

# Increases in Climate-Related Highway Maintenance Costs in a Permafrost Environment, Yukon, Canada

Astrid B. Schetselaar and Christopher R. Burn, Department of Geography and Environmental Studies, Carleton University



## INTRODUCTION

Near-surface permafrost thaw has been a primary cause of damage to road infrastructure as the ground's bearing capacity is significantly reduced. Road damage is also associated with hydrologic and slope processes which may be influenced by increased precipitation and changes in the hydrological regime of the ground as permafrost thaws.

The objective of this research is to quantify the financial impact of climate change on highway infrastructure maintenance in Yukon and to describe differences in maintenance costs in relation to the physiographic setting of highway sections.

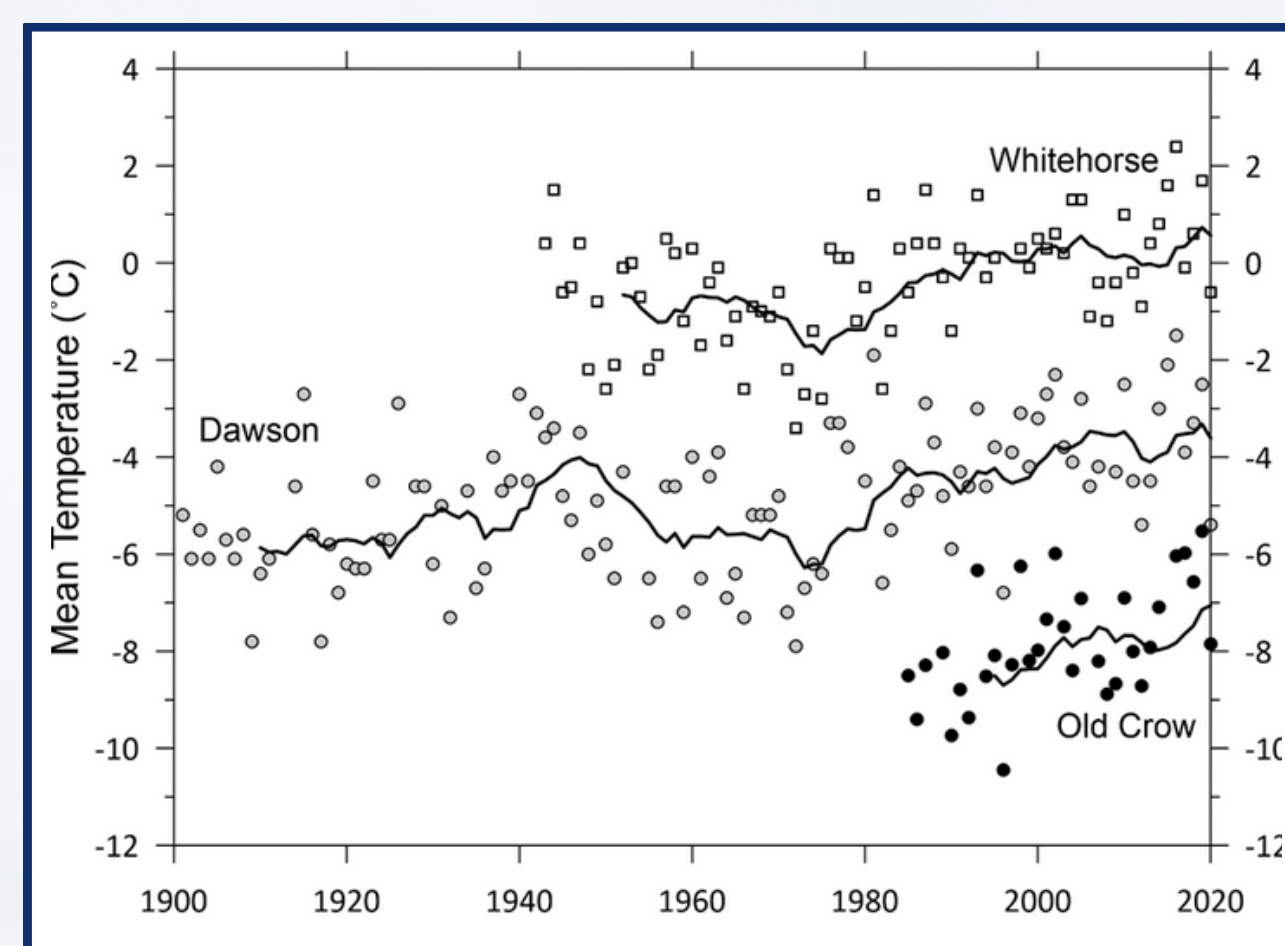


Fig. 1 Annual mean temperature increased in Yukon by about 2 °C between 1961-1970 and 2011-2020. The lines show the running mean of the previous ten years of data. The record from Old Crow begins in the mid 1980s.

## STUDY AREA

- Yukon's highway network is comprised of primary and secondary highways, spanning approximately 4800 km, maintained by 21 camps, each responsible for a specific road section.
- The highway network was divided and costs were analyzed based on 7 different regions which internally exhibit similar physiographic conditions:
  - Shakwak Trench
  - Coast Mountains
  - Southern Lakes
  - Liard-Ross Lowland
  - Lewes Plateau
  - Central Yukon Plateaus
  - Ogilvie Mountains-Eagle Lowland



## CLIMATE-RELATED MAINTENANCE ACTIVITIES

### 1. SNOW REMOVAL



Picture Credit: Cathy Brais

### 2. ICING CONTROL



Picture Credit: Louis-Phillippe Roy

### 3. CULVERT ACTIVITIES



Picture Credit: Chris Burn

### 4. REPAIR OF SLIDES & WASHOUTS



Picture Credit: Chris Burn

## RESULTS: YUKON'S HIGHWAY NETWORK

- During 1994–2022, climate-related activities accounted for an average of 35% of the total operation and maintenance budget with snow removal activities incurring the greatest costs overall.
- Mean climate-related maintenance expenditures have increased (in constant dollars) from CAD7.1M in 1994–1999 to CAD10.9M in 2017–2022, or by about 54%.
- Annual total climate-related costs were 25% of the total budget in 1994–1999 but they have increased to an average of 47% in 2017–2022, with costs reaching 54% of the total budget in 2020.
- The dominant activities vary around the network with physiographic context in each region

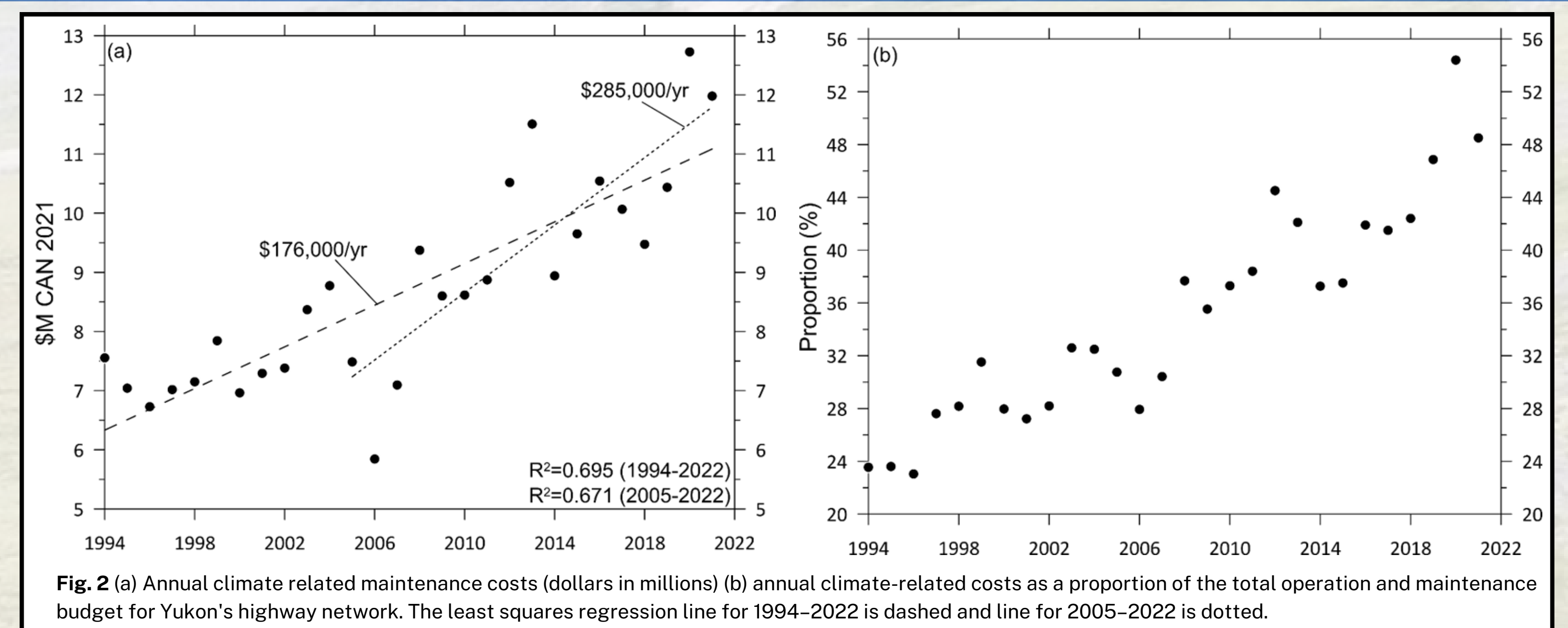
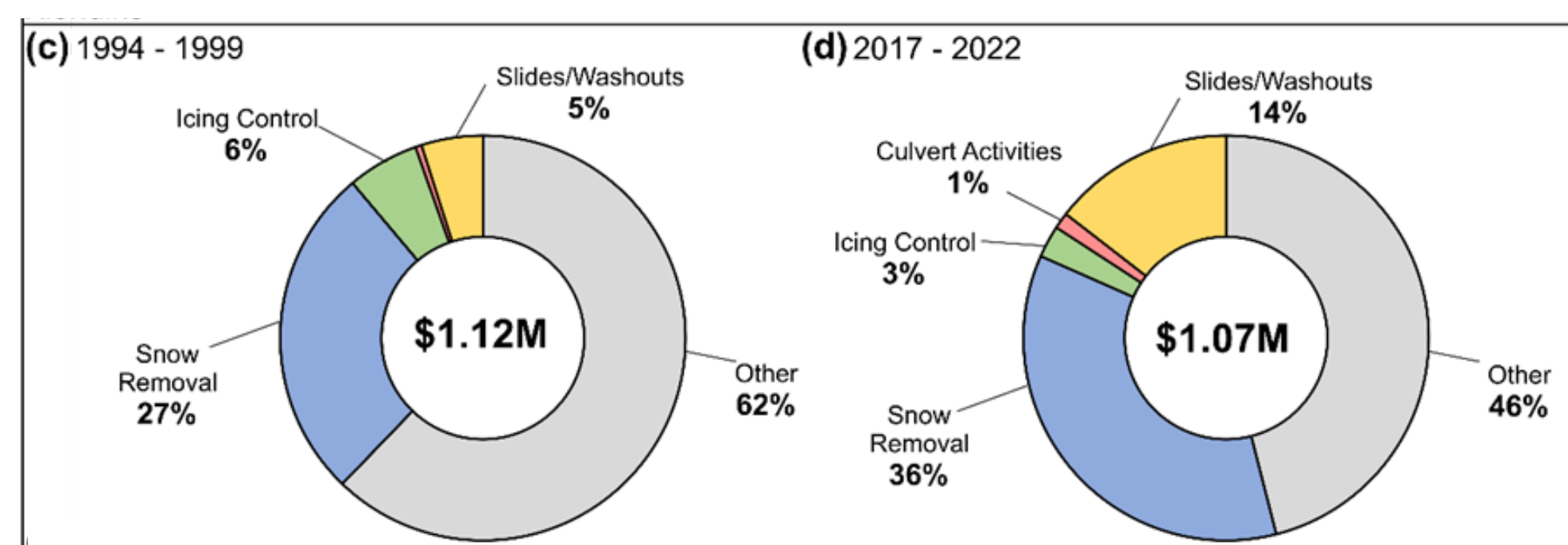
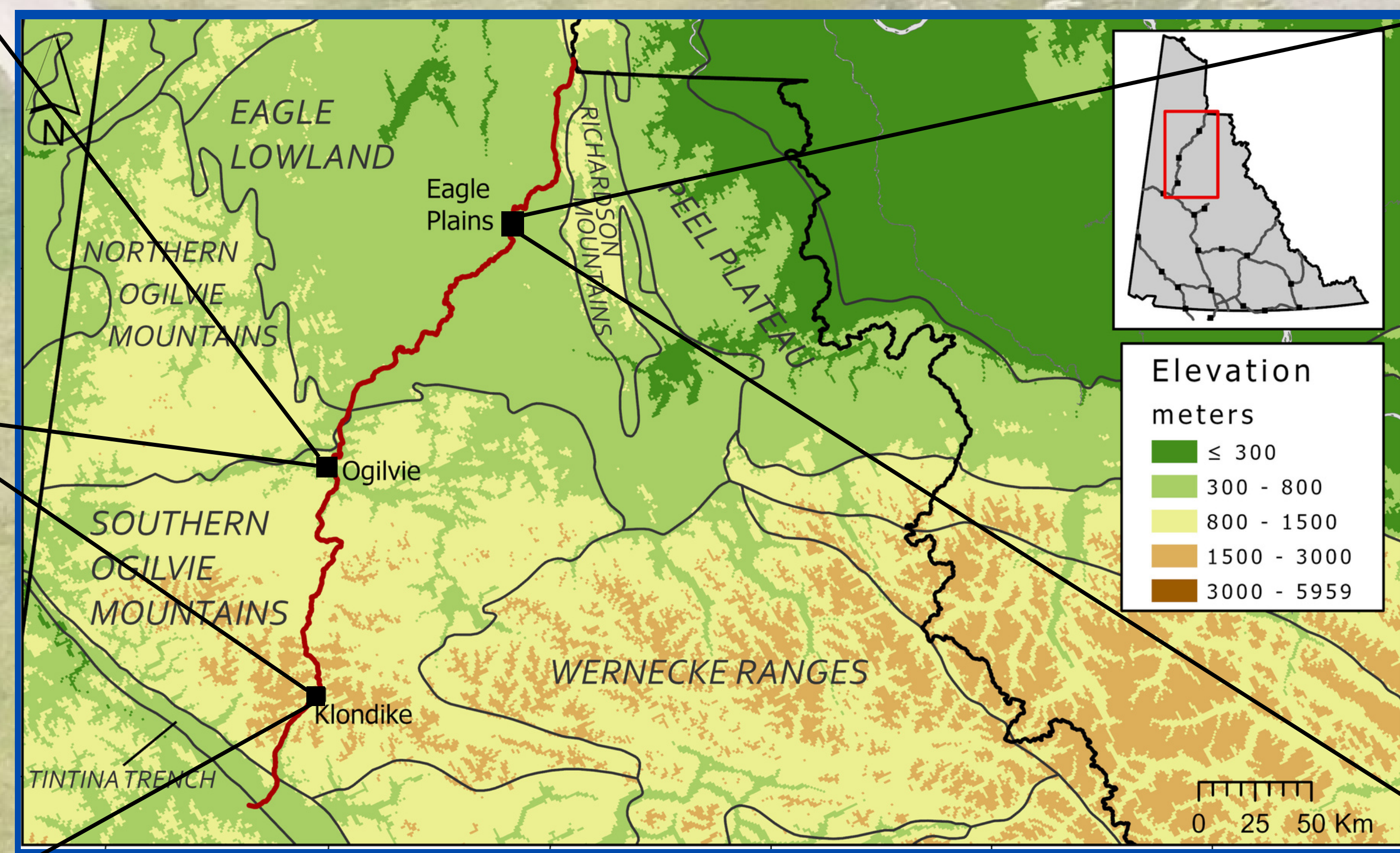
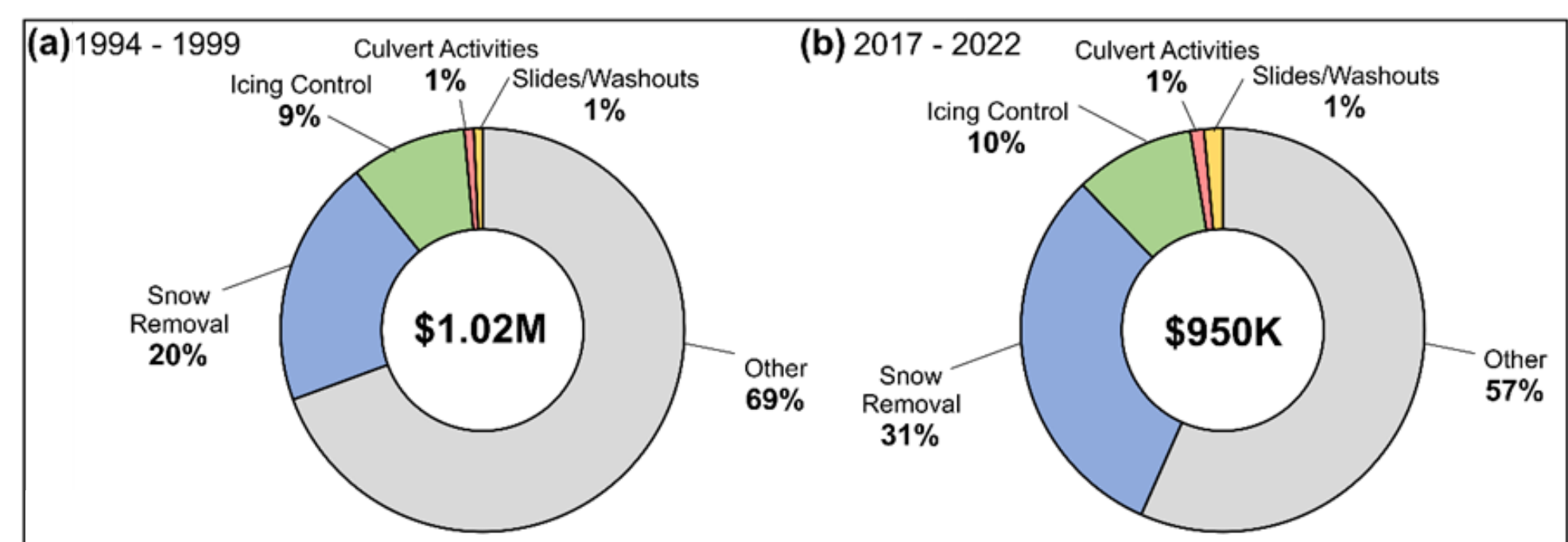


Fig. 2 (a) Annual climate related maintenance costs (dollars in millions) (b) annual climate-related costs as a proportion of the total operation and maintenance budget for Yukon's highway network. The least squares regression line for 1994–2022 is dashed and line for 2005–2022 is dotted.

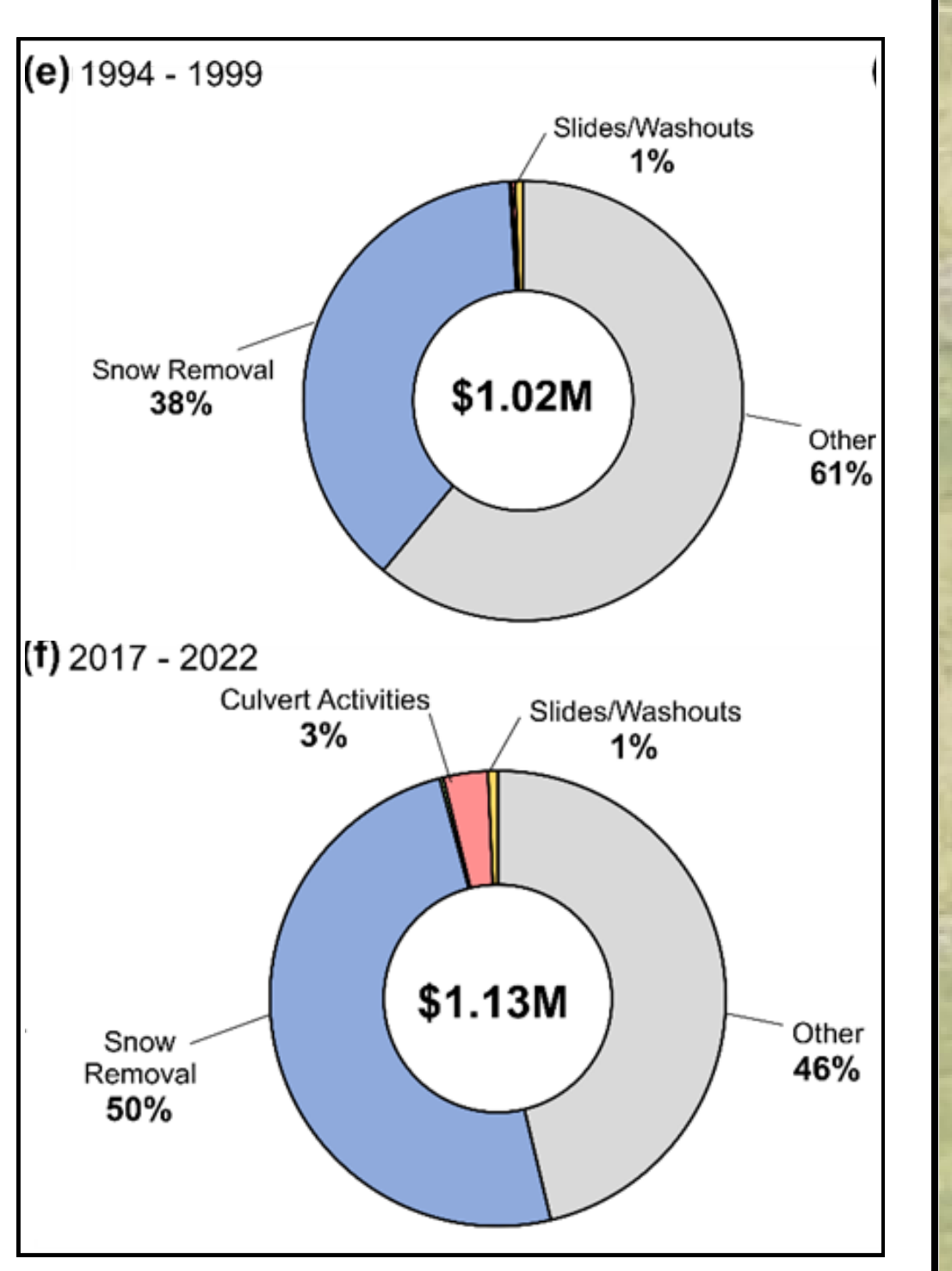
## OGILVIE



## KLONDIKE



## EAGLE PLAINS



## DEMPSTER HIGHWAY

- Over the 465 km of the Dempster Highway, constructed entirely in a permafrost environment, mean climate-related maintenance costs have increased from CAD1.2M in 1994–1999 to CAD1.5M in 2017–2022 (constant 2021 CAD) but each maintenance section has a distinct expenditure profile related to landscape characteristics
- **Klondike:** Icing control expenditures ranged between \$20,000 and \$150,000 annually.
  - The highway is situated near the base of slopes in discontinuous permafrost where icing development is common due to permafrost restricting infiltration and flow.
- **Ogilvie:** Mean annual expenditures for landslides and washouts tripled from \$51,100 in 1994–2007 to \$176,500 and occurred more frequently in 2008–2022.
  - The road is close to the bottom of steep hillslopes and is adjacent to Engineer Creek and Ogilvie River. Proximity of to hill slopes, heavy rainstorms, blocked culverts, and limited infiltration of frozen ground enhance occurrence of landslides and washouts.
- **Eagle Plains:** Snow removal expenditures increased by \$11,000/yr.
  - Unobstructed winds in a tundra environment.

## CONCLUSIONS

1. Climate-related maintenance expenditures for the highway network as a whole have increased over 1994–2022.
2. Expenditure profiles are associated with physical characteristics such as topography, climate and permafrost conditions.
3. Intermittent events (i.e. slides and washouts) are occurring at increasing frequency.
4. In a permafrost environment, the nature of surface and terrain conditions influence hazard assessment and management.



## REFERENCES

1. Bostock, H.S. 1948. Physiography of the Canadian Cordillera. With Special Reference to the area North of the Fifty-fifth Parallel. Geological Survey of Canada, Ottawa, ON. Memoir 247. doi:10.4095/103300.
2. Environment and Climate Change Canada (ECCC). 2020. Canadian Climate Normals 1981-2010. Gatineau: ECCC.
3. Heginbottom, J. A., M. A. Dubreuil, and P. A. Harker. 1995. Canada - Permafrost, in National Atlas of Canada, 5th ed., Natural Resources Canada, Ottawa, Ont.
4. Mathews, W. H. 1986. Physiographic map of the Canadian Cordillera. Geological Survey of Canada, "A" Series Map 1701A. doi: 10.4095/122821
5. Nelson, F., Anisimov, O. & Shiklomanov, N. 2001. Subsidence risk from thawing permafrost. *Nature* 410, 889–890 doi:10.1038/35073746

## ACKNOWLEDGEMENTS



## CONTACT INFORMATION

Astrid Schetselaar, MSc. Student,  
Department of Geography and  
Environmental Science  
Carleton University  
✉ astridschetselaar@gmail.com

