Investigation and Quantification of Water Track Networks in Boreal Regions Using Remote Sensing and Geophysical Data

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Introduction

When there is a **constraining subsurface boundary** such as permafrost, clay, and bedrock, surface runoff and near-surface seepage form immature channel networks, known as "**water tracks**," through the soil. Due to the extensive presence of **permafrost** in polar environments, water tracks (Figure 1) are the **dominant drainage pathways** and thus impose significant control on arctic and subarctic hydrology (Levy et al., 2011).

Figure 1: Water Tracks in arctic tundra. Photo Courtesy of Frontier Scientist

Existing literature on water tracks is limited and is largely confined to tundra areas (Figure 1) devoid of vegetation. Nonetheless, water tracks are still observed in subarctic boreal regions.

Objectives

Short-term Objectives

1. Develop a methodology for mapping water tracks in **boreal regions**
2. Conduct a preliminary study to assess the geotechnical impact of the water track drainage networks on engineered infrastructures

Long-Term Research Goals

1. A systematic understanding of water tracks and their interactions with major infrastructure.

Case Study 1: Goldstream Road

Study Area

The Goldstream Road (Figure 2) in Fairbanks, Alaska experiences high amounts of damage, possibly due to prominent water tracks (Figure 3) that intercept with the road.

Figure 2: The Location of Goldstream Road

Figure 3: A prominent track intercepting the road

In 2012, the Alaska Department of Transportation (AKDOT) in conjunction with the U.S. Army Cold Region Research Engineering Laboratory (CRREL) conducted a geophysical study on the Goldstream Road. The data from the geophysical study has been released for this study. See Figure 4 for sample data.

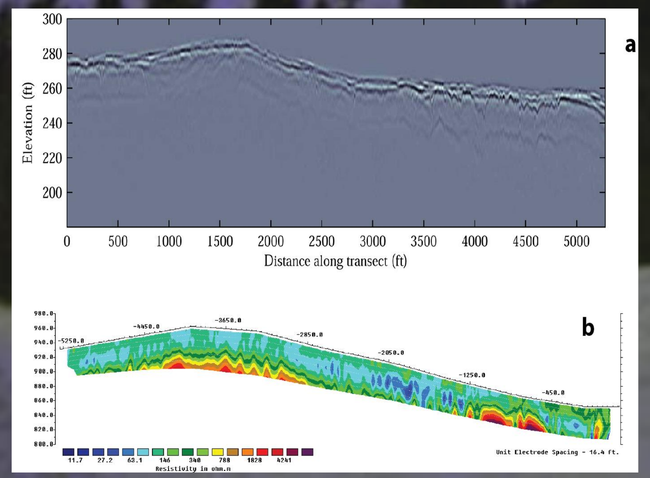

Figure 4: Goldstream Road geophysical results, MP 6-7 (Schnabel et al., 2014).
a) Topographically corrected GPR survey collected March 2011
b) CCR-ERT transect collected spring 2012 (courtesy of CRREL)

Water Track Characterization on Goldstream Road

Two sets of measurements were taken during a **pre-winter** and **post-winter** times.

Each set of measurement was taken along two transects: **vertical** (along the water track) and **horizontal** (across the track). See Figure 5.

Figure 5: Set of transect lines

Statistical P test was performed on the acquired data. Differences in moisture content and temperature between the horizontal and vertical transects were statistically significant. See Figure 6 below.

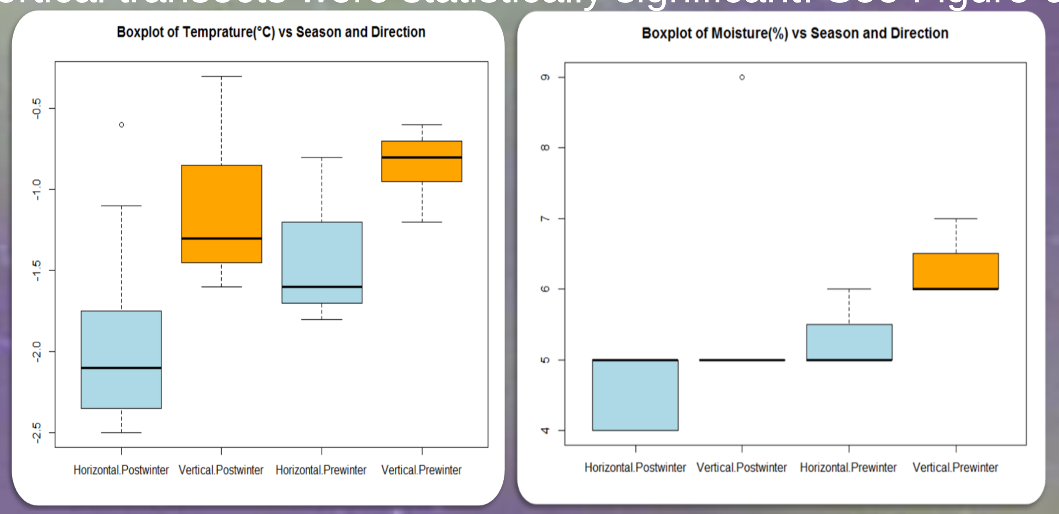

Figure 6: Boxplots of soil temperature and soil moisture along and across water track.

Mapping Water Track Distribution near Goldstream Road

- 2010 SPOT 5 images have been procured and Normalized Difference Vegetation Index (NDVI) processing was conducted (Figure 7 and 8). Potential linear/curvilinear tracks of healthy vegetations were highlighted (Figure 8) and need to be groundtruthed after the snowmelt.

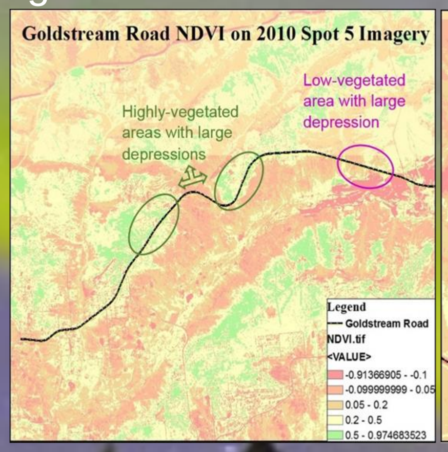

Figure 7: NDVI image of the Goldstream Road

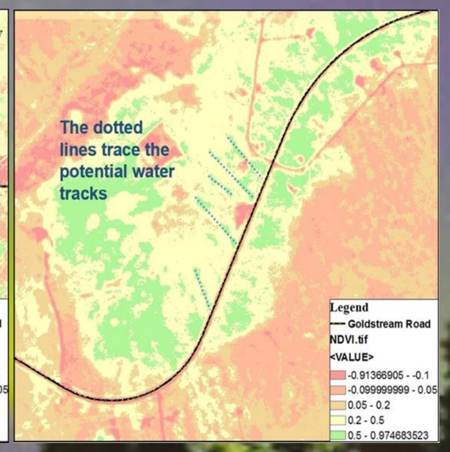

Figure 8: Potential water tracks outlined around Mile 4-5 of the road

- High spatial-resolution DEM (57 cm x 57 cm) and orthophoto (14 cm x 14 cm) were acquired by Dr. Matt Nolan in September 2014. Using the acquired images and other Web Map Services (WMS), linear and curvilinear features were manually digitized and were stored in a water track geodatabase, with relevant attributes such as width, vegetation on/off track, interception with infrastructure, etc. Figure 9 shows some mapped water tracks.

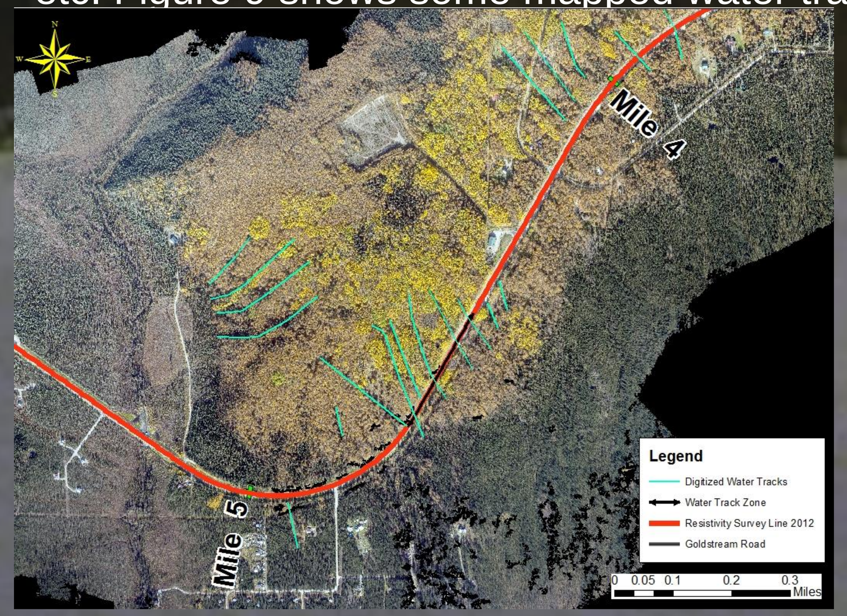

Figure 9: Digitized water tracks near Mile 4 and 5 on Goldstream Road. Basemap is orthophoto acquired by Dr. Matt Nolan. Note that vegetation changes between coniferous and deciduous.

Preliminary correlation with geophysical data from 2012

When the apparent resistivity measurements from 2012 study were plotted around the characterized track, the resistivity dropped in the vicinity of the approximate location zone of the track (Figure 10).

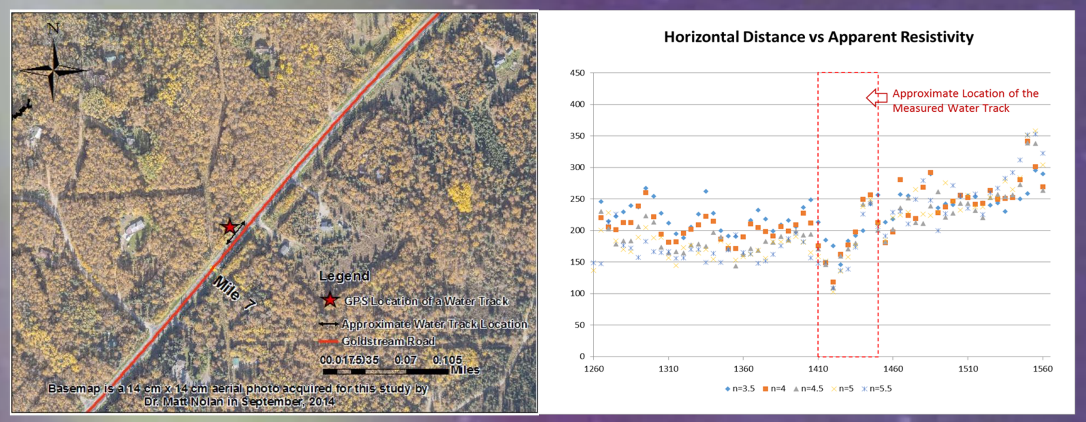

Figure 10: Plot of apparent resistivity around the characterized track. The location of the track was approximated with a range of 30-m zone to offset the errors.

Case Study 2: Martin's Property

Prominent water tracks and linear/curvilinear subsidence were observed at the residence of Bob and Mary Martins', northeast of Fairbanks, Alaska (Figure 11).

Figure 11: Conditions at Martin's property located Northeast of Fairbanks

Several surveys were conducted at the property:

- Thermal Infrared cameras (i.e., FLIR S40 and T620) successfully detected the different thermal regime above a water track (Figure 12).

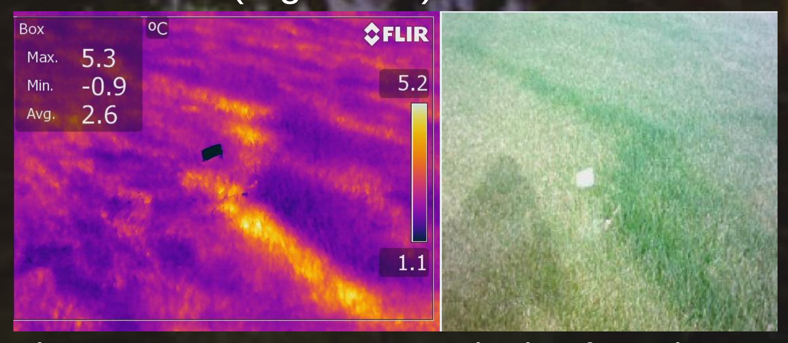

Figure 12: More evapotranspiration from the water track was sensed as warmer than the surrounding in October 2014.

- Intrinsic permeability characterization along a transect line through a water track revealed contrasting difference in the permeability of the natural soil and the foundation fill. Refer to Figure 13 below.

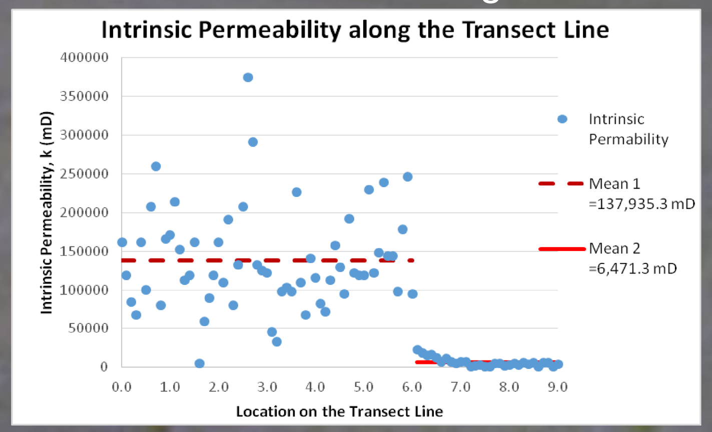

Figure 13: Plot of permeability along the survey line. The mean of the first 6-m zone (fill) is over 21 times higher than that of the last 3-m zone (natural soil).

Conclusion

- Temperature and saturation are critical parameters in identifying water tracks in the boreal region.
- Formation of water tracks is not limited to lateral subsurface boundary, but also they can form along the boundary between two units with relatively different hydraulic properties such as fill and natural soil.

Synthesis

- Water tracks exist in both permafrost and non-permafrost (seasonal-frost) areas of the Sub-Arctic.
- This study highlights the unexplored nature of water tracks, and the complexity of mapping them due to unknown characteristics and variations of water tracks.

Future Work

- More characterizations including intrinsic hydraulic properties need to be performed.
- More water track investigations are necessary to define the different types of water tracks that exist in the Sub-Arctic.
- Precise mapping techniques for each type of water track need to developed based on better understanding and characteristics of water tracks.
- Interaction of water tracks and infrastructure should be investigated with a systematic understanding of water tracks and with better techniques of mapping the distribution of water tracks.
- Most Significantly: **More research interest and funding** are needed to investigate water tracks and their interaction with infrastructure **as the potential damage and threats are slowly being uncovered with the recent climate changes in the polar environment…**

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