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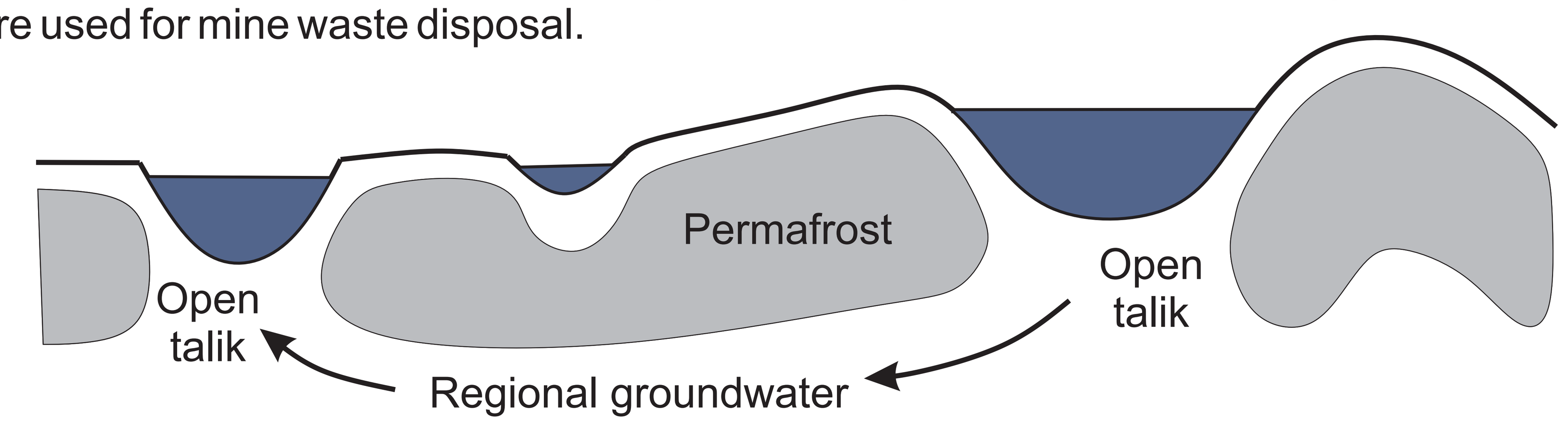
ESTIMATION OF MAXIMUM LAKE DEPTH FROM THE SURROUNDING TOPOGRAPHY: TOWARDS A REGIONAL ASSESSMENT OF THE OCCURRENCE OF TALIKS BELOW ARCTIC LAKES

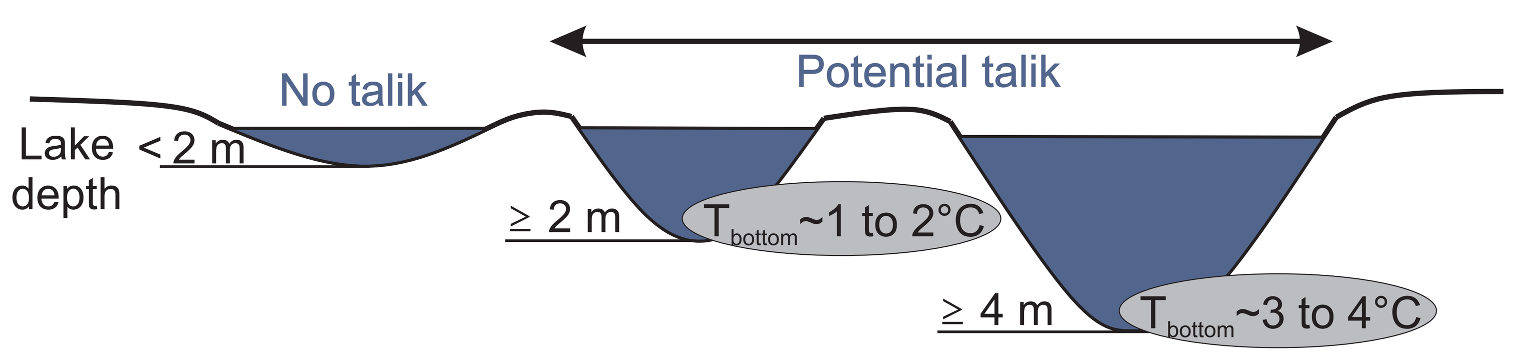
A-M. LeBlanc[1], J. Chartrand[1], and S.L. Smith[1]

INTRODUCTION

In continuous permafrost regions, taliks (areas of unfrozen ground), are mainly found beneath large and deep lakes (> 2 m depth) that do not freeze to their bottom. Open taliks connected to regional groundwater can affect the development of mining projects due to these potential pathways for contaminant transport. It is therefore important to determine which lakes are potentially underlain by open taliks, especially where lakes are used for mine waste disposal.



The presence of open taliks beneath lakes can be estimated using the steady-state equations of the thermal disturbance of lakes in permafrost environment [1]. Although lake depths are not required in these equations, the knowledge of the maximum depth may be used to set the lake-bottom temperature [1], such that:



The maximum lake depth may be estimated with topographic variables from the surrounding landscape [2]. This approach assumes that common geological processes form the landscape and the lakes, such as glacial processes. A violation of this assumption would be thermokarst lakes.

OBJECTIVES

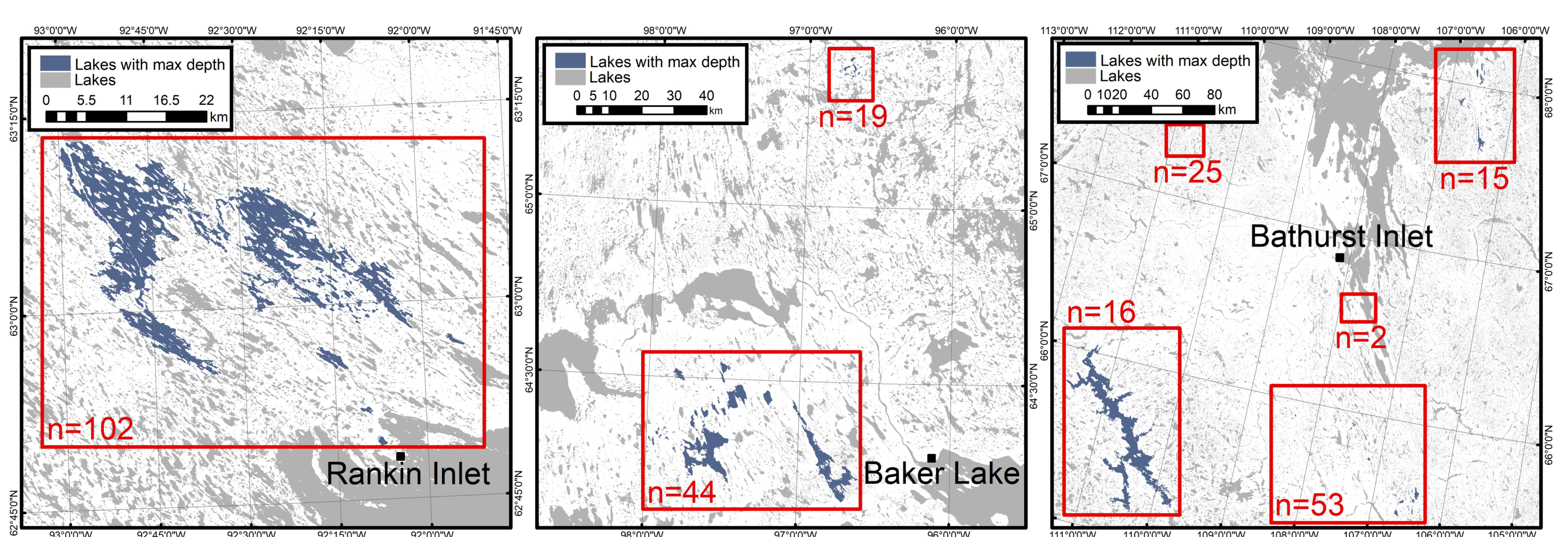
- Explore the use of a high-resolution elevation model (ArcticDEM) to extract topographical variables surrounding lakes in Nunavut to run predictive models of maximum lake depth;
- Evaluate the performance of models based on 3 classes of lake depth: 0-2, 2-4 and ≥ 4 m (based on low and high probability of open talik, and relationship between lake-bottom temperature and depth).

DATA

Topographical data: HRDEM [3] based on ArcticDEM mosaic at 2-m spatial resolution

Lake surface area: Hydrographic features at 1:50 000 [4]

Maximum lake depth: **274 lakes** with known maximum depth; information collected as part of NRCan projects [5] and environmental impact assessment (public registry of the Nunavut Impact Review Board (www.nirb.ca))



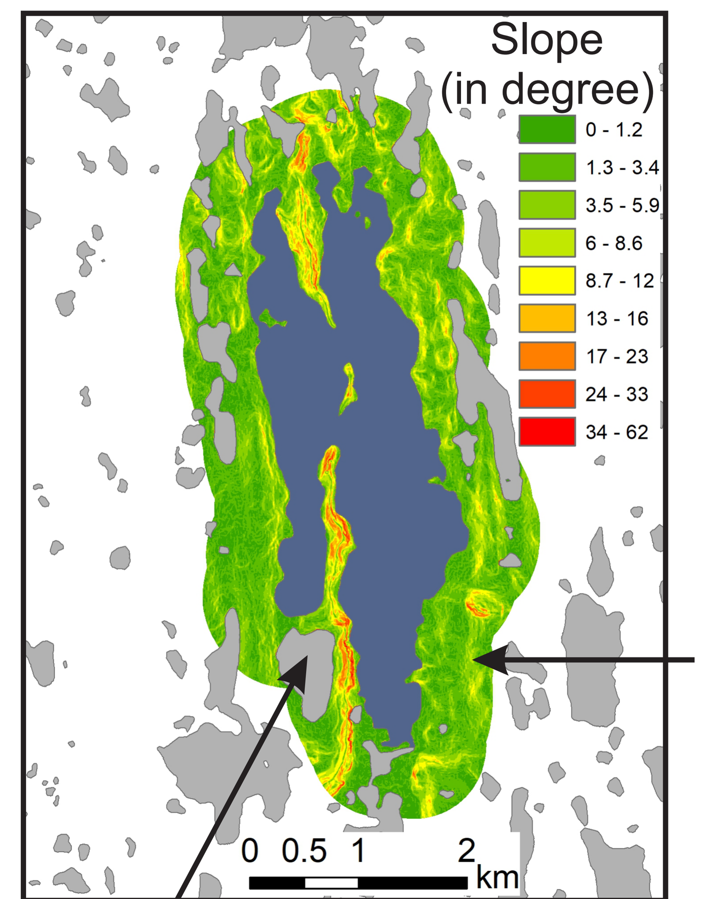
avg. max depth = 2.4 m
avg. mean elevation change = 1.6 m

avg. max depth = 6.1 m
avg. mean elevation change = 3.3 m

avg. max depth = 11.9 m
avg. mean elevation change = 7.3 m

METHODOLOGY

1. GIS ANALYSIS FOR EACH LAKE WITH KNOWN MAXIMUM LAKE DEPTH



No DATA for other lakes overlapping the buffer of a given lake

Potential predictors (independant variables)

Lake area

Surrounding topography:
- Max elevation
- Min elevation
- Mean elevation
- Max slope
- Mean slope
- Median slope
- Mean elevation change =mean elevation - lake elevation*

Surrounding topography:
Buffer = 25% of lake size (equivalent diameter)
→ HRDEM (elevation data)
→ Slope

* lake elevation from HRDEM (includes lake flattening correction; attribution of the minimum elevation found at the edge of each lake to all pixels within the lake boundaries)

2. STATISTICAL ANALYSIS

Predictors (independant variables) → Response (dependant variable: maximum lake depth)

Log transformation for skewed variables

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Exploration of the variables

↓

Stepwise regression (identify useful subset of predictors) | Pearson's partial correlation coefficient

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Multiple linear regression models (exploration of models)

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- Model 1: Subset of predictors
- Model 2: Lake area + one topographical variable
- Model 3: Lake area

↓

Check if linear regression assumptions are met (diagnostic plots of residuals)

↓

Validation of maximum lake depth: Training 80%, Validation 20%

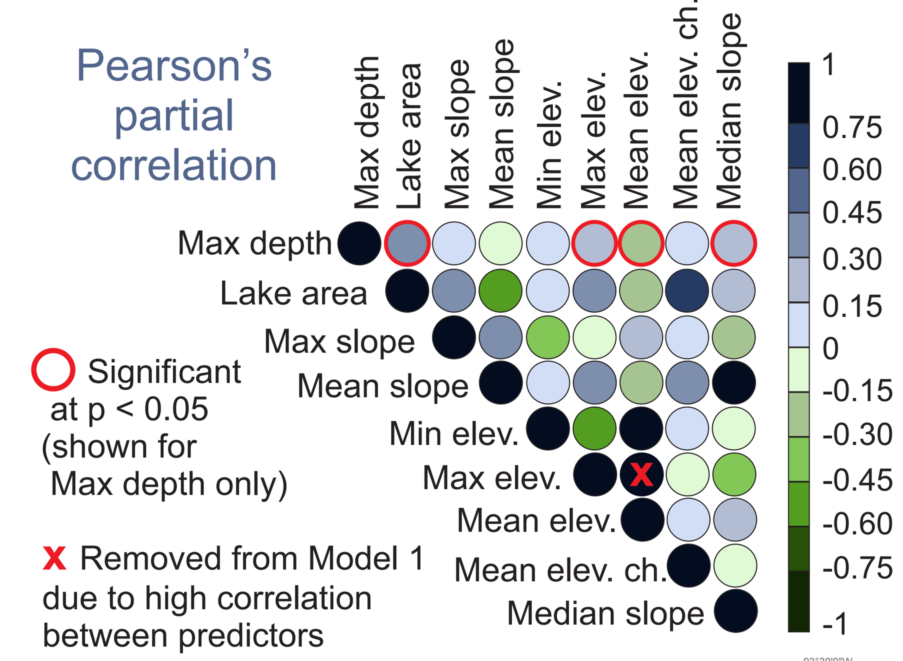
RESULTS

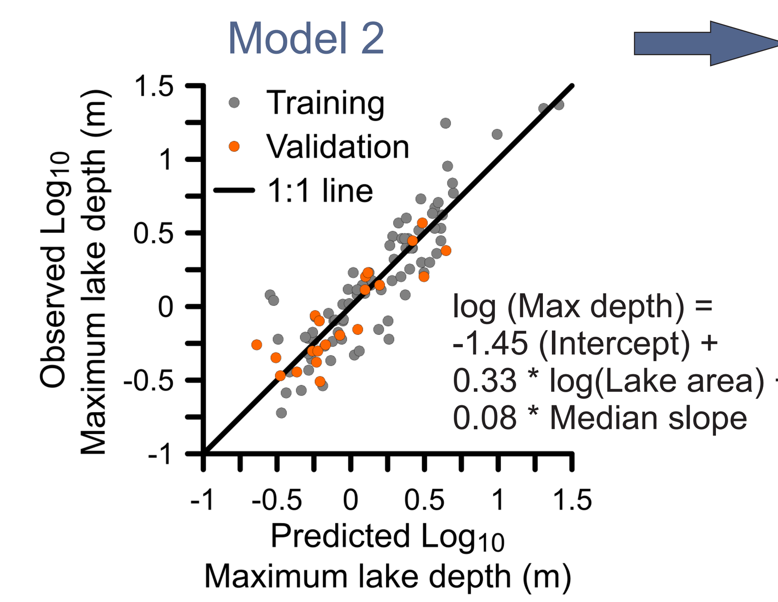
1. RANKIN INLET AREA (n = 102 LAKES)

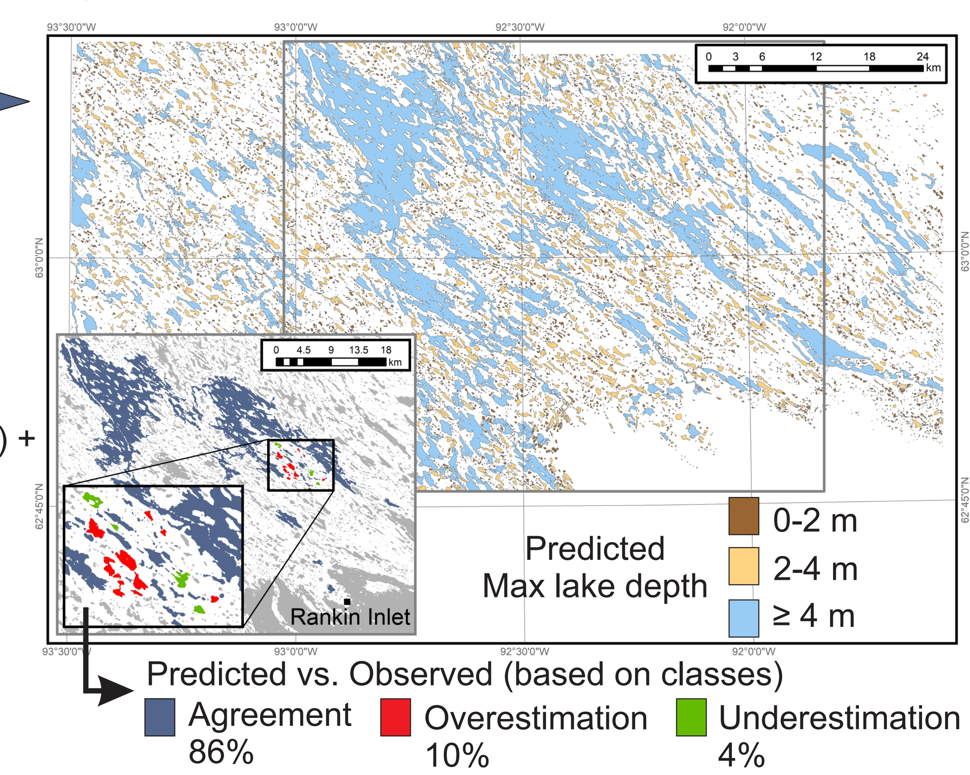
Model 1: Lake area, Median slope, Mean elevation, Max elevation
Ajusted R^2 = 0.81 (training)
R^2 = 0.78 (validation)
RMSE = 0.184 log_{10} m

Model 2: Lake area, Median slope
Ajusted R^2 = 0.79 (training)
R^2 = 0.77 (validation)
RMSE = 0.189 log_{10} m

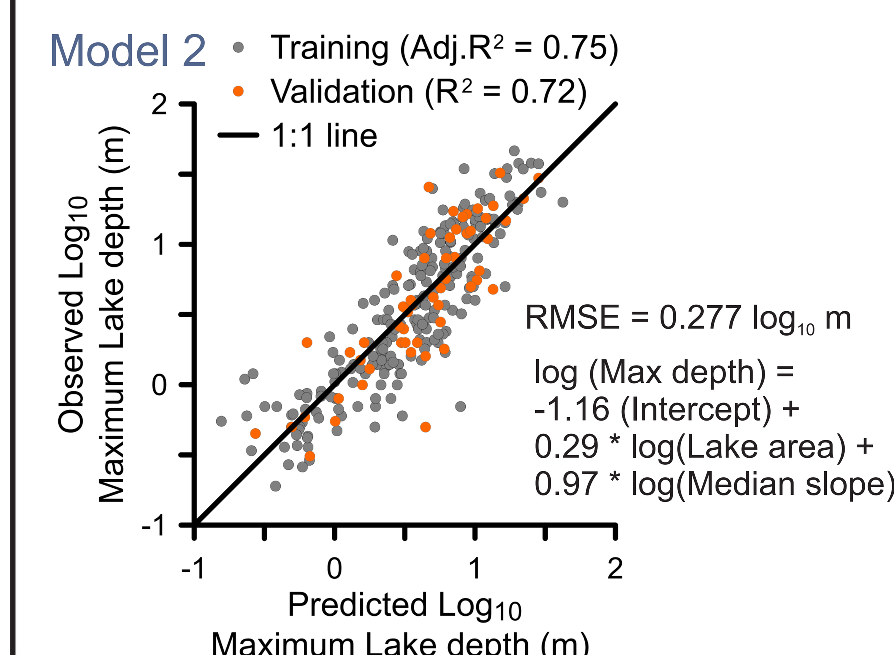
Model 3: Lake area
Ajusted R^2 = 0.78 (training)
R^2 = 0.72 (validation)
RMSE = 0.194 log_{10} m

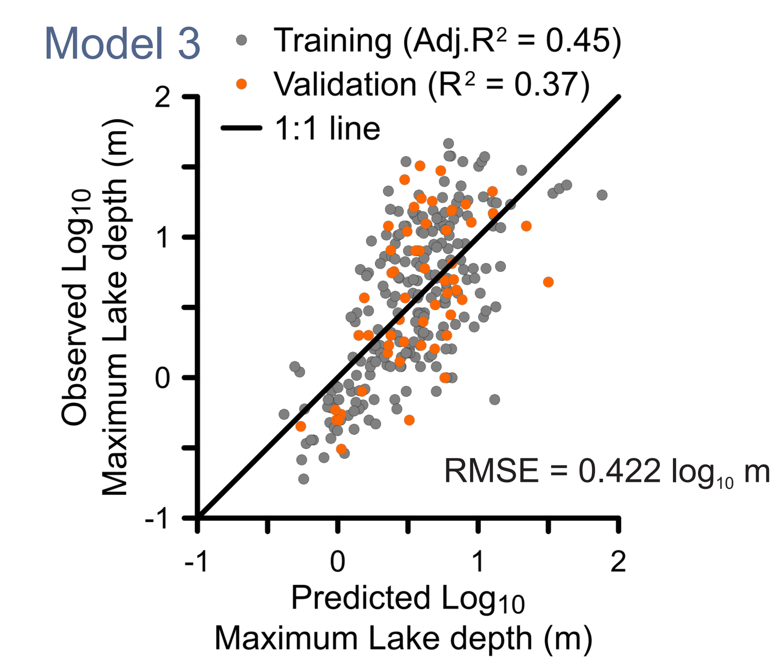






2. ALL REGIONS (n = 274 LAKES)





CONCLUSIONS

- Lake area and Median Slope were the best predictors of Max depth, explaining 79% (Rankin inlet area alone) and 75% (all 3 regions together) of the variance in maximum lake depth;
- Good agreement (86%) is obtained in terms of lake depth classes for Rankin Inlet;
- For Baker Lake and Kitikmeot regions, using lake area as the only predictor reduces the performance of the model (potentially a greater influence of topography for these regions); indicating that local to regional lake depth modelling may be necessary;
- Next step: Include lake depth (associated lake bottom temperature) into equations of [1] to reduce the uncertainty in assessing the potential of open taliks.

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[1]Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario

For more information, please contact A-M. Leblanc (anne-marie.leblanc@canada.ca).

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