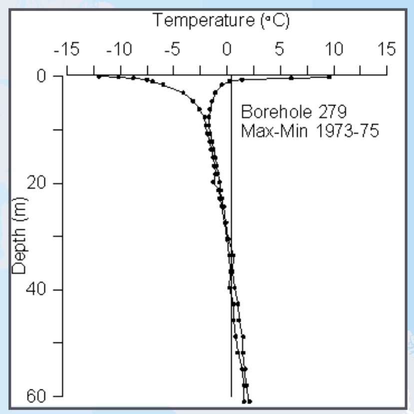

Figure 6.
Borehole ground temperature envelope measured at a site in undisturbed, forested terrain. Note the thin surface thaw layer, and general increasing temperatures with depth beneath the zone of seasonal fluctuations. These are indicative of permafrost in equilibrium with present climate.

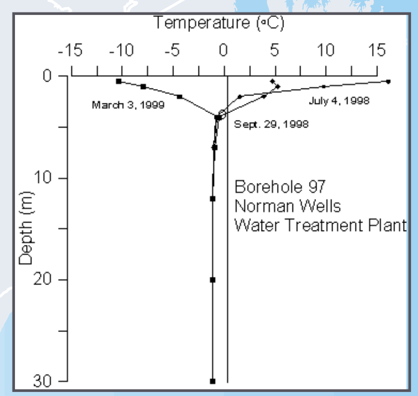

Figure 7.
Borehole temperatures measured at a site that had been cleared and covered with fill (disturbed). Note the greater near surface temperatures and thaw depth associated with site clearance. It is thought that climate change will magnify this warming and permafrost thaw, and induce ground settlement in many ice=rich locations.

Did you know?
In the north, loss of permafrost may cause terrain slumping, infrastructure instability, the drainage of small lakes and increased sediment loads in rivers, and potentially threatening northern wetlands.

KEY ISSUES FOR COMMUNITIES

While focussed on Norman Wells and Tuktoyaktuk, other communities in the north will likely face similar issues and concerns.

The potential impacts of climate change may require consideration in the following areas for northern communities (this is not an exhaustive list):

Roads and airfields: More maintenance may be required due to enhanced frost effects and thaw settlement. Late opening and early closing of winter and ice roads, reducing the climatic window for an ice road.

Building foundations: The loss of strength in thawed or thawing permafrost and induced creep owing to climate warming. Building foundations could experience settlement due to ground warming. Shallower foundations in relatively warm ice-rich permafrost will be especially susceptible.

Slopes: Increased risk of slope instability (creep and landslides) due to an increase of depth and/or rate of thaw, loss of strength.

Coastal areas and infrastructure: Climate warming coupled with a rising sea level and decrease in sea ice extent will likely increase the frequency and magnitude of storm surges and result in increased rates of shoreline erosion.

Offshore infrastructure: Changes in Arctic ice cover and thickness will also have an impact on the design of offshore structures for ice loading.

Linear infrastructure such as pipelines, energy distribution lines, water/sewer facilities: An increase in differential ground movement will likely lead to increased maintenance costs for existing structures and more elaborate designs for new infrastructure.

Water transportation: Communities served by barge may have an extended shipping season because of decreases in ice cover and season, although changes in water levels may provide constraints to river shipping.

Natural environment: The natural environment around communities will also be affected by a warming climate. Likely impacts include increased forest fire frequency, changes to water regimes, and a northward shift of southern plants and animals.

Did you know?
An analysis of temperature records shows that the Earth has warmed an average of 0.5°C over the past 100 years. The 20th century was the warmest in the past 1200 years, with 1997 and 1998 being the warmest years on record. The intensity of warming has varied from decade to decade, from region to region and from season to season. Warming is expected to be the greatest in northern regions.

THE POTENTIAL FOR COMMUNITY-BASED ADAPTATION

Northern communities should start to develop strategies and plan for adaptation to climate change. In general, buildings already in place or currently being planned have been designed with current climate and permafrost conditions in mind. Future changes to climate and permafrost may result in increased maintenance costs for existing infrastructure, and more elaborate designs for new construction.

Some potential adaptation strategies that could help offset some impacts are outlined below:

Improved construction techniques;
New infrastructure should be developed with the expected climate and permafrost (geotechnical) conditions at the end of the structure's lifespan in mind. It cannot be assumed that the permafrost helping to support a structure today will be stable in 50 years. This may require improved construction techniques, such as more fill, improved foundations, or the use of thermosyphons. Anticipatory approaches to climate change will be especially necessary for certain types of infrastructure with long anticipated lifespan, known climate thresholds, difficulties in retro-fitting, and large development costs.

Vigilant monitoring of infrastructure problems;
Climate change and permafrost degradation are ongoing processes, with steadily increasing impacts. Monitoring permafrost and infrastructure conditions should be undertaken. Retro-fitting of infrastructure and increased maintenance may become necessary.

Maintain good drainage around structures and roads;
Water ponding can accelerate permafrost degradation and increase frost heaving. Such ponding should be avoided.

Avoid ice-rich terrain;
Ground settlement will be greatest in ice-rich terrain, and such areas should be avoided as much as possible.

Snow clearance;
Snow is an excellent insulator, and snow can prevent cold winter temperatures from entering the ground. The clearance of snow from some areas may help maintain permafrost.

Avoid excessive ground disturbance;
Vegetation provides a barrier, or insulating effect, between the air and ground. Ground clearance (removal of vegetation) can significantly warm ground temperatures even without a change in air temperature. It is best to have minimal disturbance to the area during construction to help preserve permafrost.

Did you know?
Engineering problems in permafrost regions most often result from an inadequate knowledge of site and climate conditions. If climate change is not incorporated into future engineered works in the north, problems may become more frequent.

← View previous page