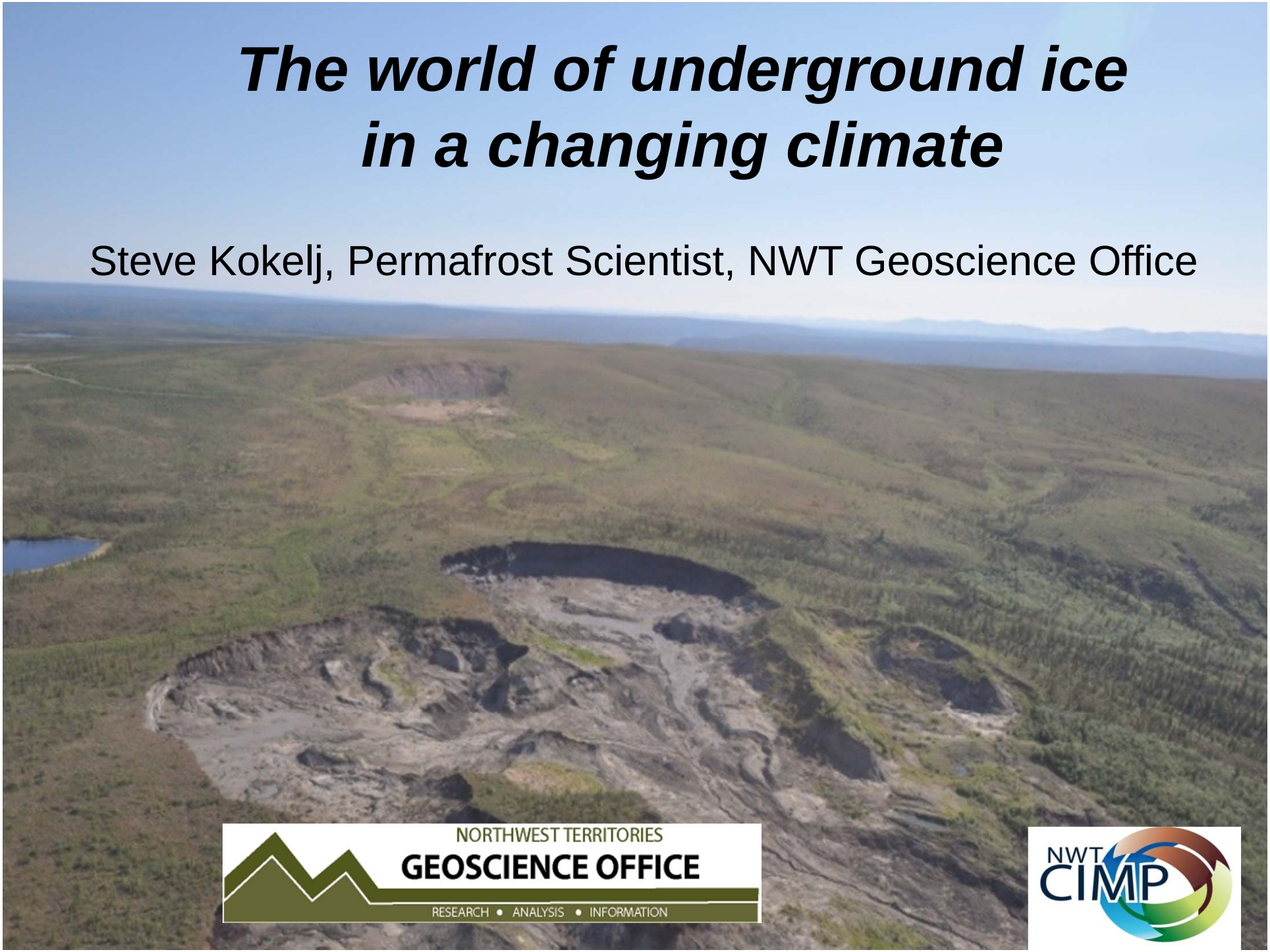
The world of underground ice in a changing climate

Steve Kokelj, Permafrost Scientist, NWT Geoscience Office



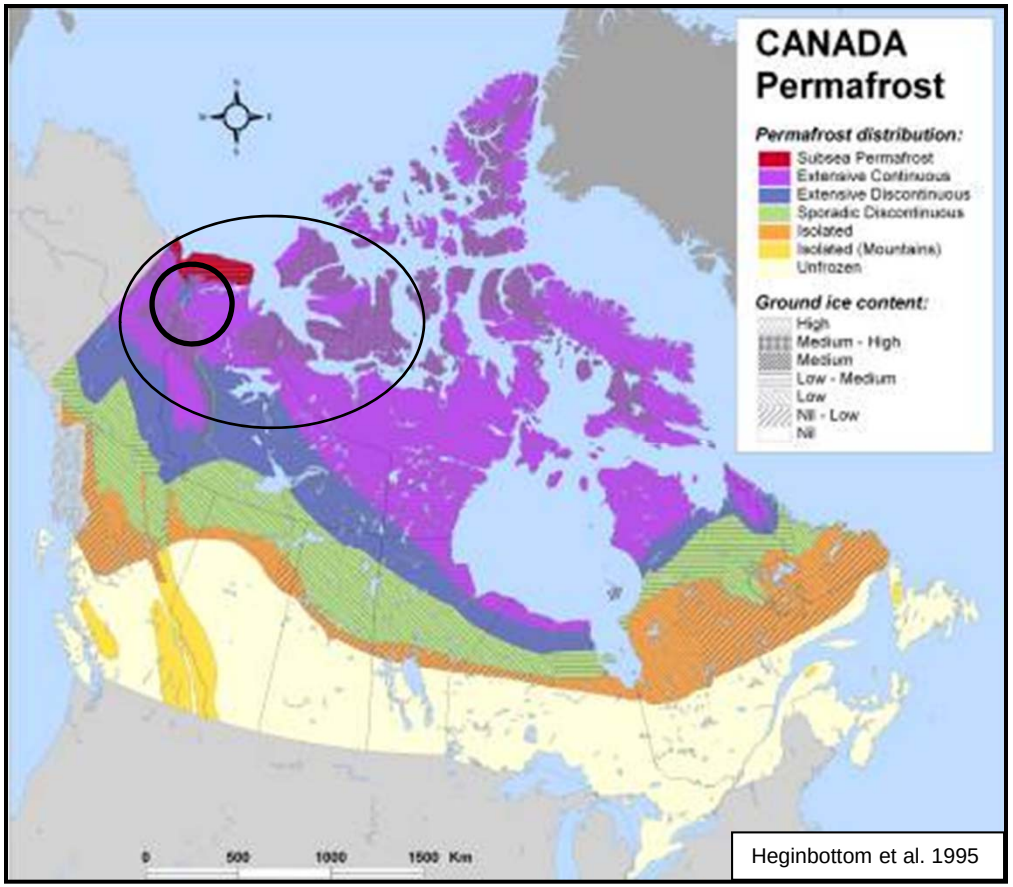
NORTHWEST TERRITORIES
GEOSCIENCE OFFICE
RESEARCH • ANALYSIS • INFORMATION

NWT CIMP

Outline

- Ice in the permafrost
  - Aggradational ice
  - Ice-wedge ice
  - Massive tabular ground ice
- Thawing of icy permafrost and landscape change

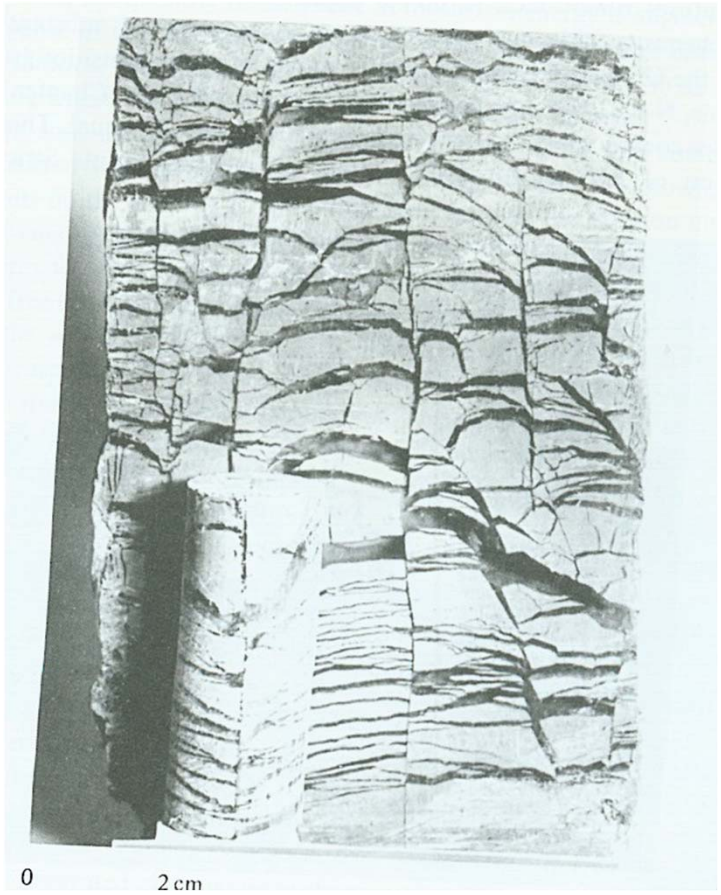
Permafrost and the north



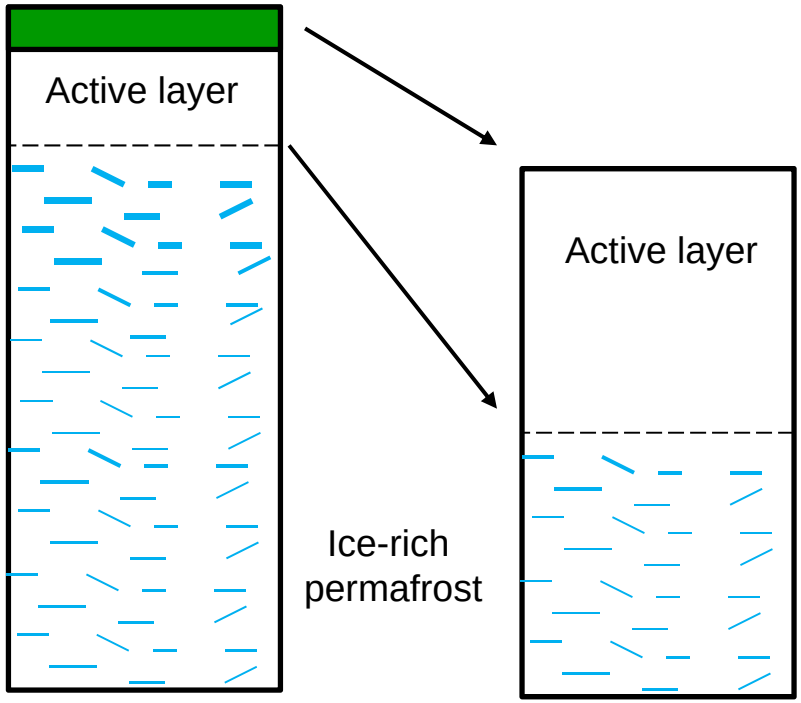
Heginbottom et al. 1995

Ground ice

Segregated ice-lenses

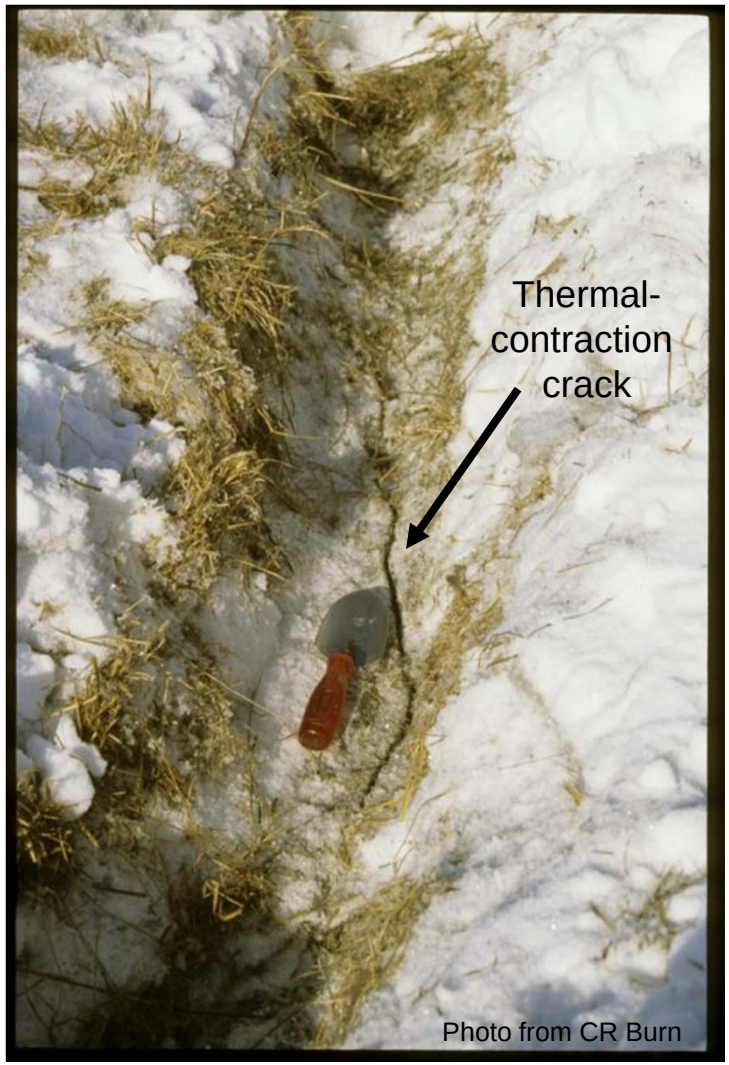


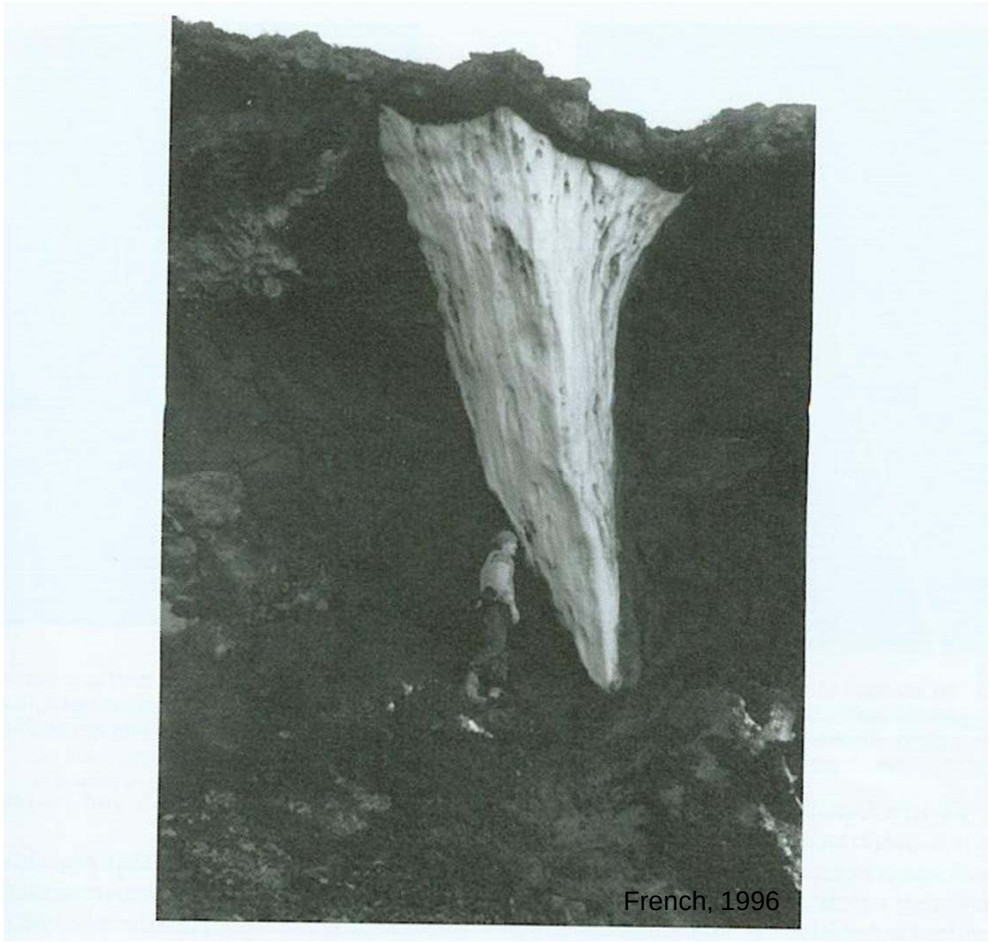
Surface disturbance – increased thaw depth
=
Surface subsidence



Drunken forest = ice-rich terrain

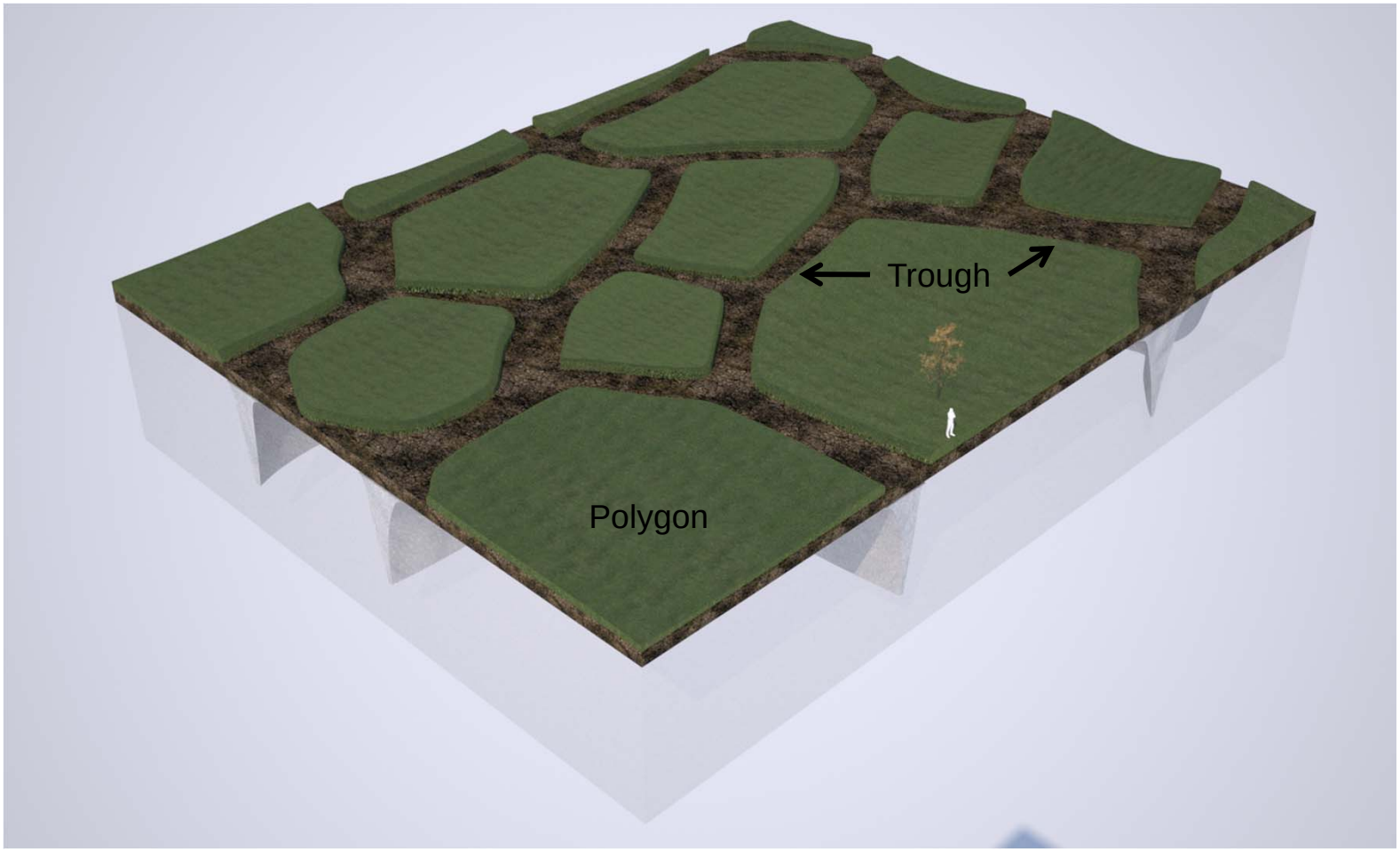
Ice-wedge ice



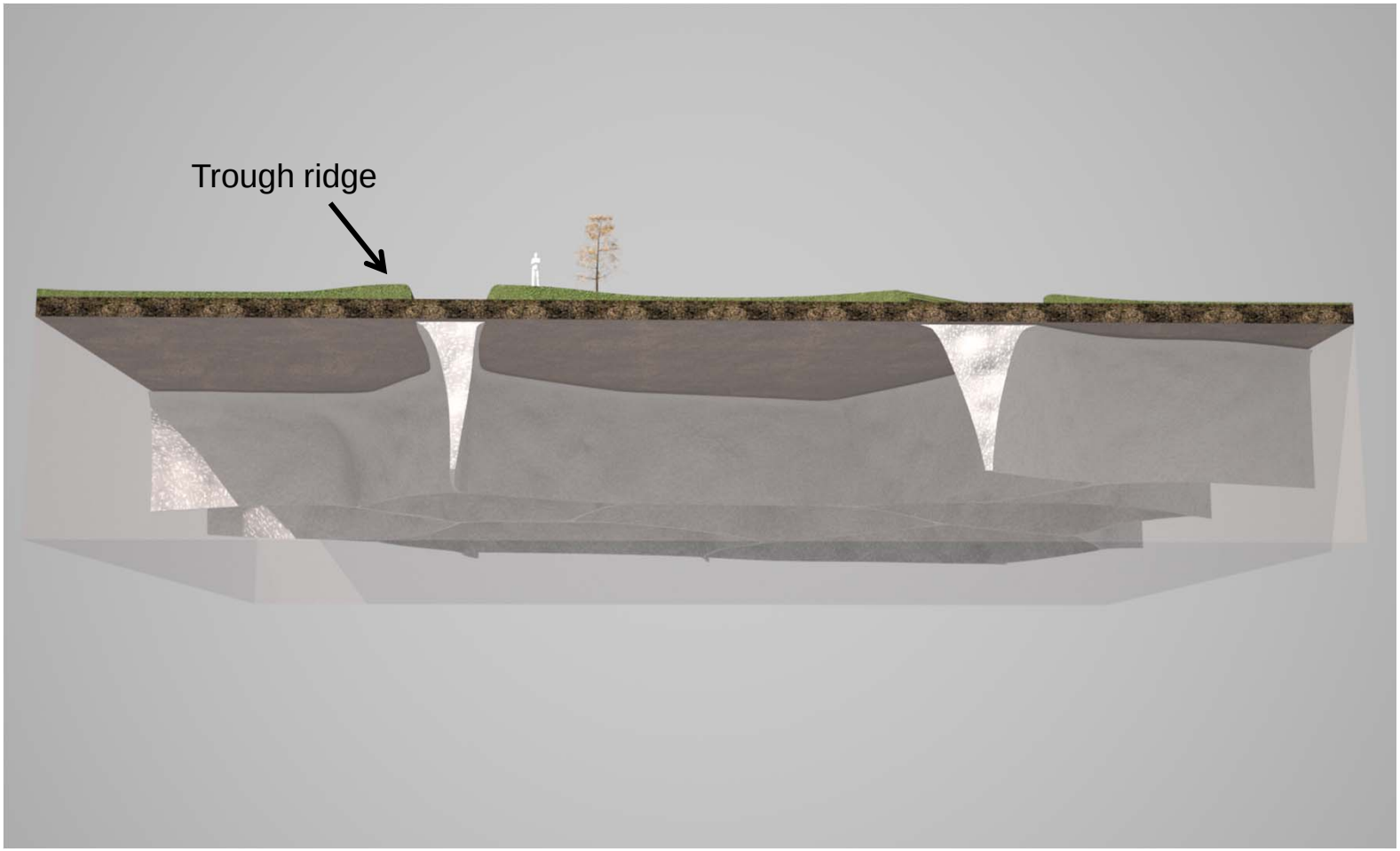


Polygonal terrain

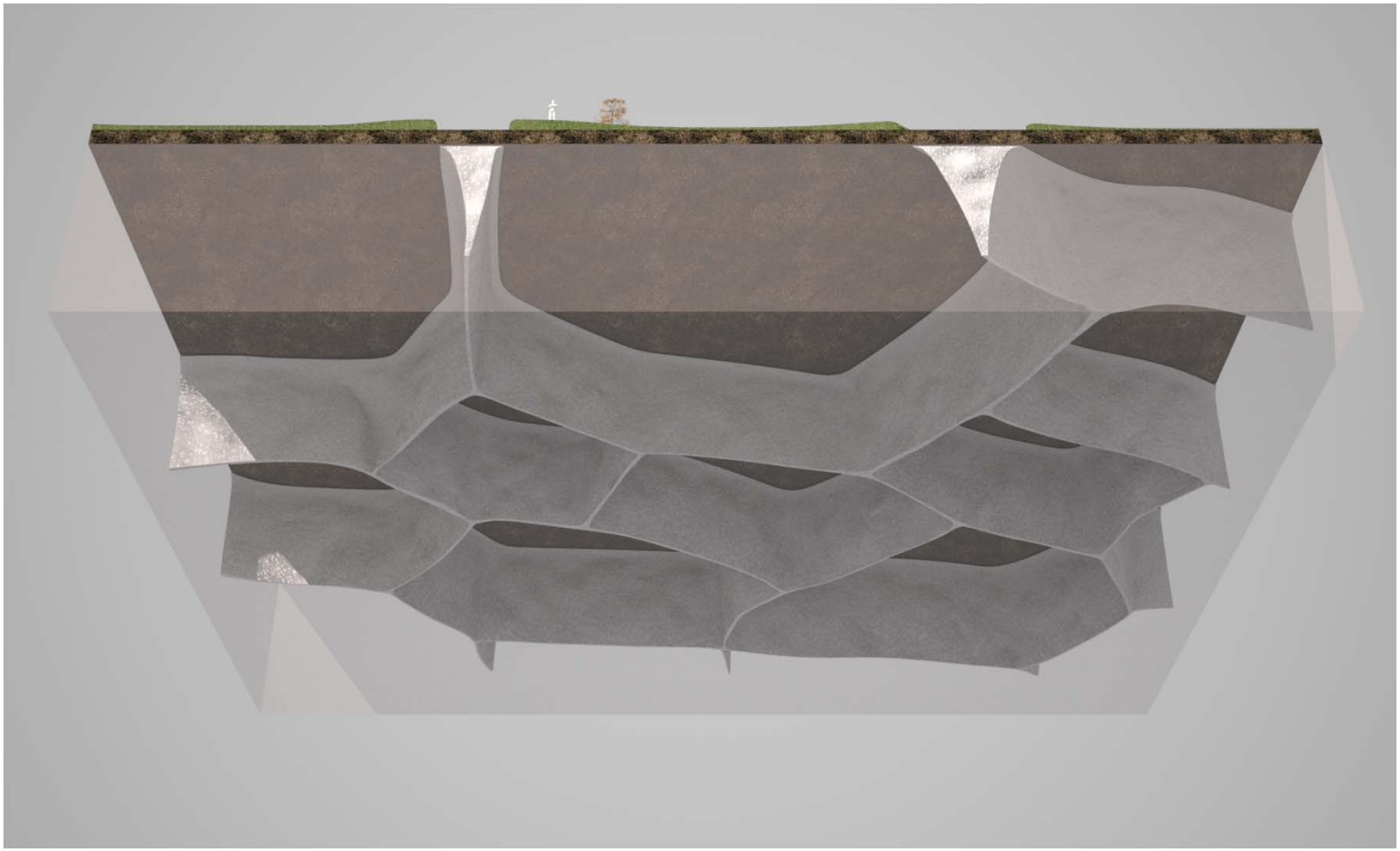
Polygonal terrain



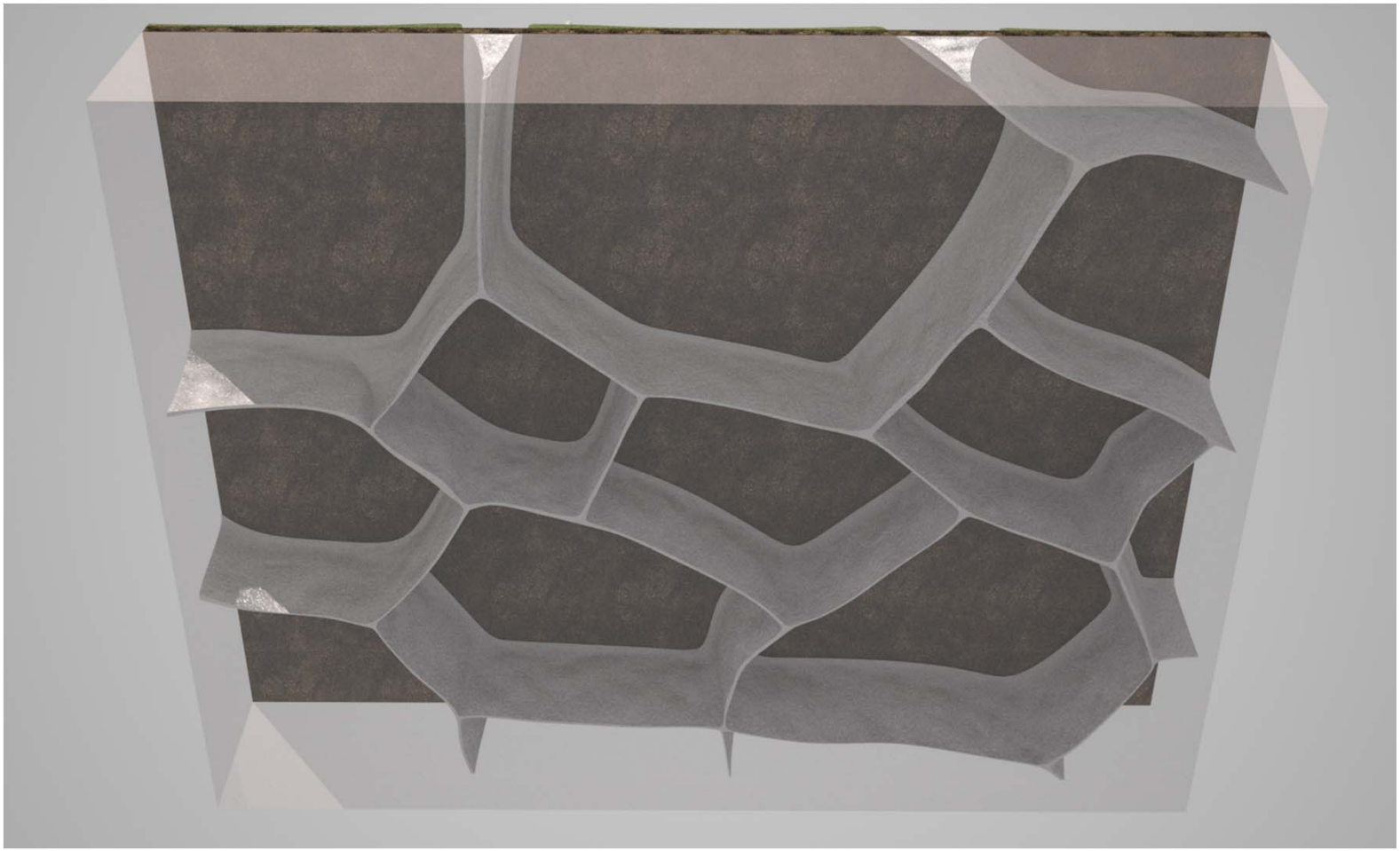
Polygonal terrain



Polygonal terrain



Polygonal terrain



Polygonal terrain and ice wedges

Massive ice and ice-cored terrain


“The hills are getting really messy”
Robert Alexie Sr. Fort McPherson
Dempster Hwy
Historic quarry
Access road
Mega slump
Carleton University
University of Victoria
Gwich’in Renewable Resources Board
Tetl’it Gwich’in RRC
University of New Brunswick
University of Ottawa
DFO
Gwich’in Tribal Council
Wilfred Laurier University
NWT Centre for Geomatics, GNWT
Culture and Heritage, GNWT
NWT CIMP

Questions

- What are the environmental impacts of large thaw slumps?
- Are there more slumps and are they bigger than before?
- What causes large, long-lived thaw slumps to form?
- What are the landscapes impacted by these disturbances?

Slump ‘Life Cycle’

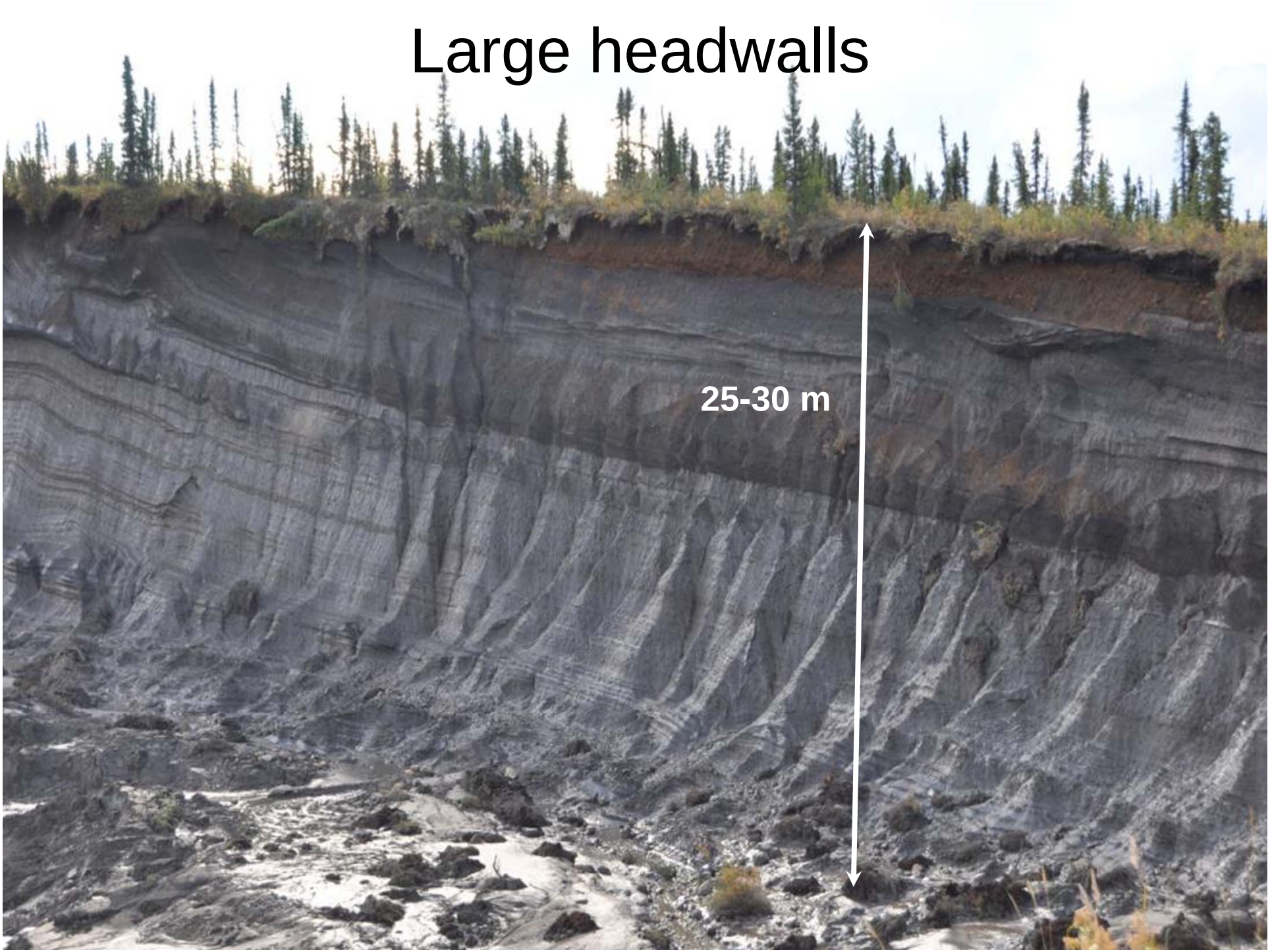
Birth
Initiation

Youth
Active Stage

Old age
Vegetated
Surface

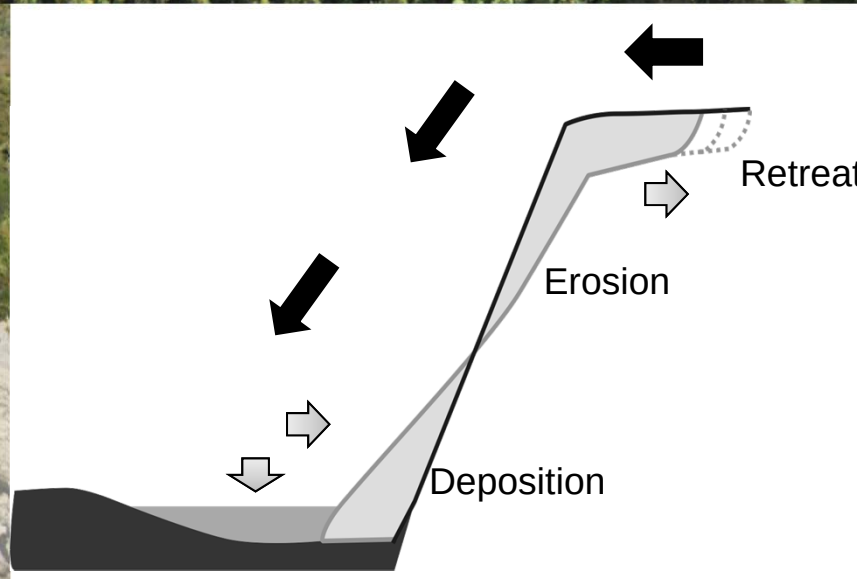
In memory of…
Relict
Features

Large headwalls

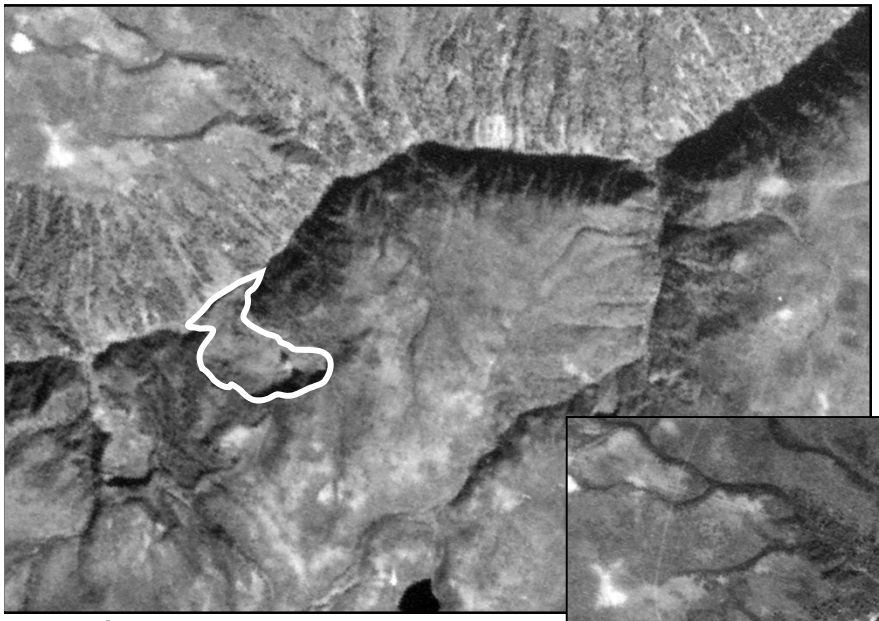


Debris run-out

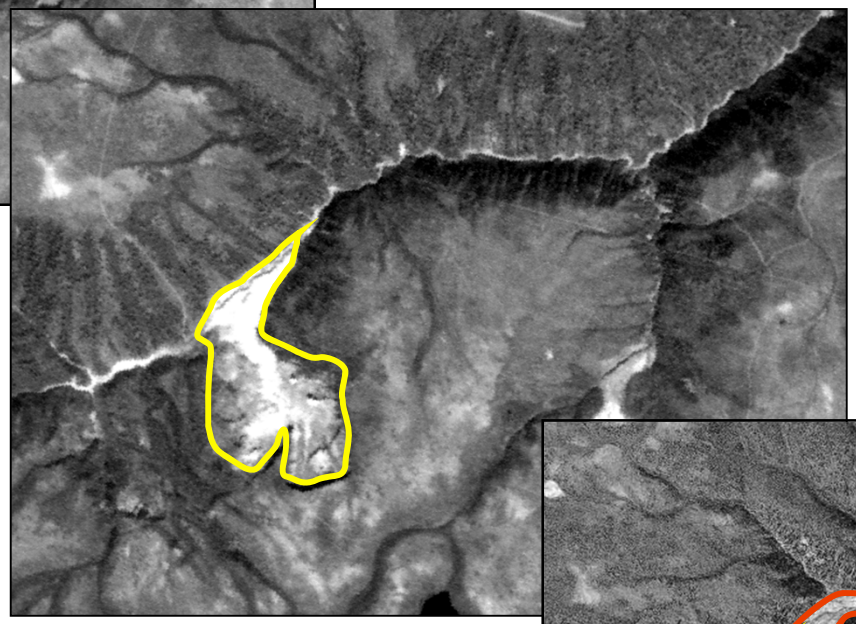
A fine-grained sediment slurry fills the trunk valley.



Mega-slump timescale

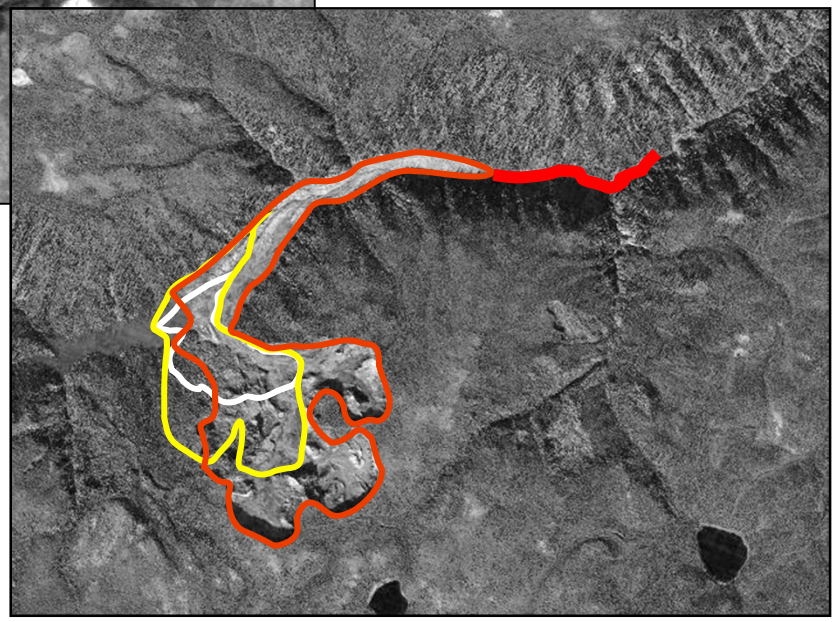


1954

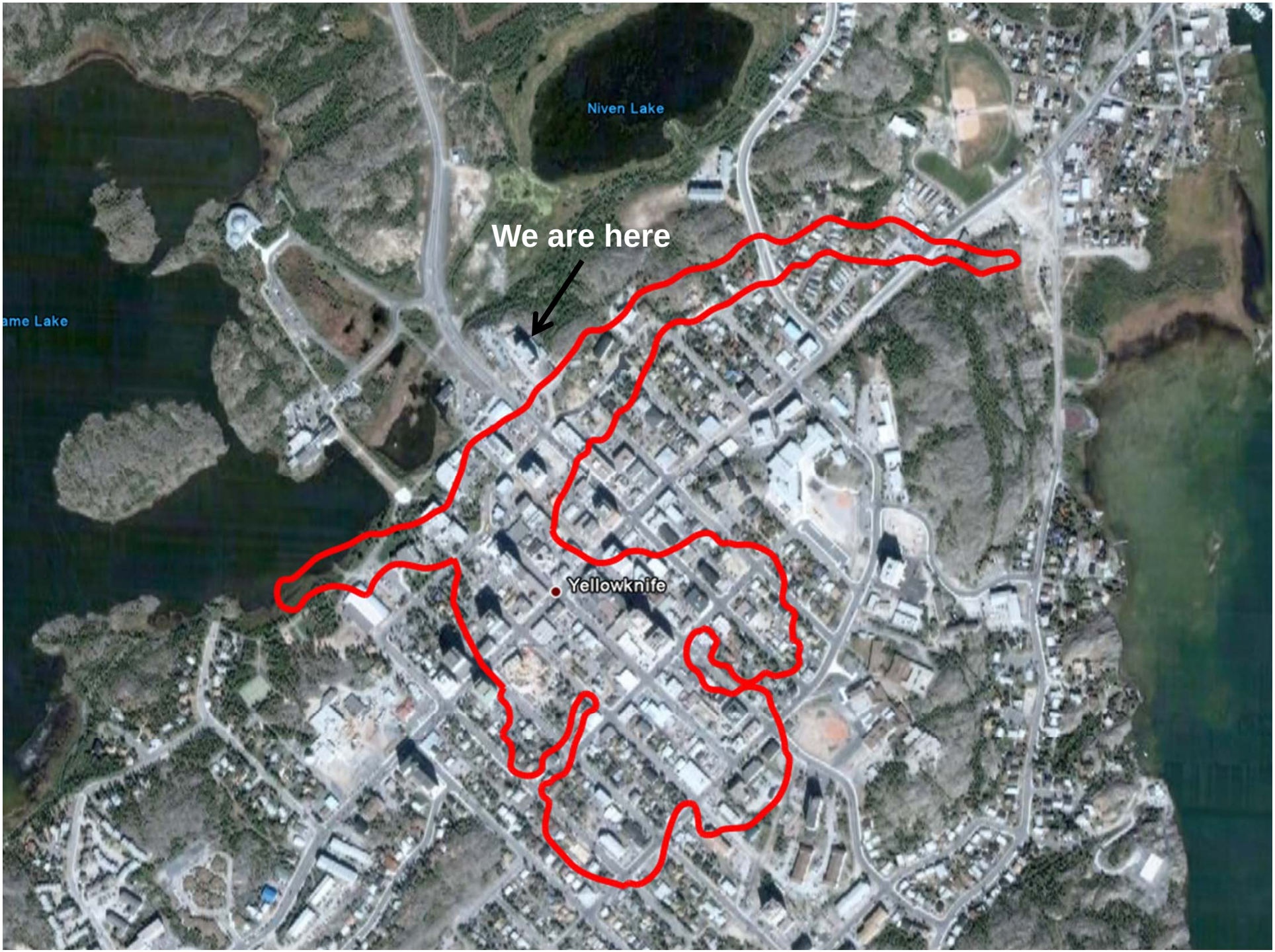


1971

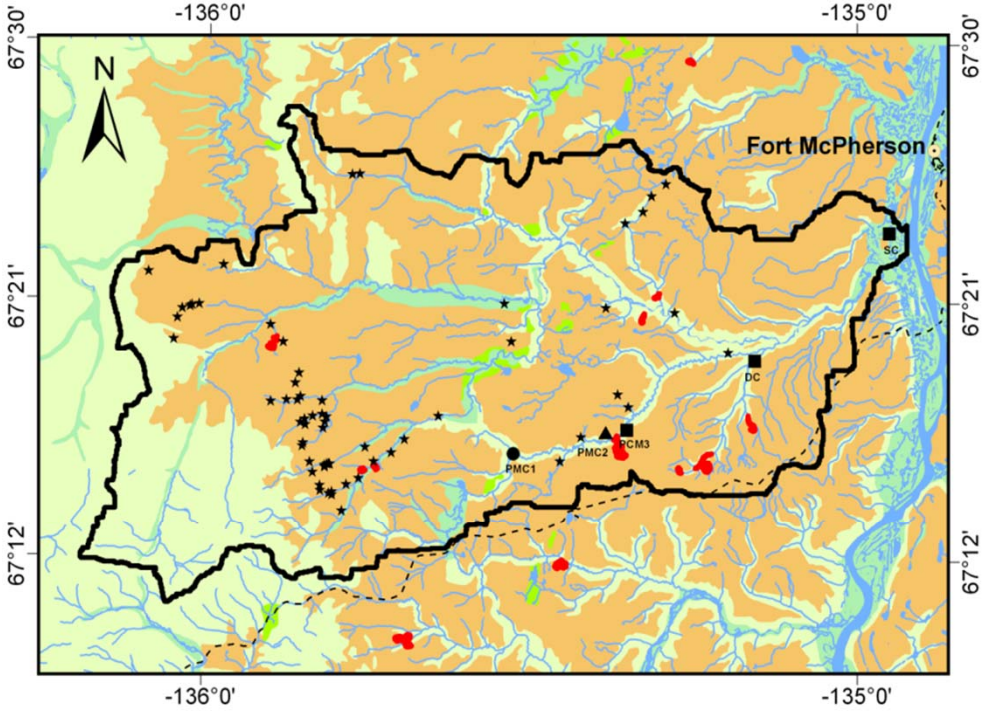
2010

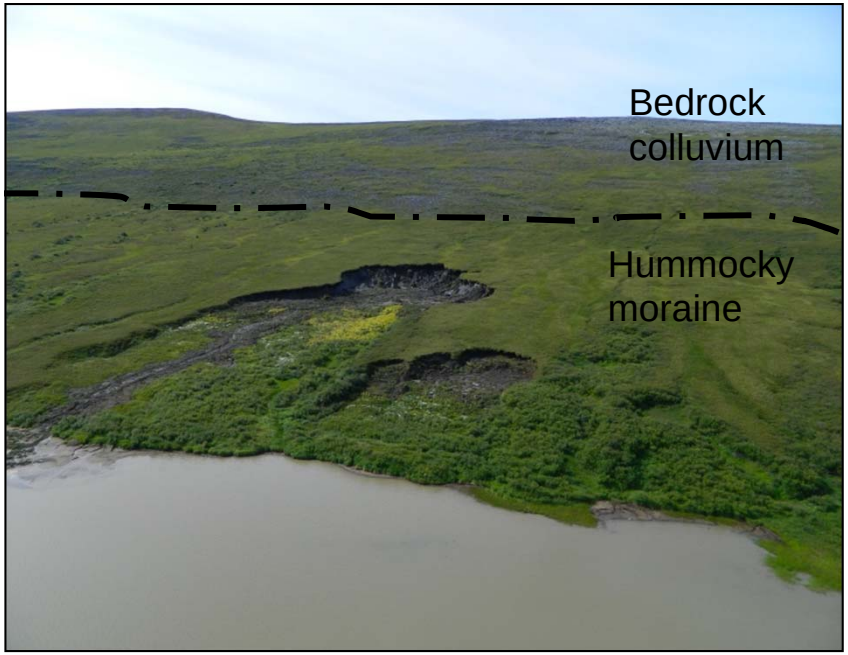


Rate of retreat = 2-15 m yr^{-1}


Niven Lake
We are here
ame Lake
Yellowknife

Peel Plateau

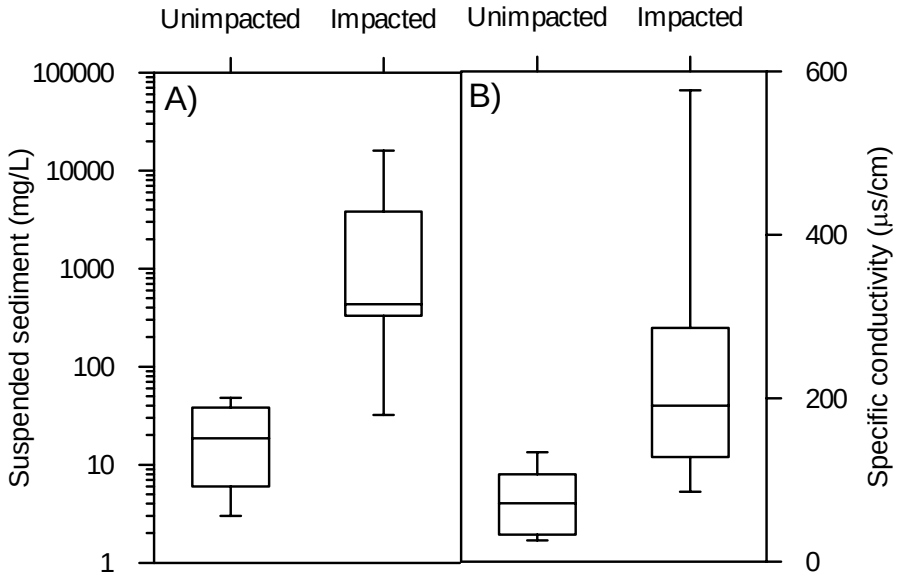




Km
0 3.5 7 14 21 28

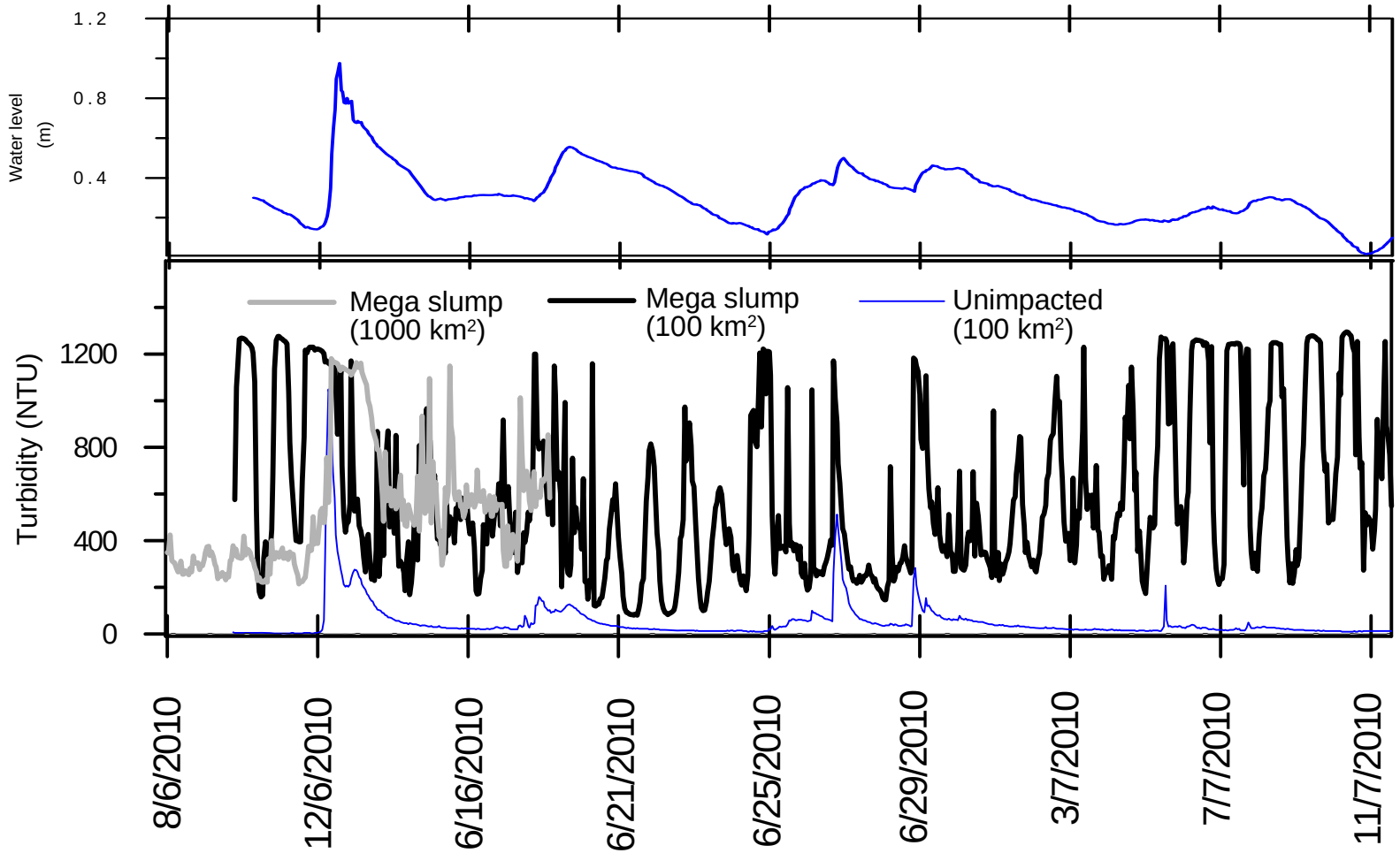
Megaslump
Drainages
Alluvial
Colluvial
Glacofluvial
Lacustrine
Morainal
Organic

Major impacts on streams and river



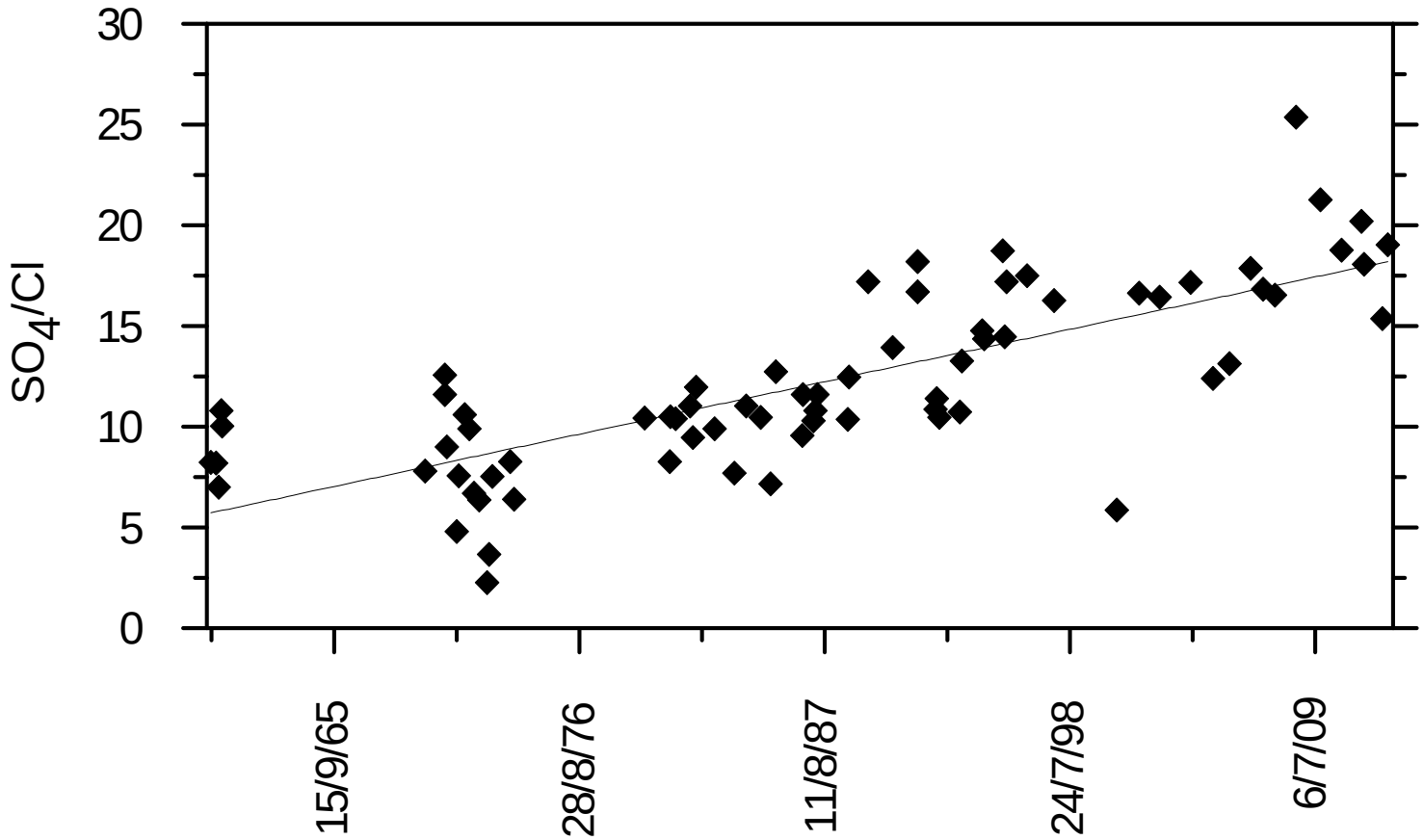
The amount and timing of sediment delivery to streams

New stream sediment pattern



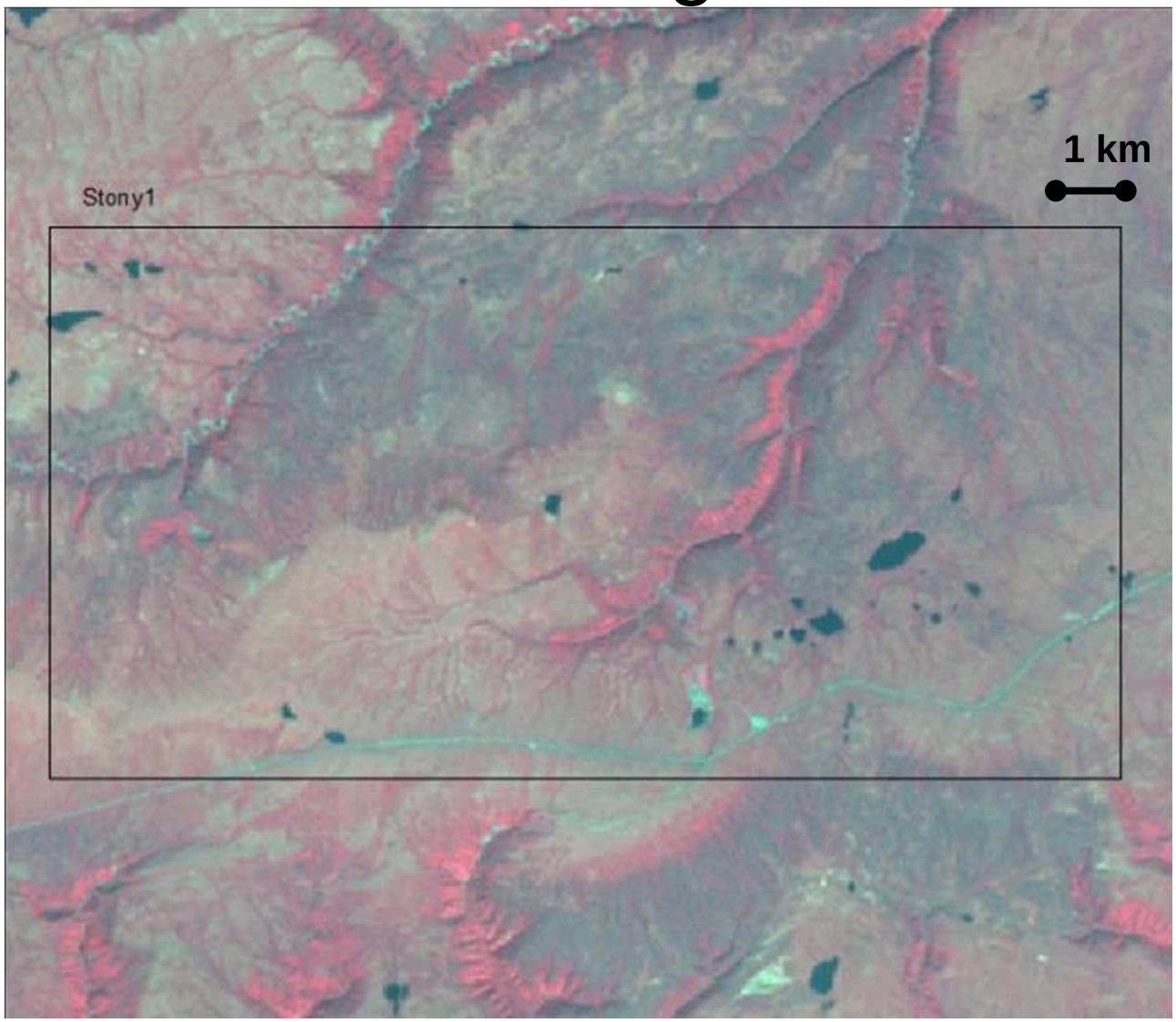
Kokelj et al., 2013, JGR

The Peel River is being impacted



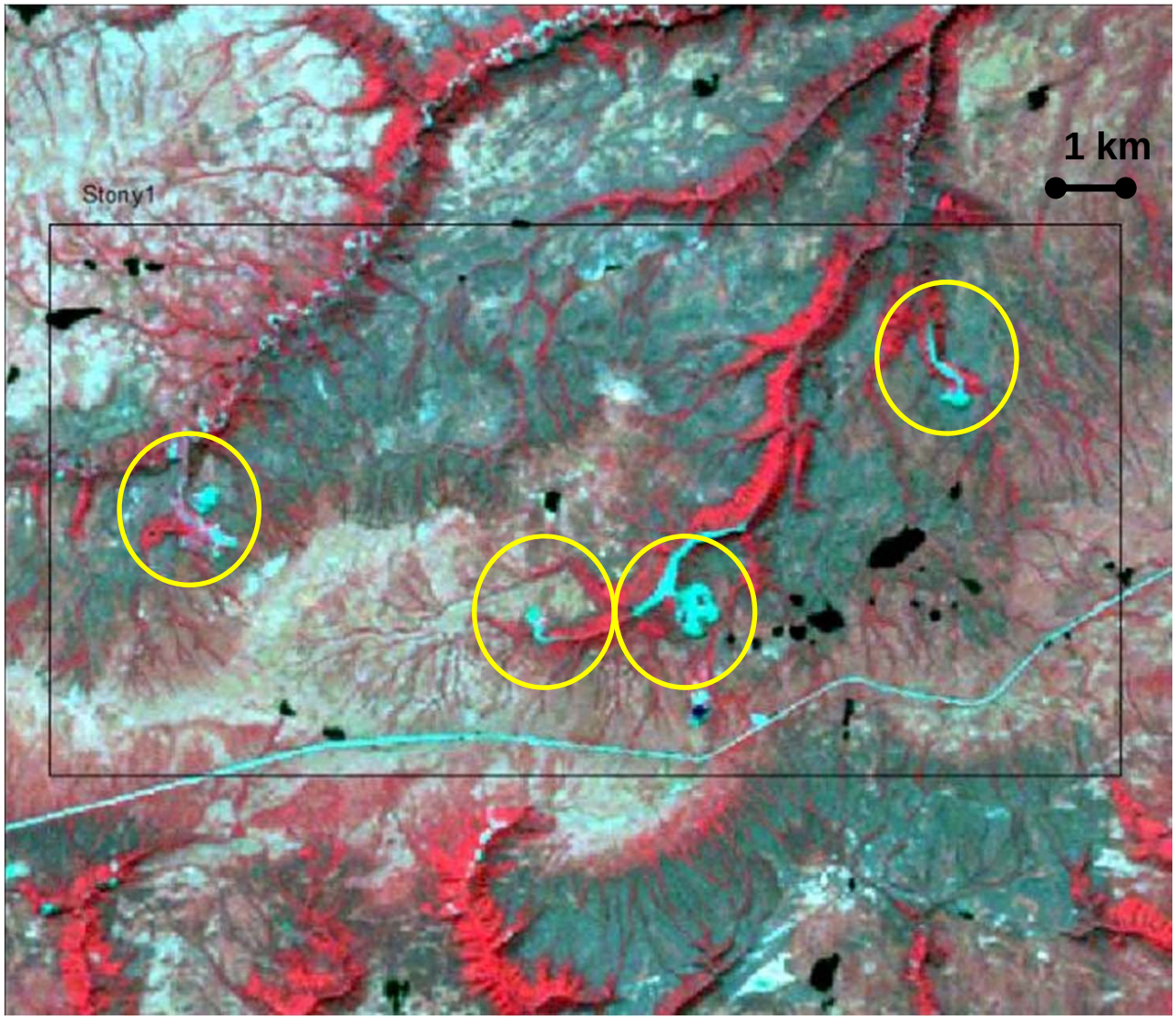
Kokelj et al., 2013, JGR

Landsat image 1985



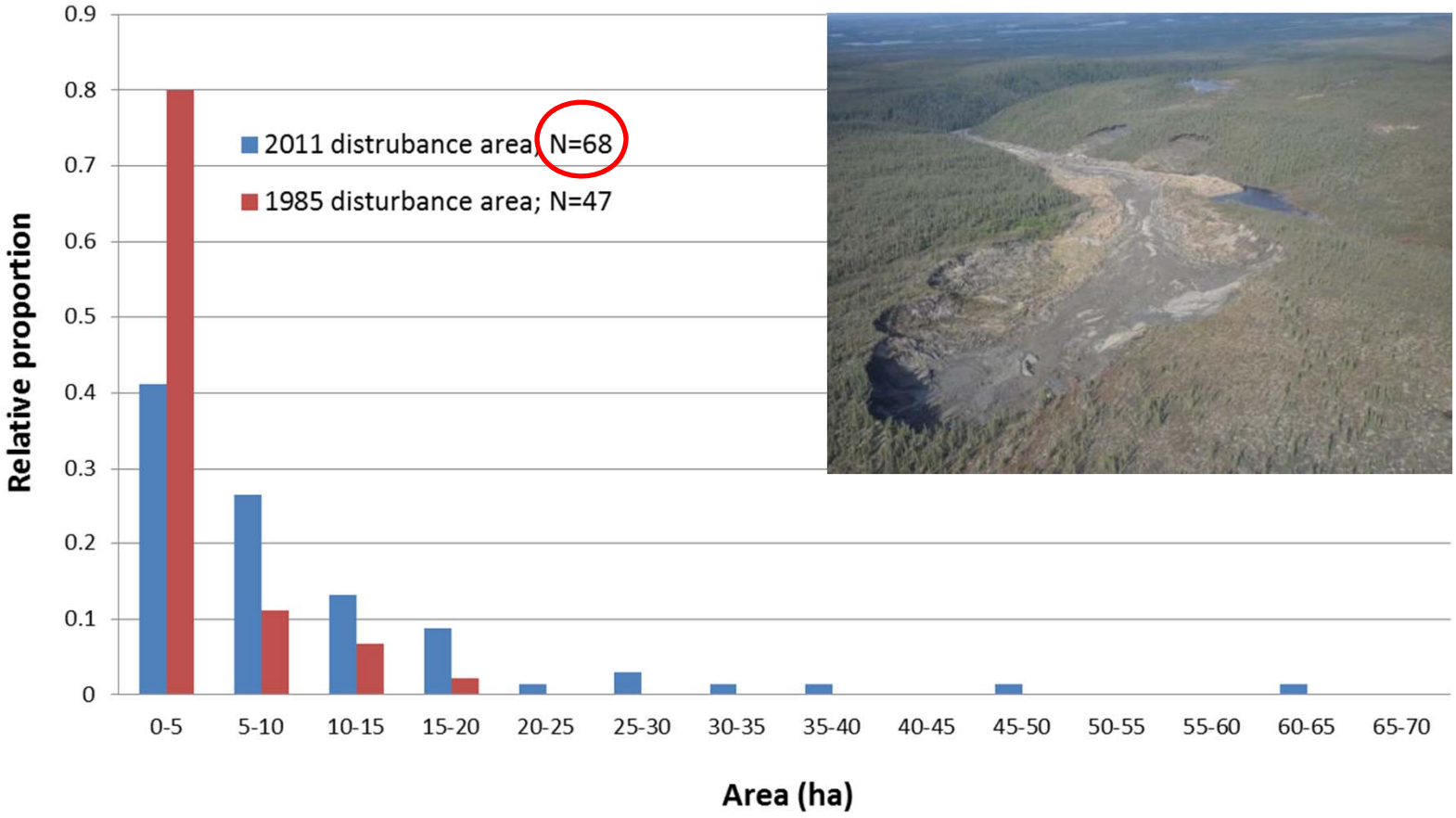
Stony 1_1985

Landsat image 2011



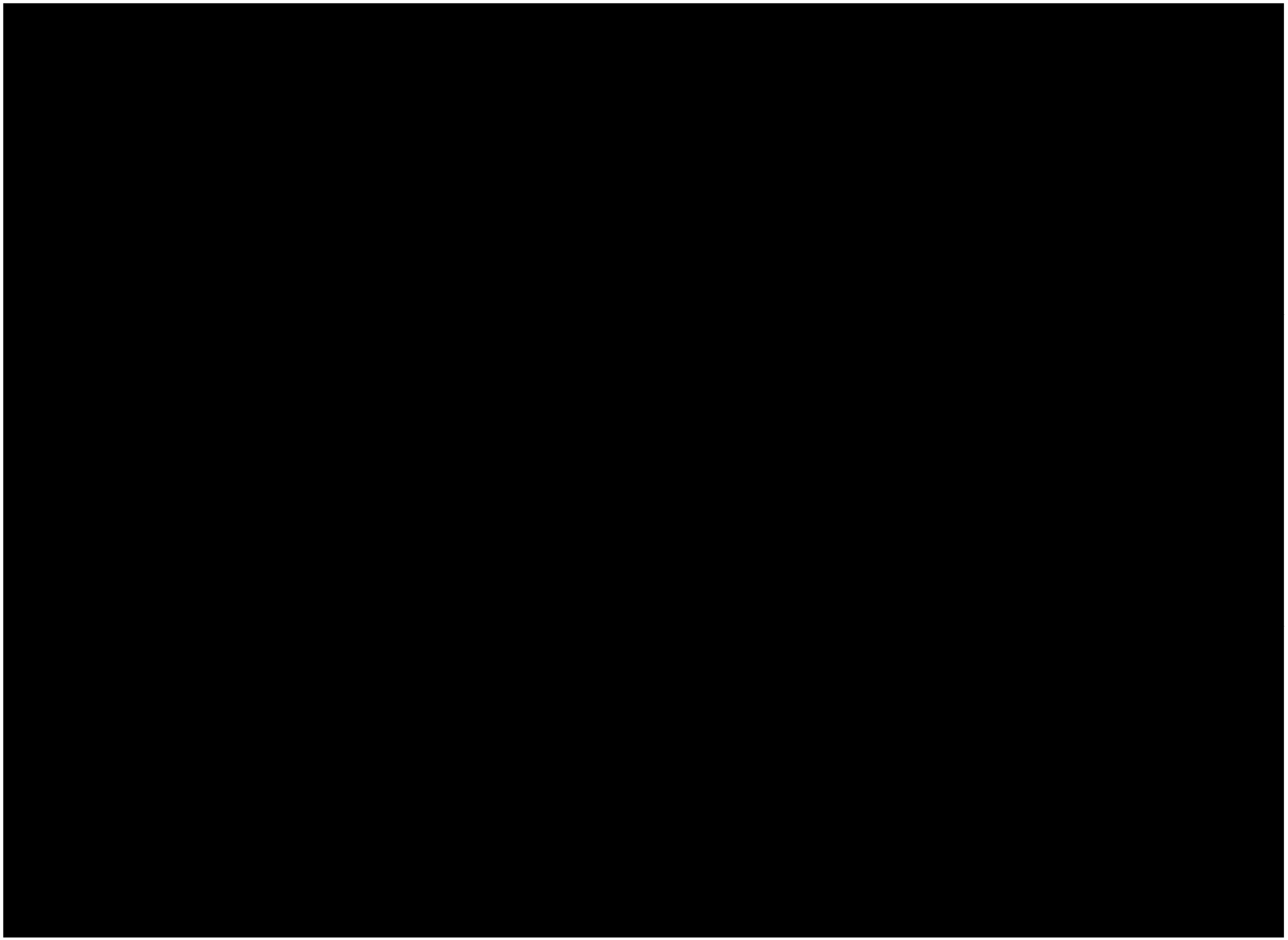
Stony 1_2011

Size distribution of slumps, 1985 and 2011

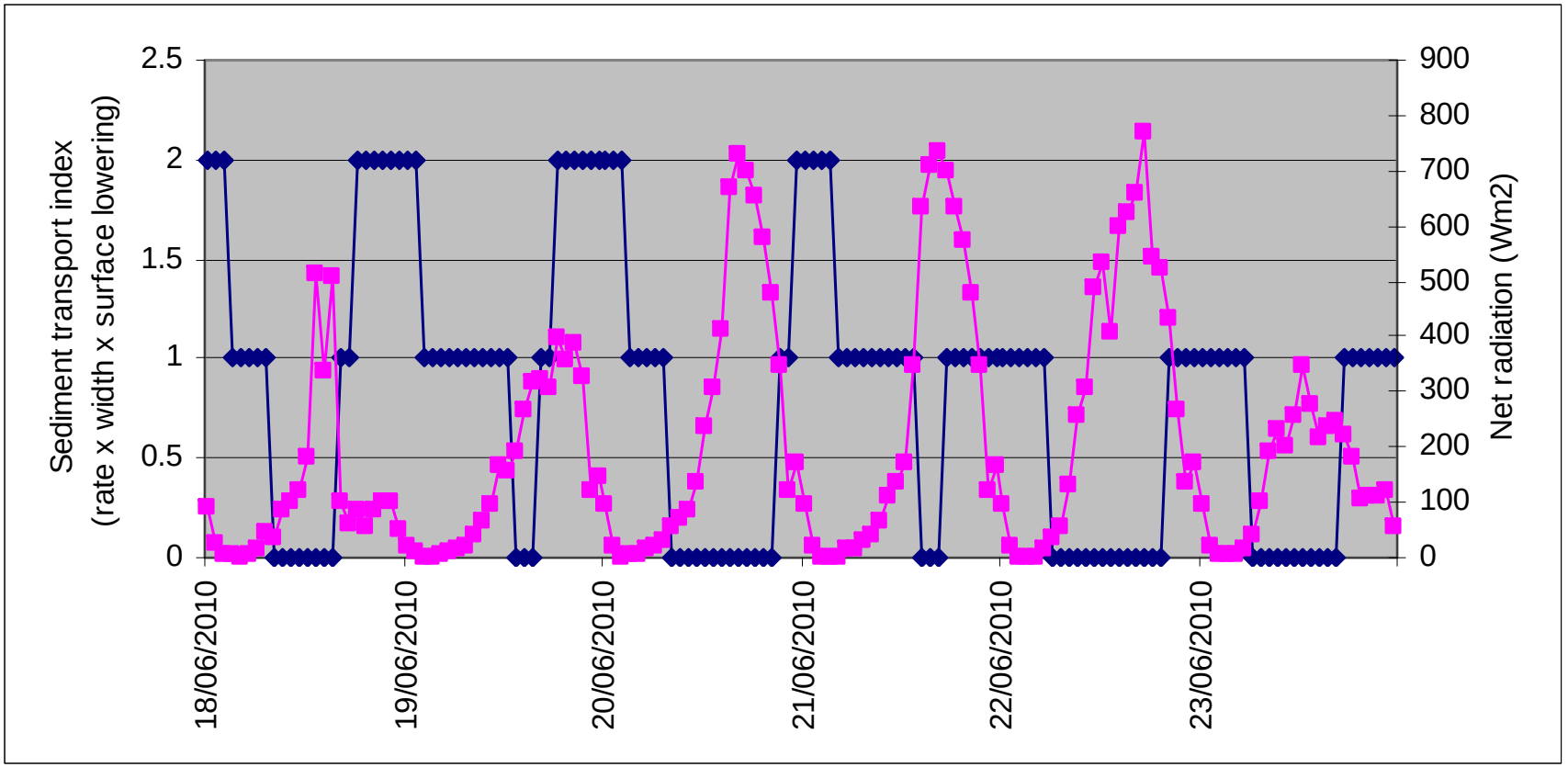


To grow or not to grow

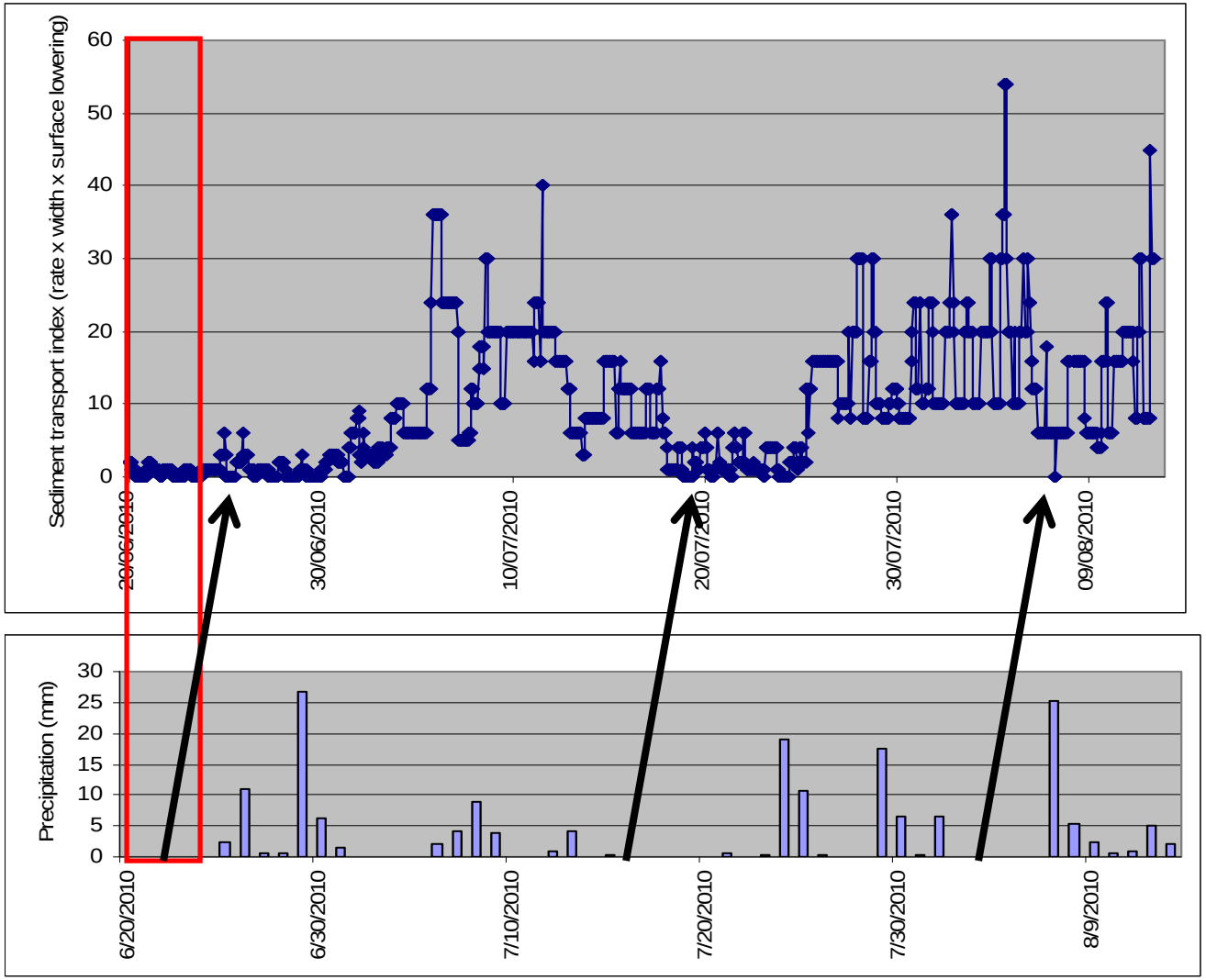
Debris flow video



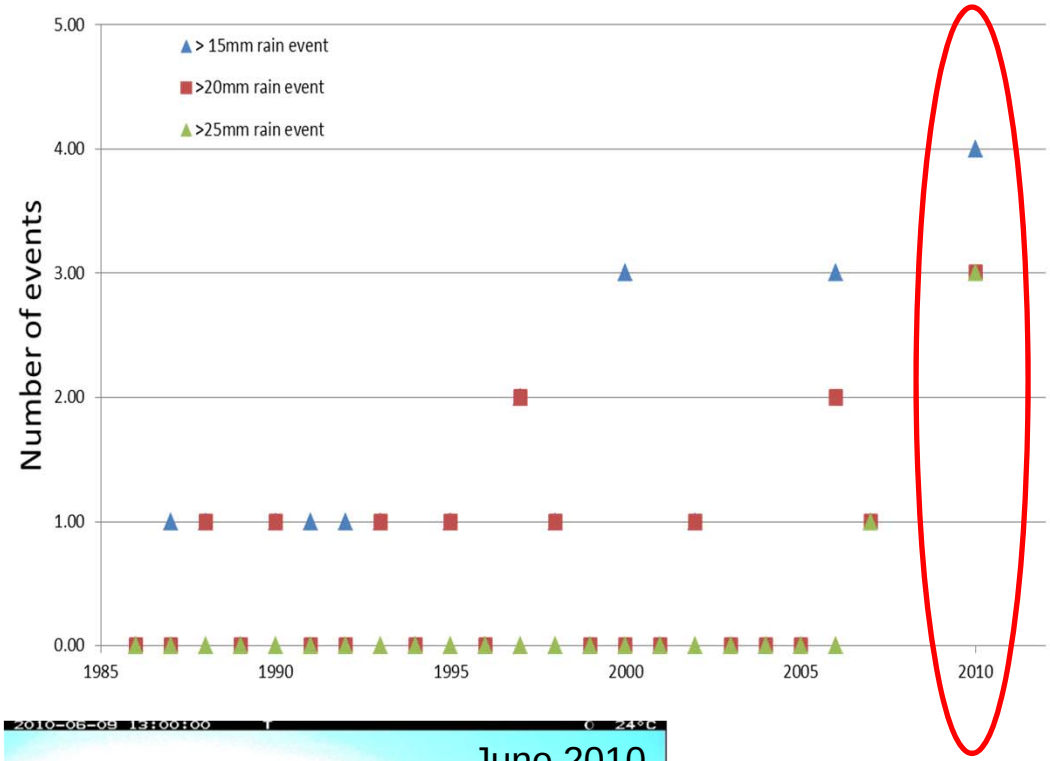
Debris flow activity, hot and dry period, June 2010

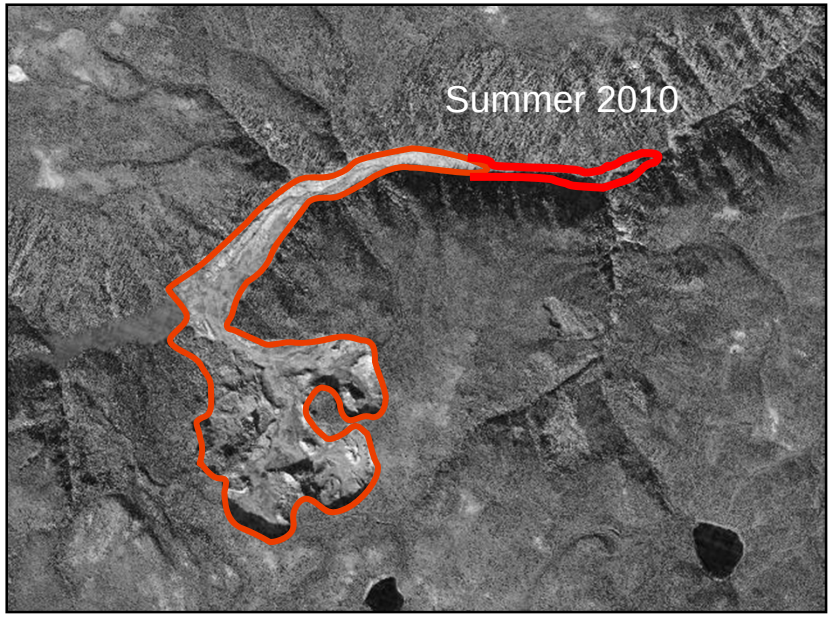


Thaw slump and debris flow activity, summer 2010



More extreme rainfall events





2010 – net removal of slump materials

Removal of debris keeps slumps youthful and growing

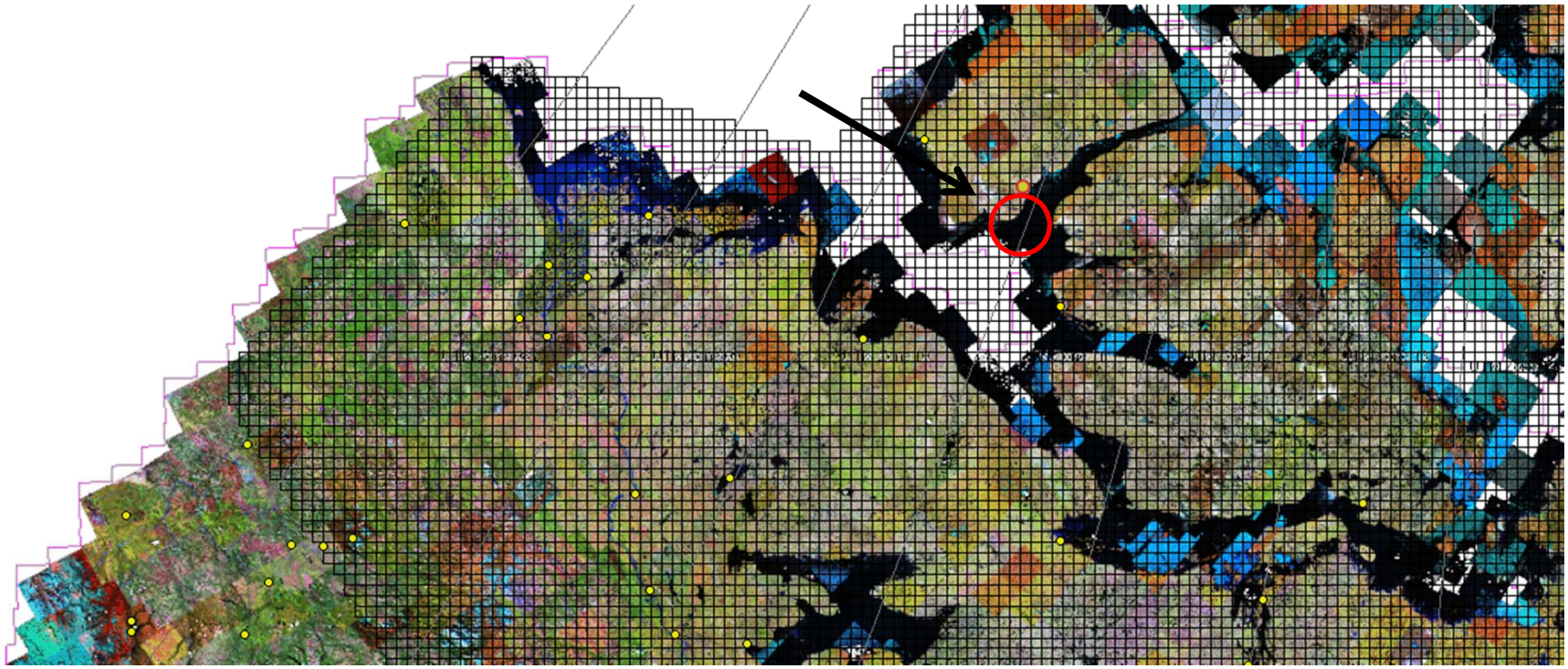
Cool and dry
Warm and dry

Wet and warm

What landscapes are being impacted?

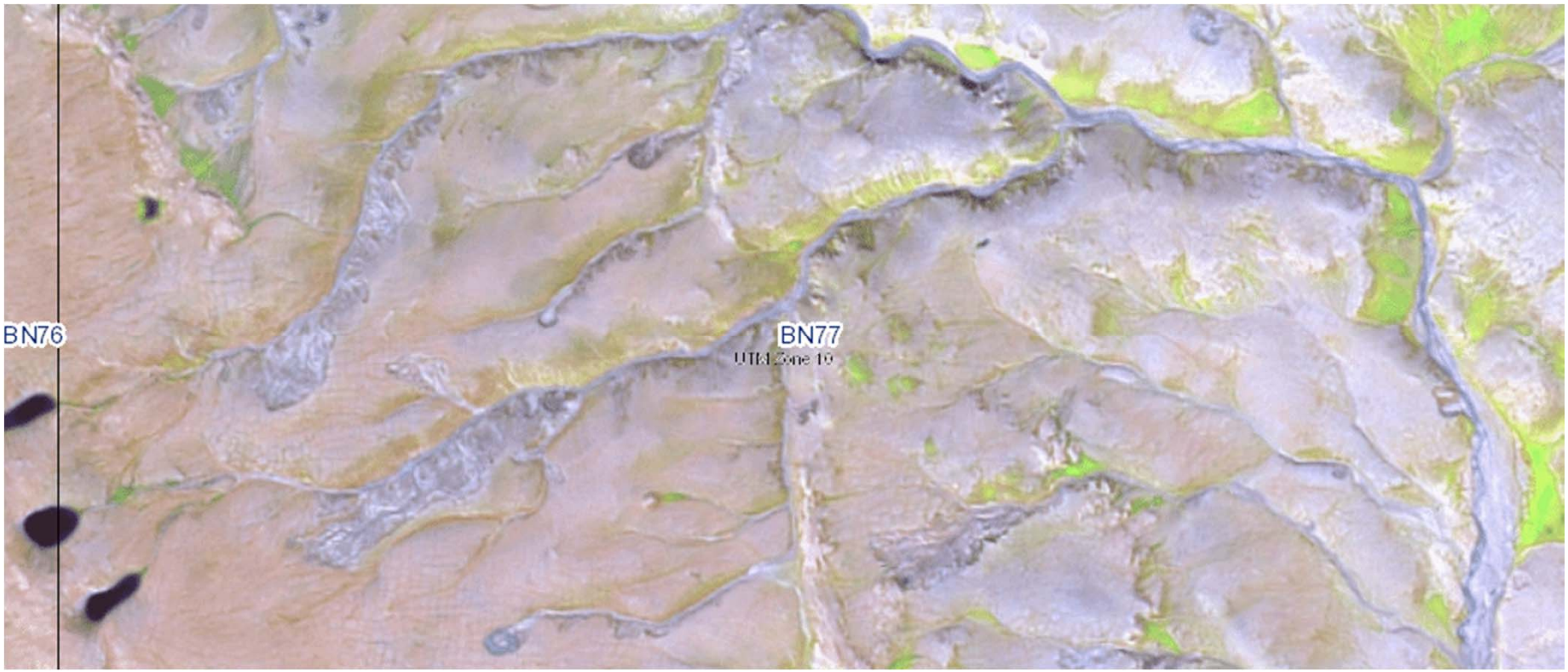
Creation of an online mapping tool

GNWT Spatial Data Warehouse

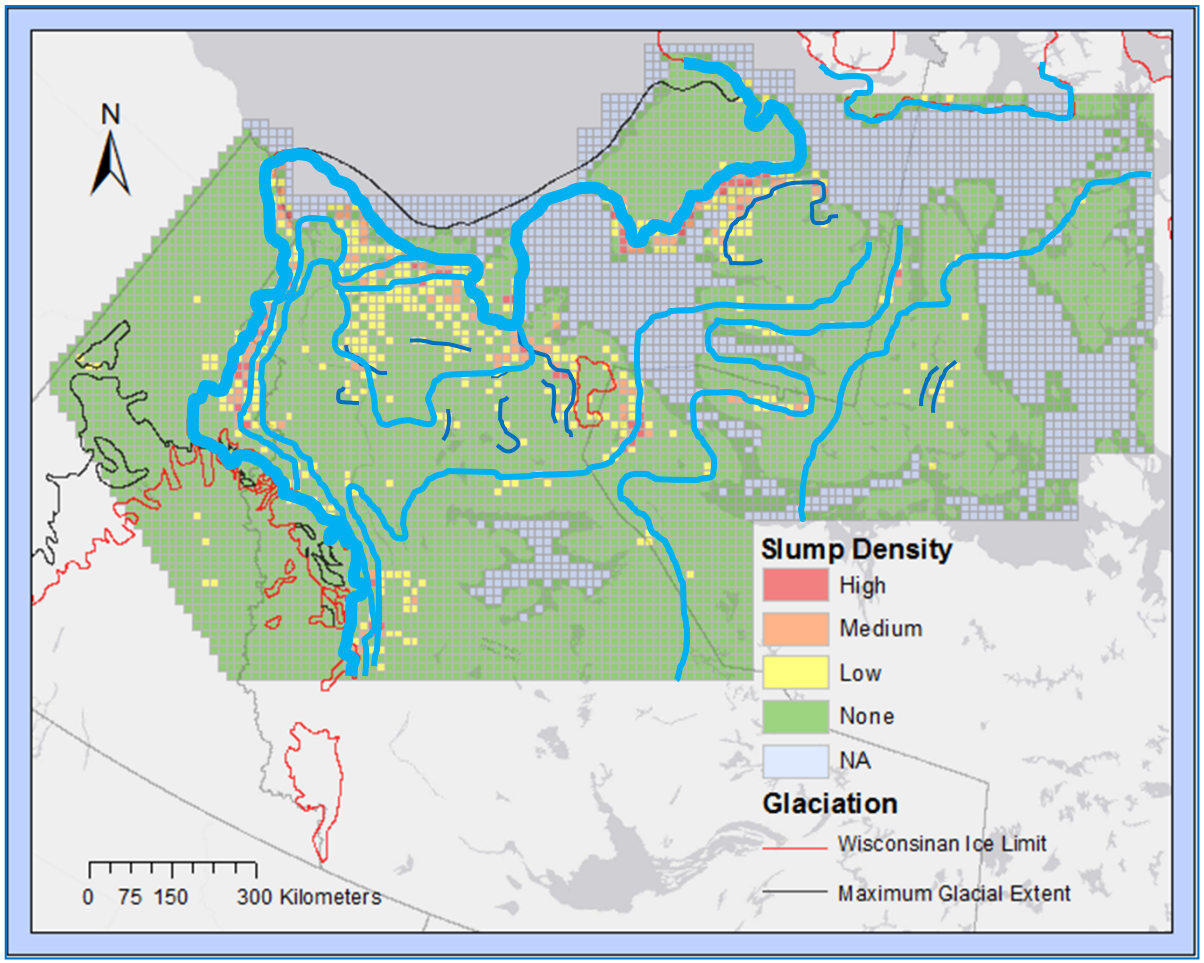


Mappers included: GNWT summer students, Culture and Heritage,
AANDC and NTGO Geomatics staff, University of Victoria

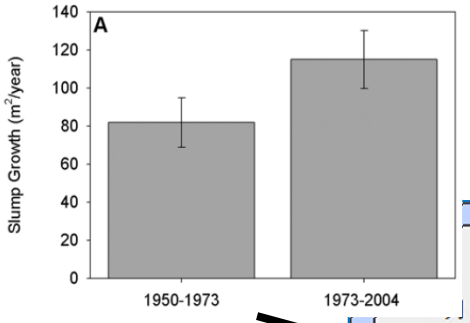
Zoom in and mappers classify grid cell

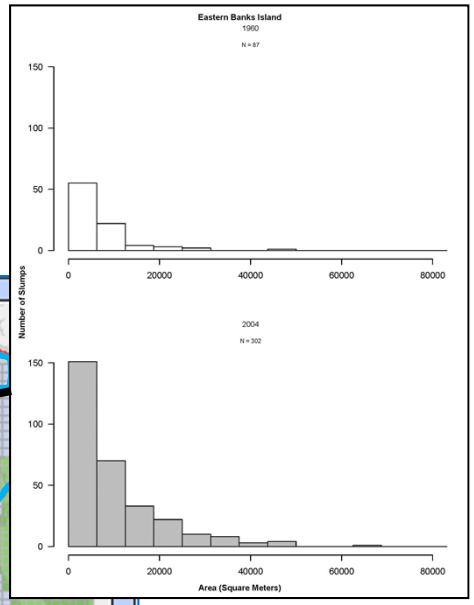


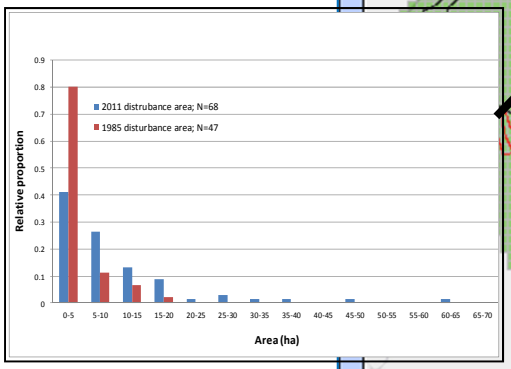
Slump density

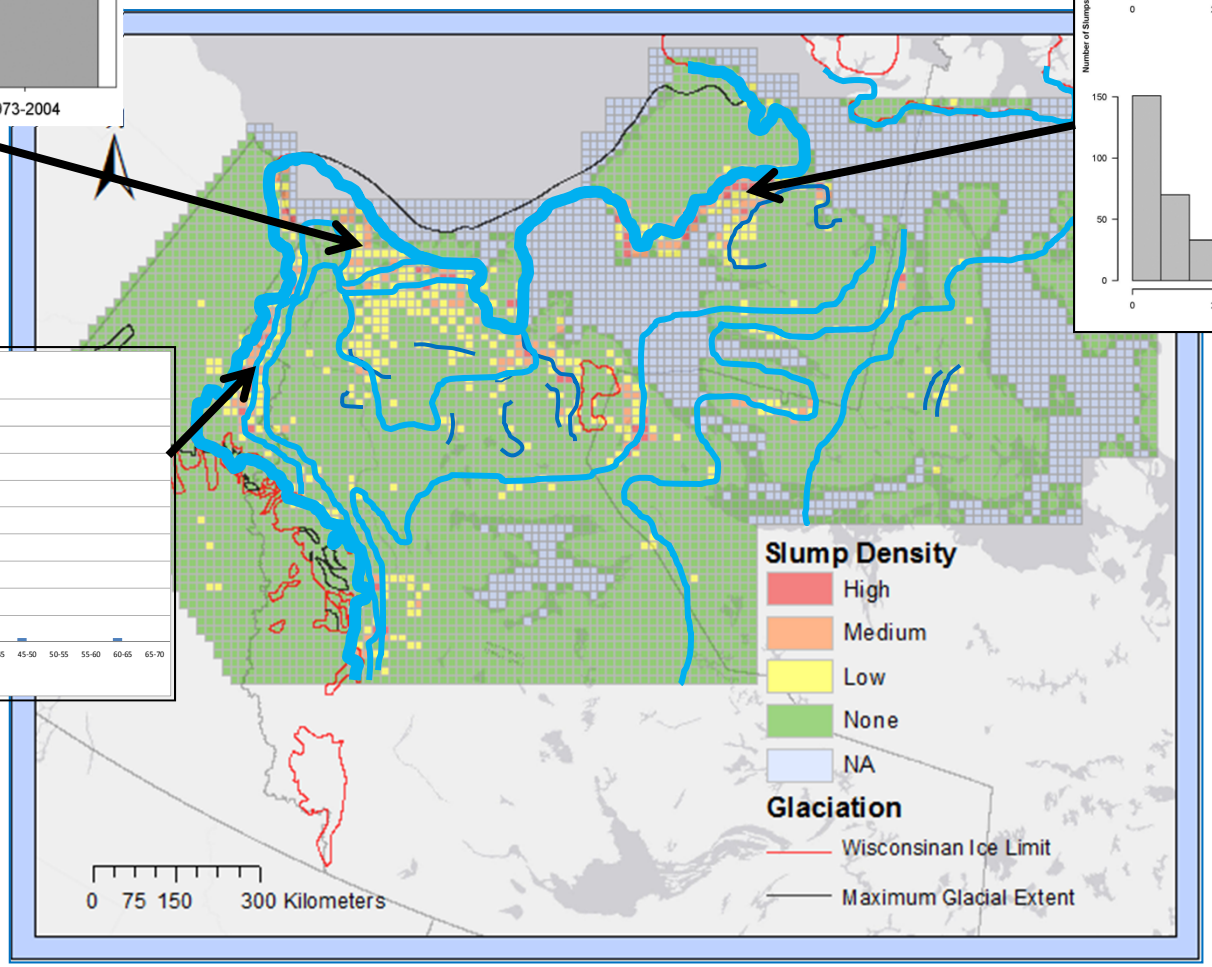


Increased slumping

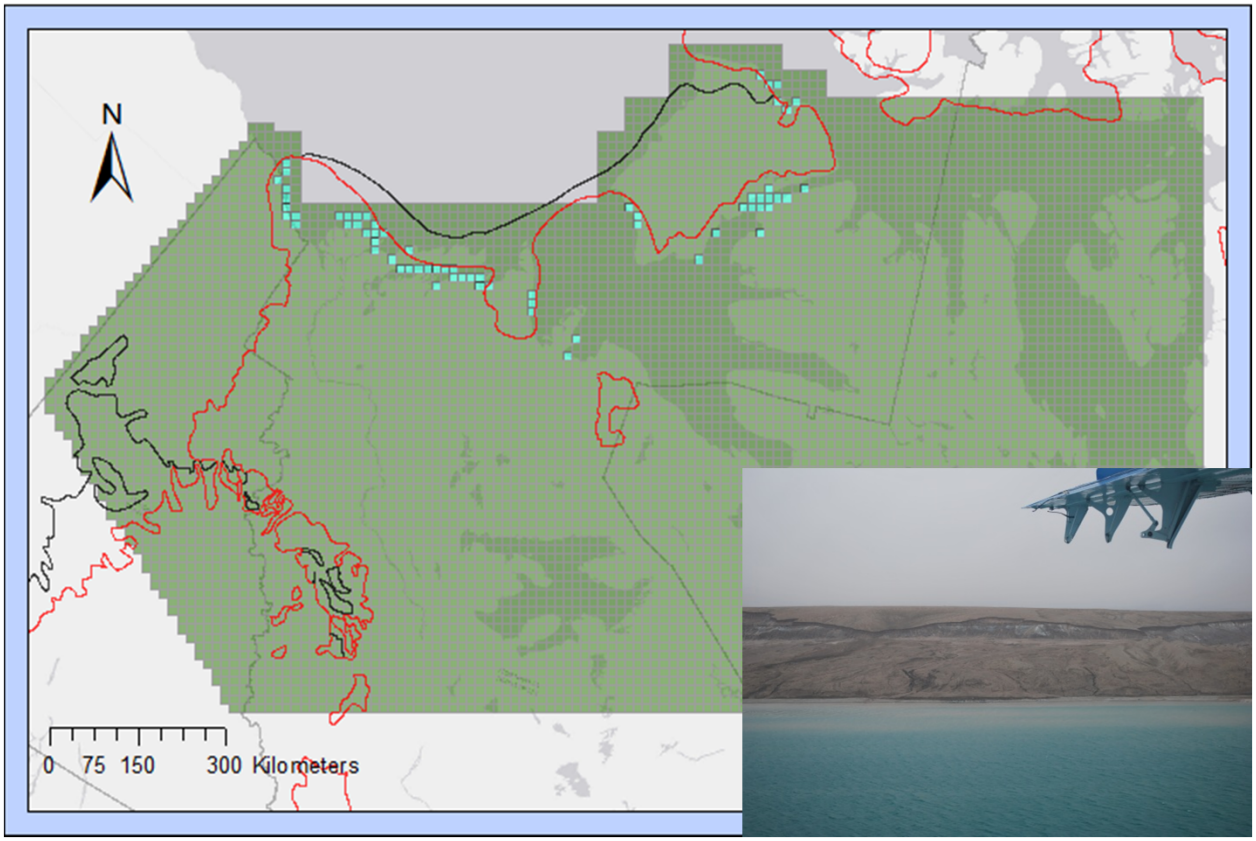




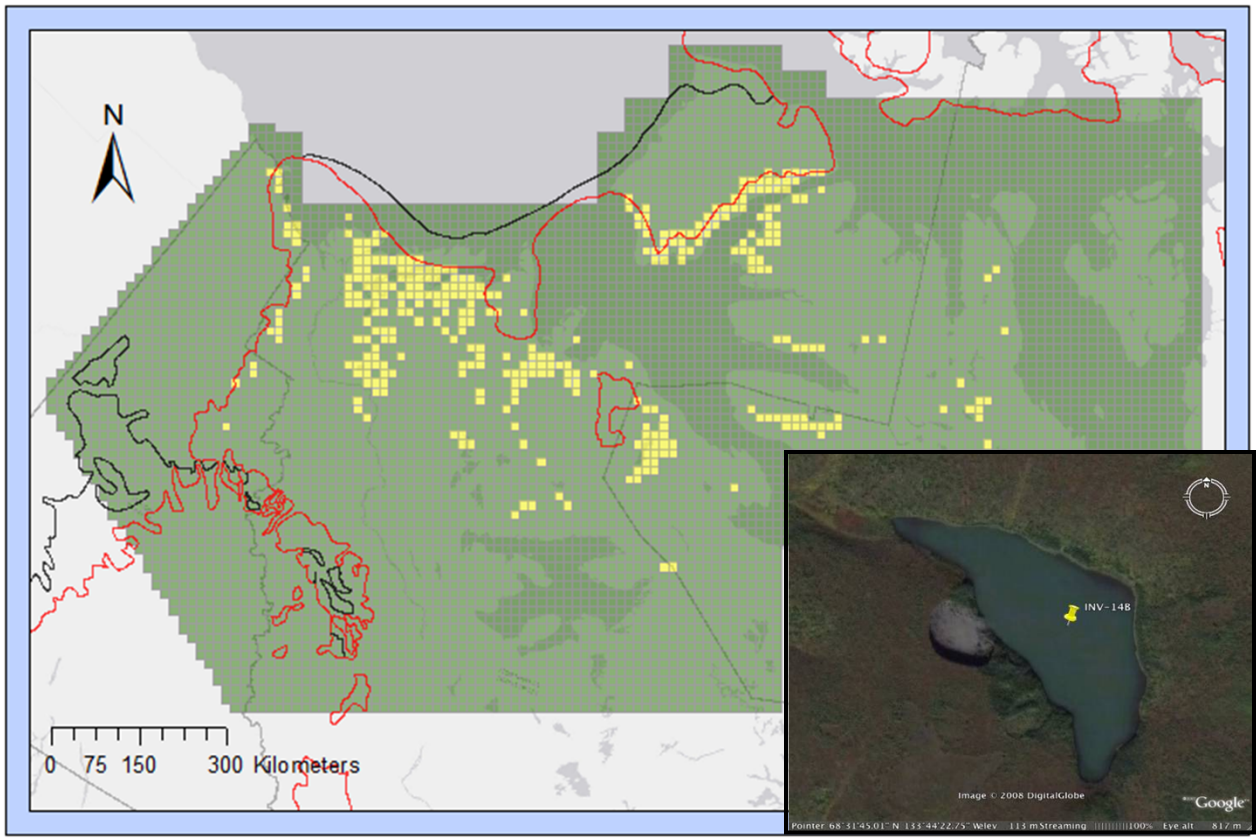




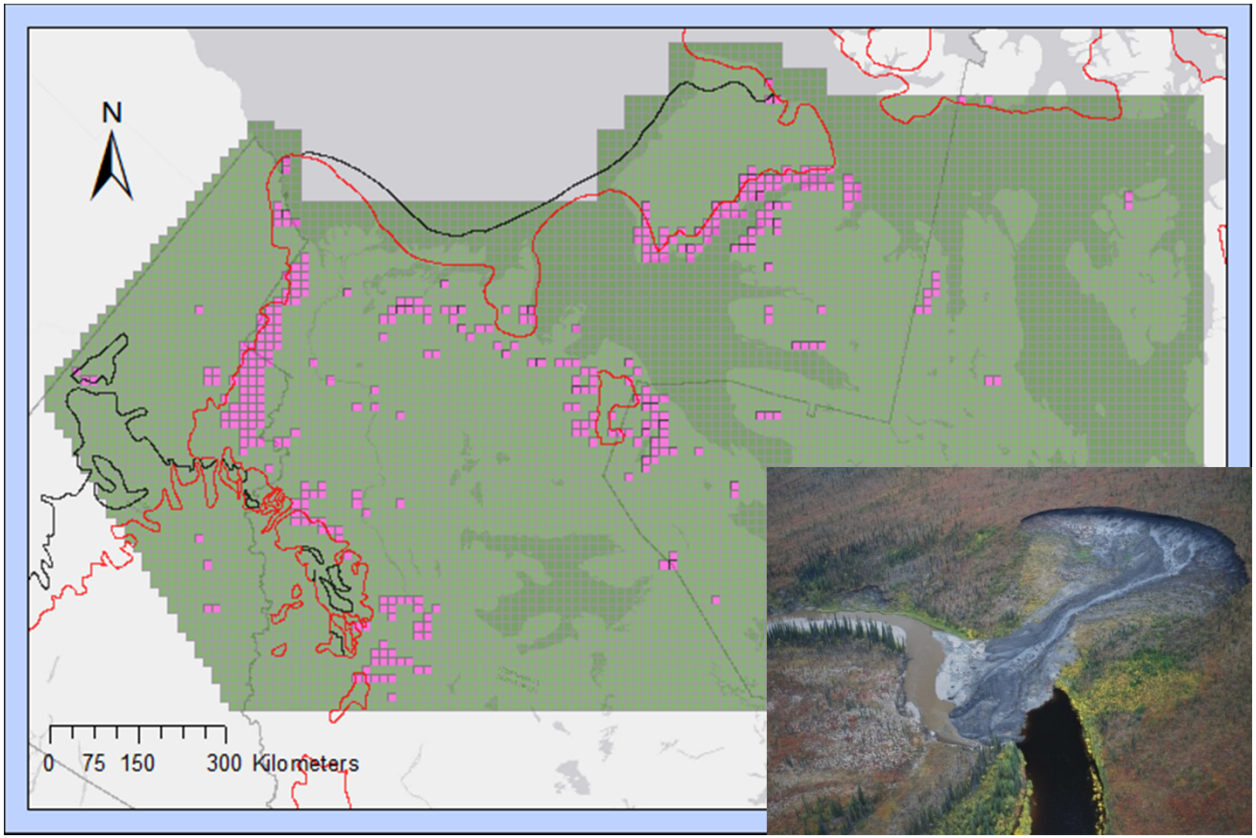
Coastal slumping



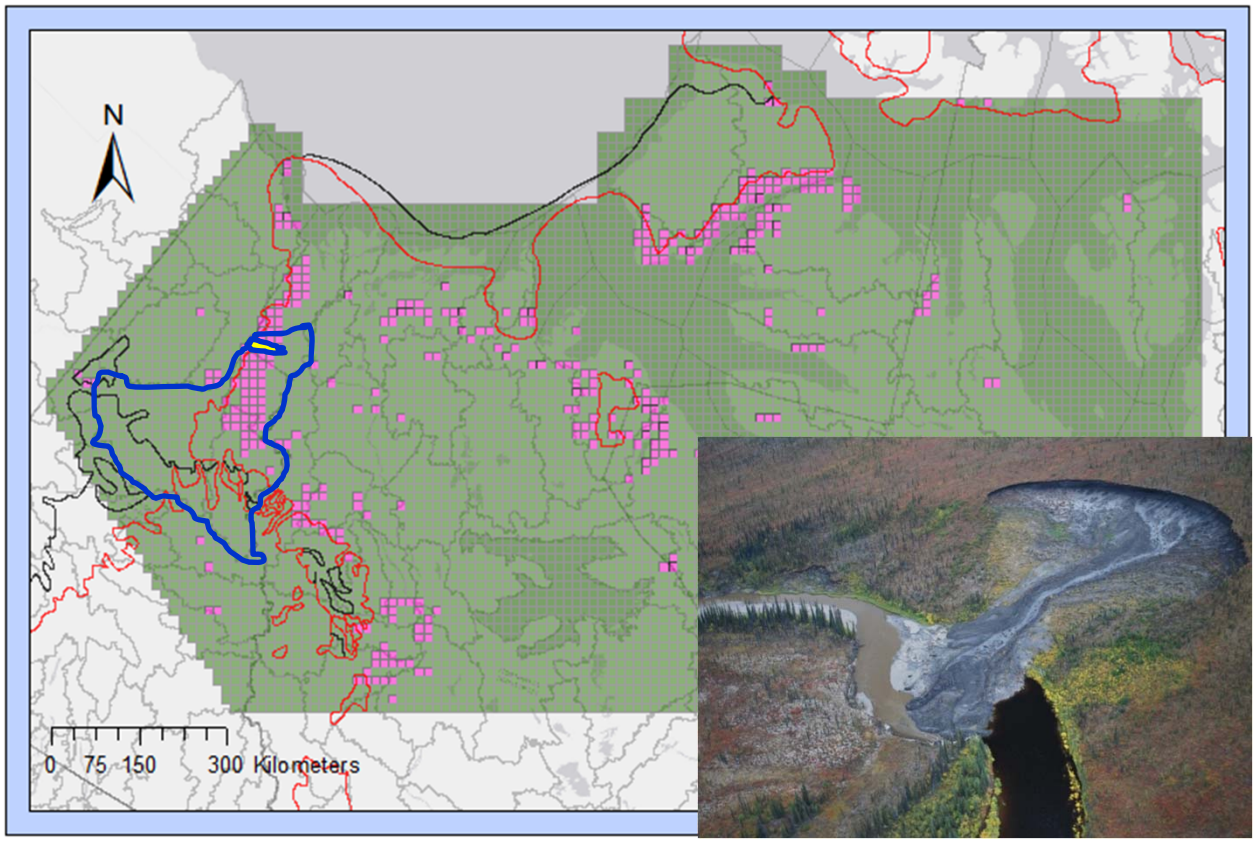
Lakeside slumping



Valley-stream side slumping



Downstream impacts can be significant



Conclusions

- The distribution of near-surface ground ice is an important control on environmental sensitivity of permafrost landscapes

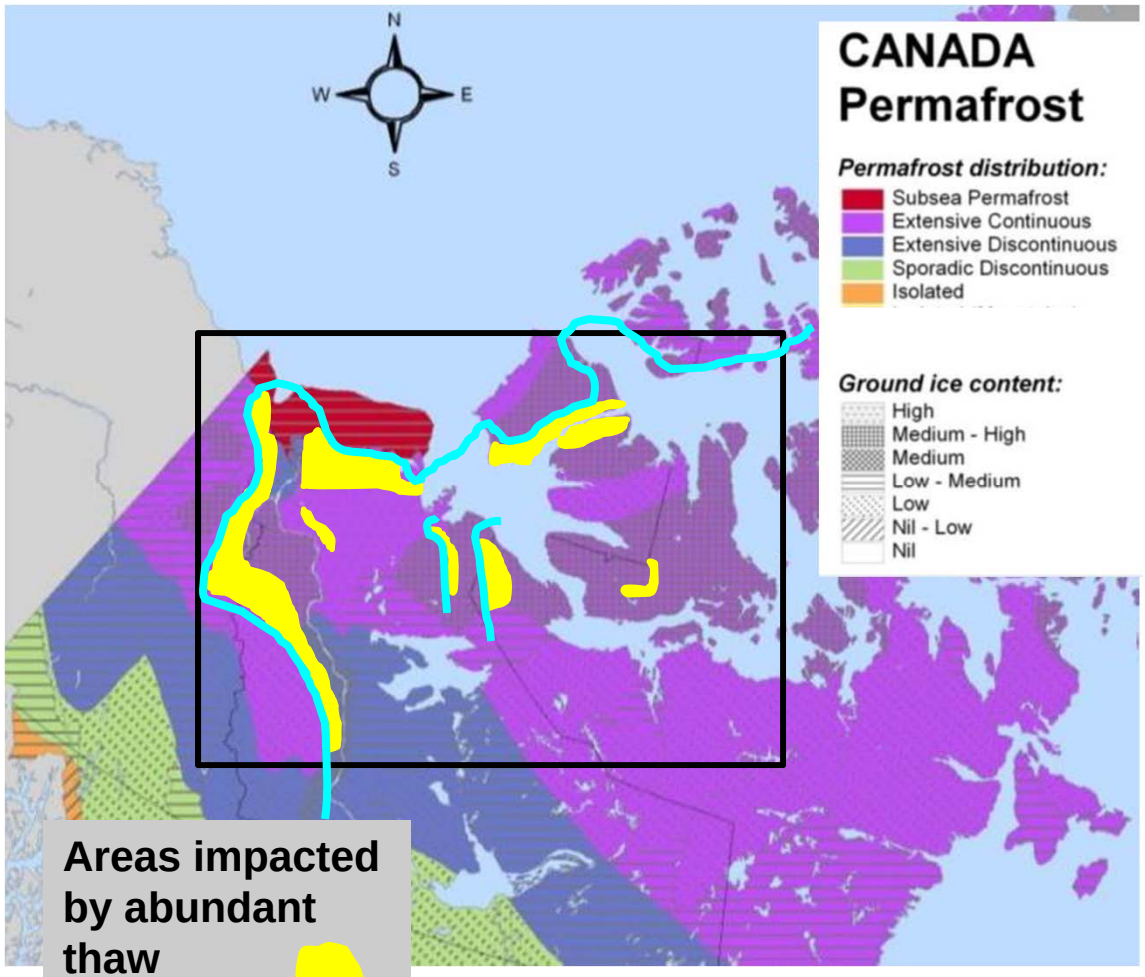
Conclusions

- Thawing of ice-rich permafrost is causing landscape changes; some landscapes are more susceptible to change than others

Conclusions

- Degradation of ice-cored terrain can cause major changes in the behaviour of streams and rivers
- The impacts are widespread and detectable in some large rivers

Major slumping follows the pattern of moraine systems associated with the Wisconsinan glaciation



Conclusions

- Knowledge of the permafrost environment and the response to climate change will inform infrastructure planning and mitigation measures

Thank you