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REGIONAL ASSESSMENT OF THE PRESENCE OF TALIKS BELOW ARCTIC LAKES, NUNAVUT

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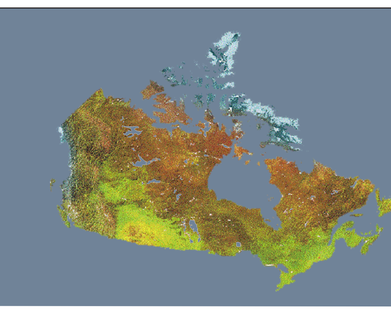
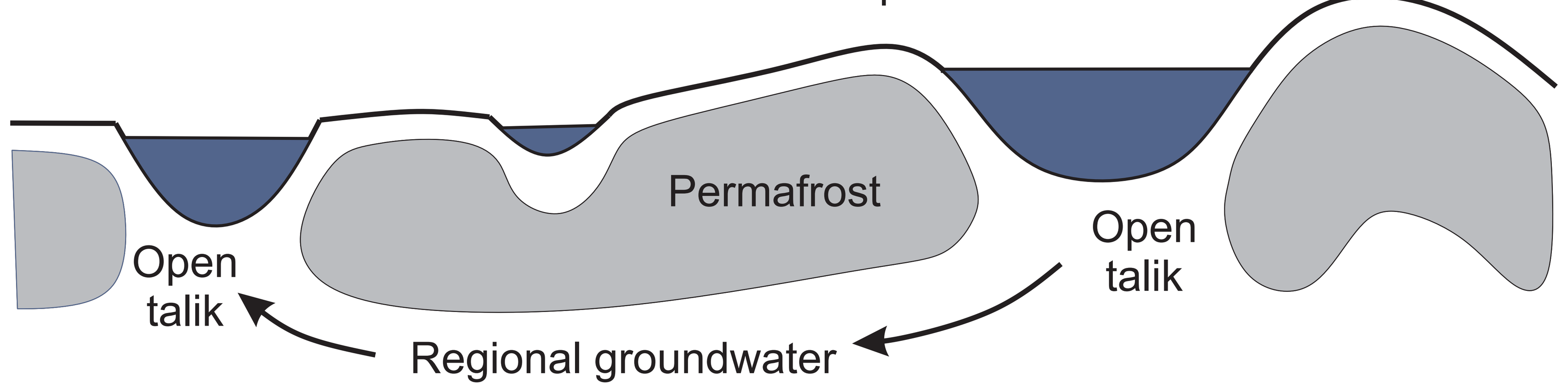


INTRODUCTION

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 by providing pathways for mine water inflow or contaminant transport. It is therefore important to determine which lakes are potentially underlain by open taliks, especially in instances where lakes are used for mine waste disposal.



The presence of open taliks beneath lakes can be assessed using steady-state model of the thermal disturbance of lakes in permafrost environment [1].

Circular lakes with terraces, Equation 1:

$$T_z = T_g + \frac{z}{I} + (T_p - T_g)\left(1 - \frac{z}{\sqrt{(z^2 + R_p^2)}}\right) + (T_t - T_g)\left(\frac{z}{\sqrt{z^2 + R_p^2}} - \frac{z}{\sqrt{z^2 + R_{p+t}^2}}\right)$$

Elongated lakes with terraces, Equation 2:

$$T_z = T_g + \frac{z}{I} + \frac{T_p - T_t}{\pi}\left(2\tan^{-1}\frac{H_p}{z}\right) + \frac{T_t - T_g}{\pi}\left(2\tan^{-1}\frac{H_{p+t}}{z}\right)$$

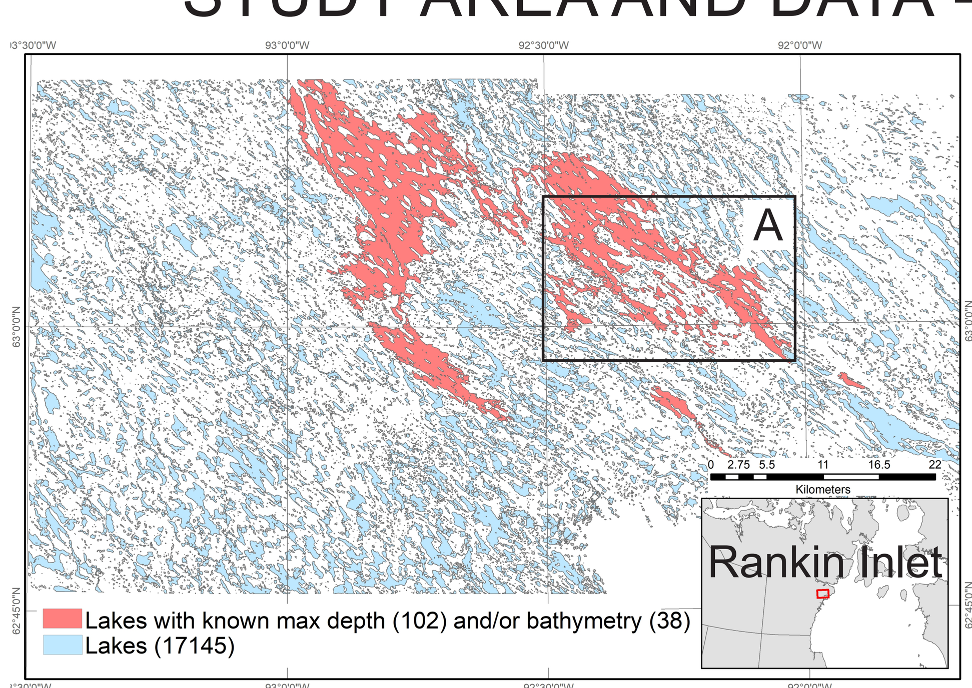
where T_z is the temperature (°C) at depth z (m); T_g, T_p, and T_t are the mean annual temperatures (°C) of the surrounding ground, the central pool, and the terrace, respectively; I is the inverse of the geothermal gradient (m/°C); R_p and R_{p+t} are the radii (m) of circular lakes, and H_p and H_{p+t} are the half width of elongate lakes of the central pool and lake, respectively.

This approach has been frenquently used by several mining projects in Nunavut [e.g.,2]. However, Equations 1 and 2 are applied in a general sense and are not customized for each lake, especially in terms of lake depth (for assigning T_p values) and lake terraces widths, which are often not accounted for.

OBJECTIVE

Develop a classification of the potential for an open talik beneath lakes in a region based on Equations 1 and 2, the average width of terraces, and the maximum relative depth of each lake.

STUDY AREA AND DATA - RANKIN INLET AREA



Ground surface temperature and geothermal gradient [2]:

T_g : -6 to -8°C

1/I : 0.012 to 0.018°C/m

Lake temperature [1,2]:

T_t : -2°C (warm terrace)
-5°C (cold terrace)

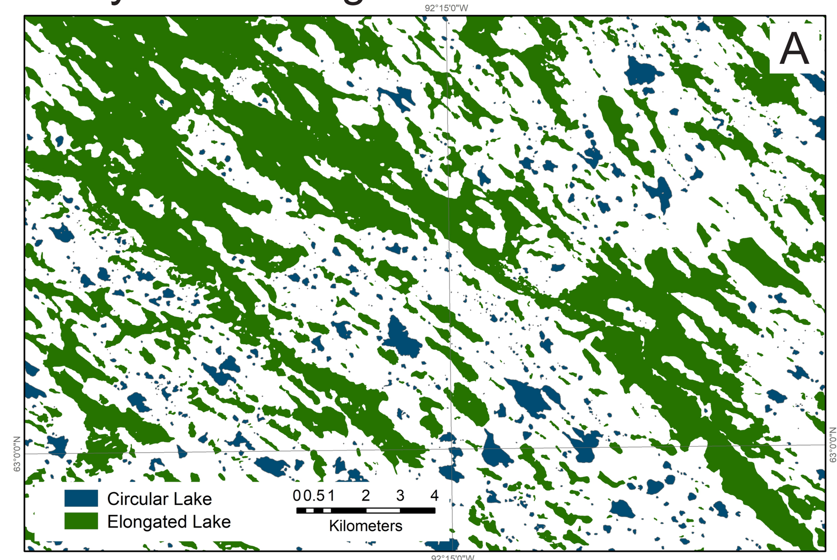
T_p : 1°C (shallow lake)
3°C (deep lake)

Lake-ice thickness [2]:
Average of 1.7 m

METHODOLOGY

1- Classification of lakes: circular or elongated lakes

Analysis of lake geometries



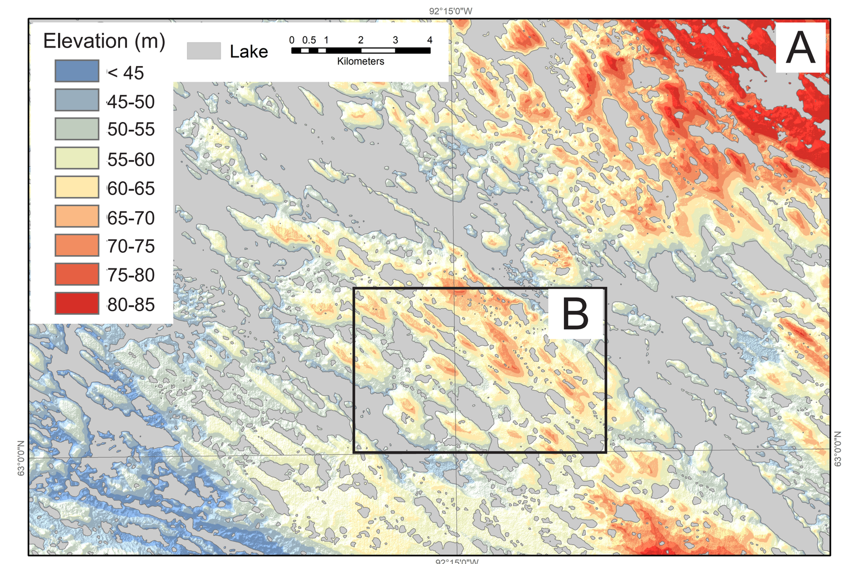
Calculation of:
Radius
if circular lake

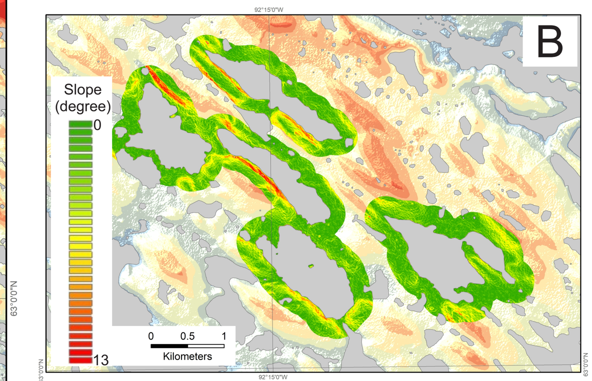
Width
if elongated lake

Hydrographic features at 1:50 000 [3]

2- Classification of lakes: shallow (< 4 m) or deep (≥ 4 m)

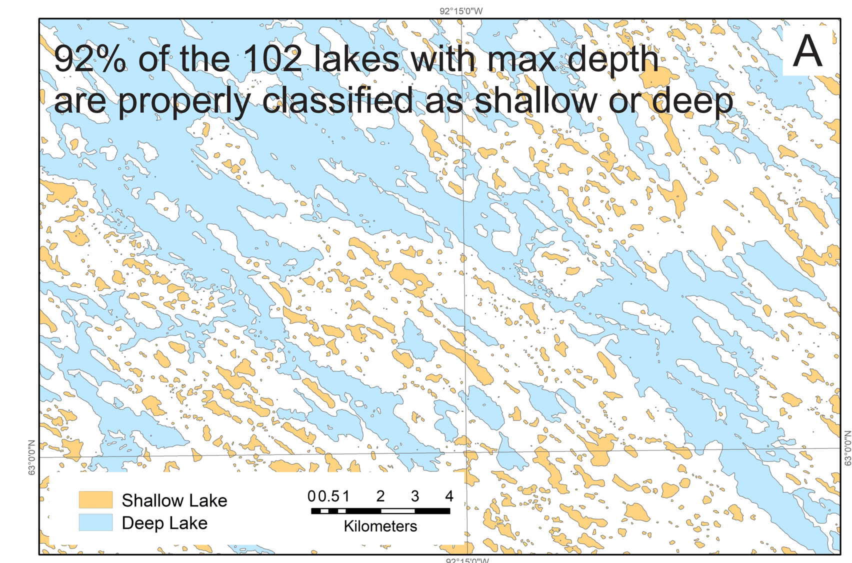
Extraction of topographical variables surrounding each lake to run predictive models of maximum lake depth [5]





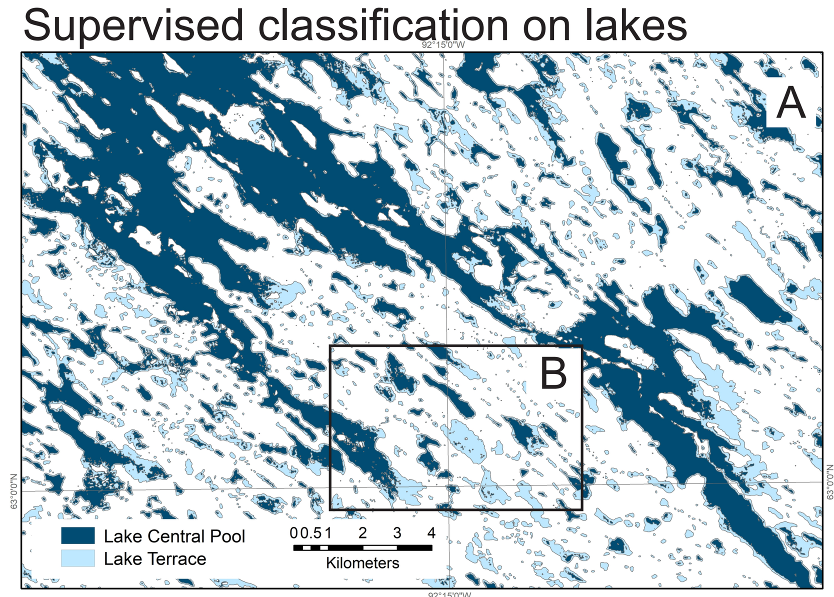
HRDEM [4] based on ArcticDEM mosaic at 2-m spatial resolution

Predicting max depth of lakes

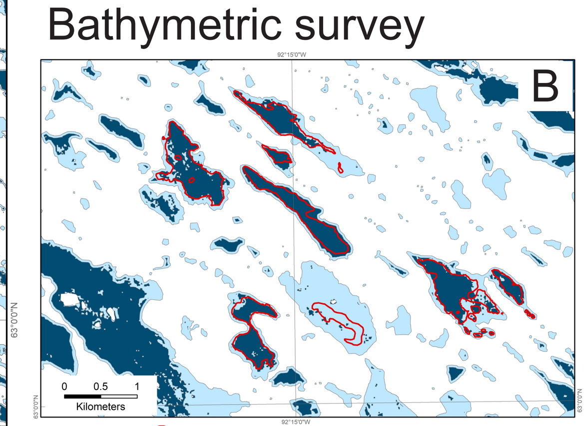


3- Assessment of terrace (width) and central pool

Supervised classification on lakes



Validation with Bathymetric survey



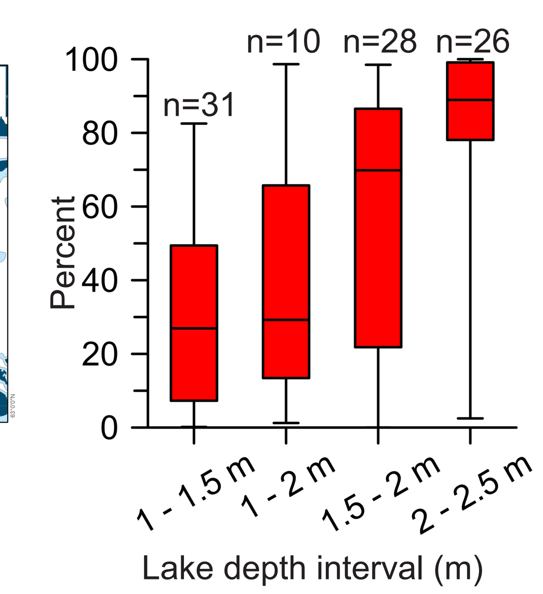
2-m contour line from bathymetric survey [2]

RapidEye, multispectral, 5 m resolution [6]

Maximum Likelihood Classification, prediction accuracy:

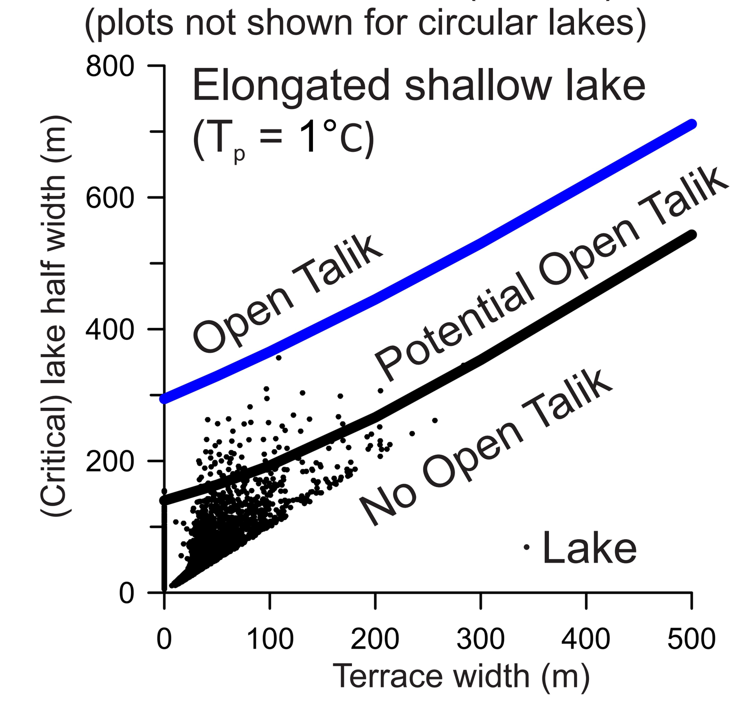
	True Positive Rate (%)	Positive Predictive Value (%)
Lake Central Pool	98	90
Lake Terrace	89	98
Average	94	94

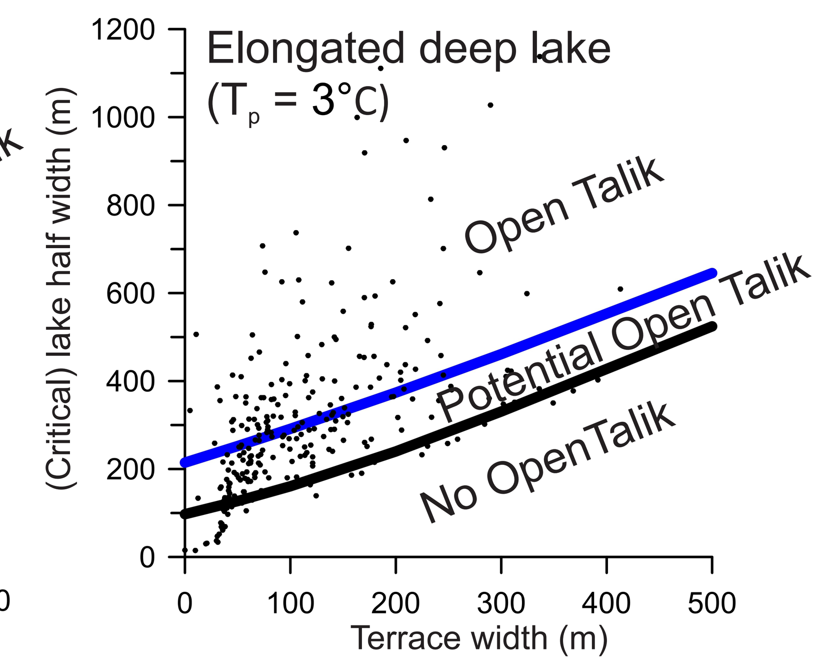
Box-Whisker of the intersect between central pool and lake depth interval



4- Steady-state model

Assessment of the (critical) radius / half width in function of terrace width
(plots not shown for circular lakes)



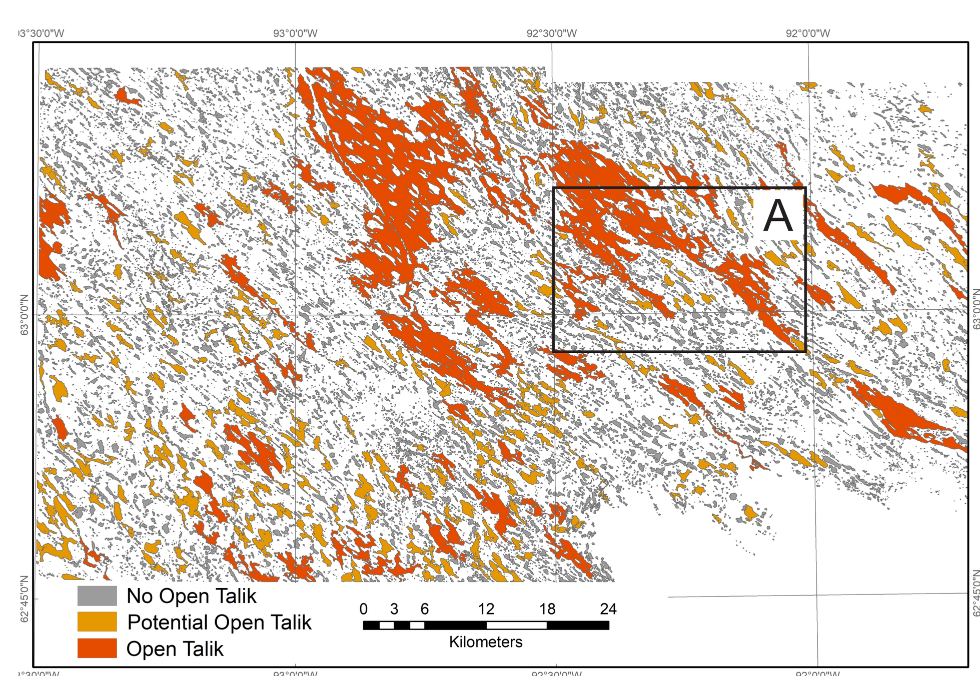


T_t=-2°C; T_g=-6°C: 1/I=0.018 °C/m

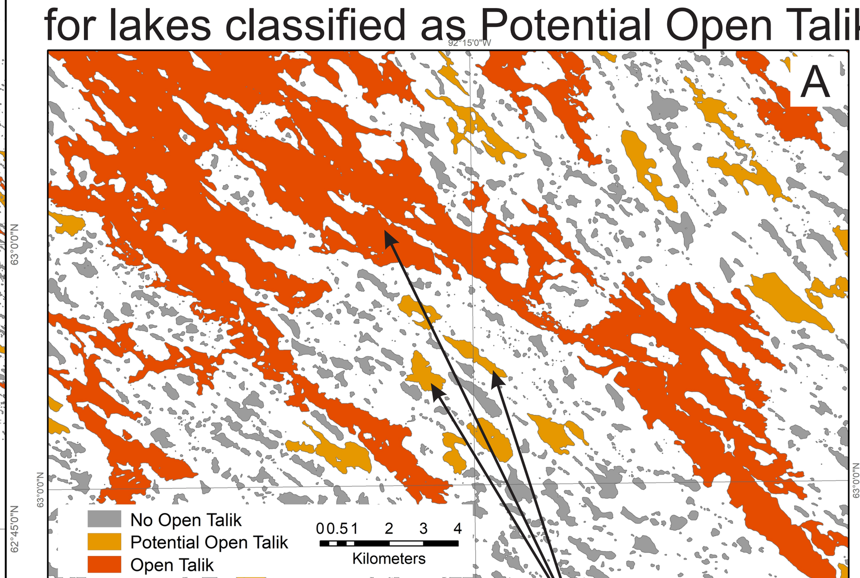
T_t=-5°C; T_g=-8°C: 1/I=0.012 °C/m

RESULTS

Classification of open talik based on results of steps 1 to 4

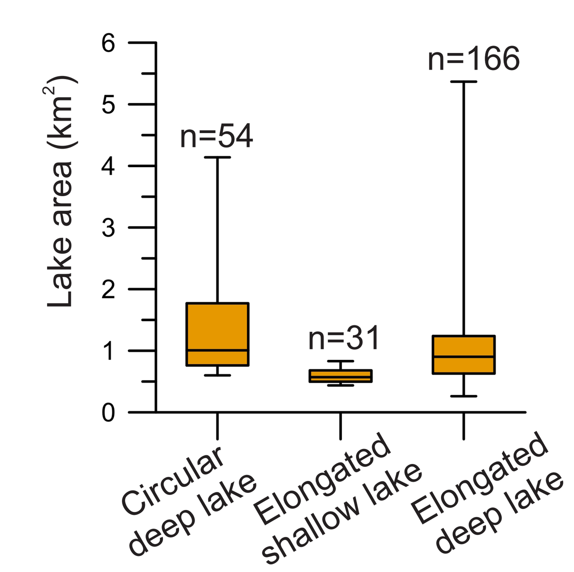


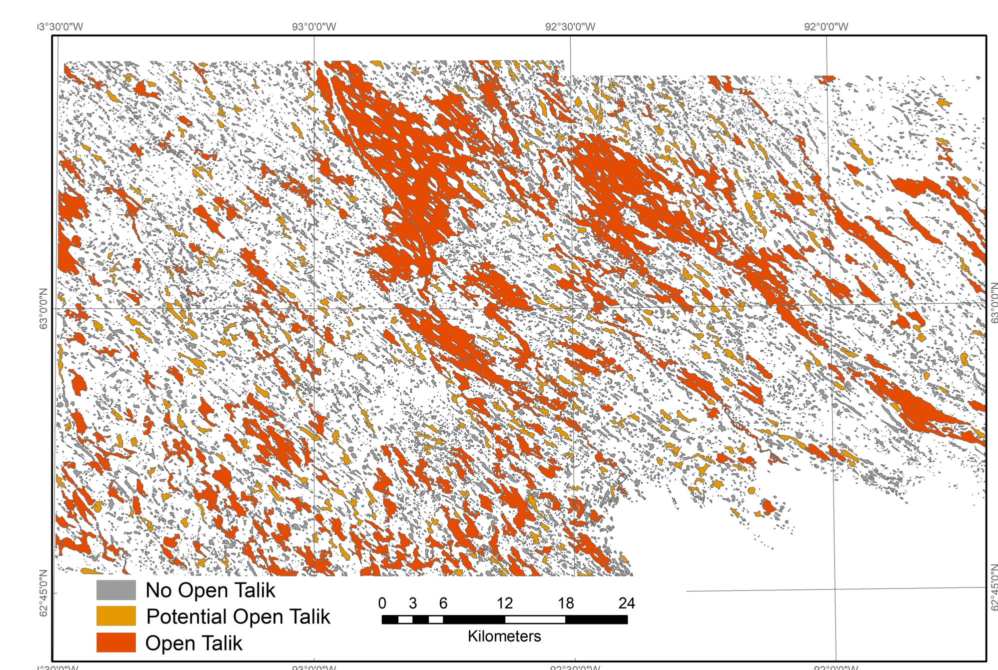
Ground validation required for lakes classified as Potential Open Talik



Meliadine mine site: lakes with known open talik [2].

Box-Whisker of lake area for Potential Open Talik





Result when lake terraces and lake depths are not customized for each lake (conservative result; increased number of lakes mapped as Open Talik)

CONCLUSIONS

Good agreement is obtained for the predictions of 1) the relative depth of the lakes (shallow or deep) and 2) the width of the terraces. The new approach further refines the existing assessment of open taliks (e.g., [2]) and leads to a less conservative result, but highlights lakes classified as Potential Open Talik (based on their areas) for which field validation is required. Field values for lake terrace temperature and lake-ice thickness, via remote sensing, can further reduce the mapping uncertainty of open talik presence.

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[1] Burn, 2002. Tundra lakes and permafrost, Richards Island, western Arctic coast, Canada. Canadian Journal of Earth Sciences, Vol. 39: 1281–1298.

[2] Golder Associated. 2014. SD 6-1 Permafrost thermal regime baseline studies - Meliadine gold project, Nunavut. 151 p.

[3] NRCan, Canadian Centre for Mapping and Earth Observation. Hydrographic features at 1:50 000, CanVec Series. (data accessible at www.open.canada.ca)

[4] NRCan, 2019. High Resolution Digital Elevation Model (HRDEM), CanElevation Series, Product Specifications, Edition 1.3. NRCan, 20p. (data accessible at www.open.canada.ca)

[5] LeBlanc, A.-M., Chartrand, J. and Smith, S.S. 2020. Estimation of maximum lake depth from the surrounding topography: towards a regional assessment of the occurrence of taliks below Arctic lakes; Geological Survey of Canada, Scientific Presentation 122, 1 poster. https://doi.org/10.4095/328242.

[6] RapidEye Satellite Imagery, acquired at "Level 3A", August 2016. Ground reflectance and top-of-atmosphere corrections were applied on image tiles prior to the classification.

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

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