Development of a methodology for the design of low-impact drainage systems along transportation infrastructure in permafrost environments

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Introduction

Design of a drainage system is one of the most important stages to consider in the construction of roads, railways and airstrips

(Johnston, 1981)

EBA, 2013

Peel Plateau

Accumulation of water and culvert degradation at km 90, Yukon

Infrastructure damages related to water

Water ponding, Inukjuak

Thermokarst development

Thermal erosion

Culvert failures

Embankment subsidence

Research Objectives

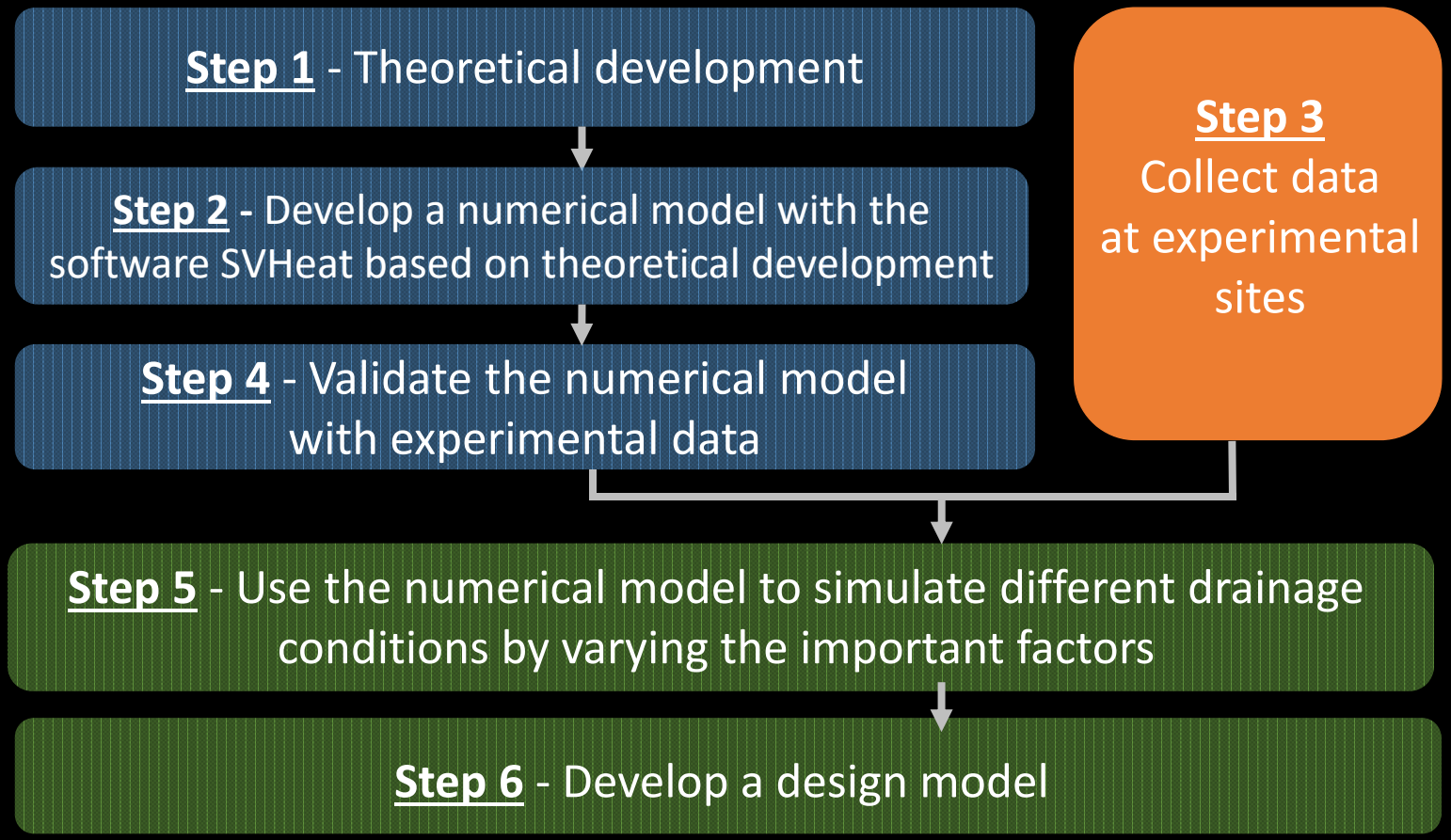
Develop **new strategies and methodology**
for the design of drainage systems
to minimize permafrost degradation resulting from water accumulation and flow

Part 1
Develop a relationship for flow-convective heat transfer (adapted Peclet number)

Part 2
Develop a flow-erosion relationship using a Cohesive Strength Meter

Assess the **allowable flow or volume of water** in a ditch to prevent excessive heat transfer to permafrost and soil erosion

Methodology



Step 1 - Theoretical Development

Adaptation of the Peclet number to evaluate the importance of convective heat transfer

$$P_e = \frac{\rho c v_f l r}{k_m}$$

$P_e > 1$ Transfer by convection

$P_e < 1$ Transfer by conduction

(Kane et al., 2001)

Does not consider latent heat

Step 1 - Theoretical Development

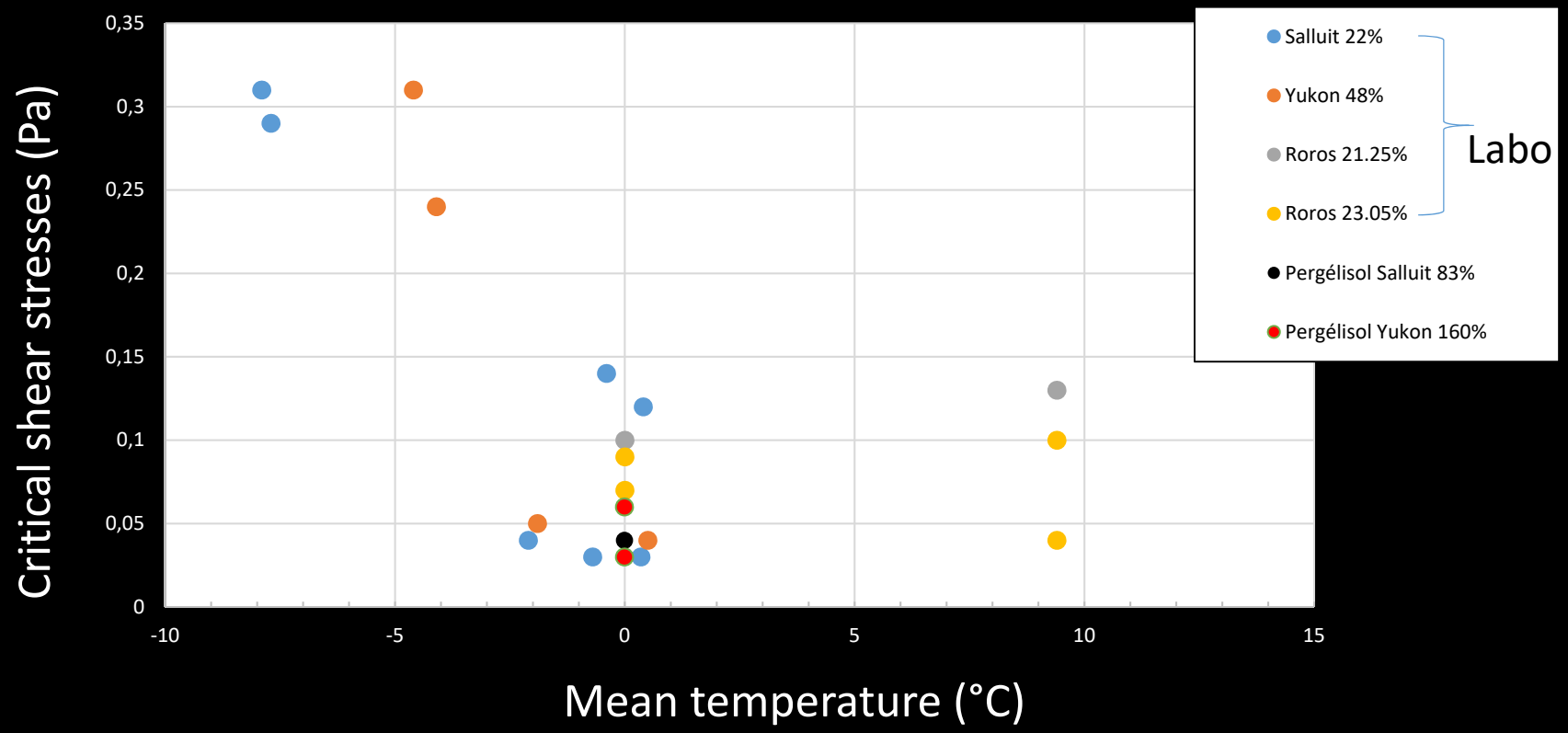
Development of a flow-erosion relationship

Cohesive Strength Meter (PARTRAC)

Critical shear stress τ_c of frozen and thawing soils

Project in collaboration with the NTNU Norwegian University of Science and Technology

Step 1 - Preliminary results

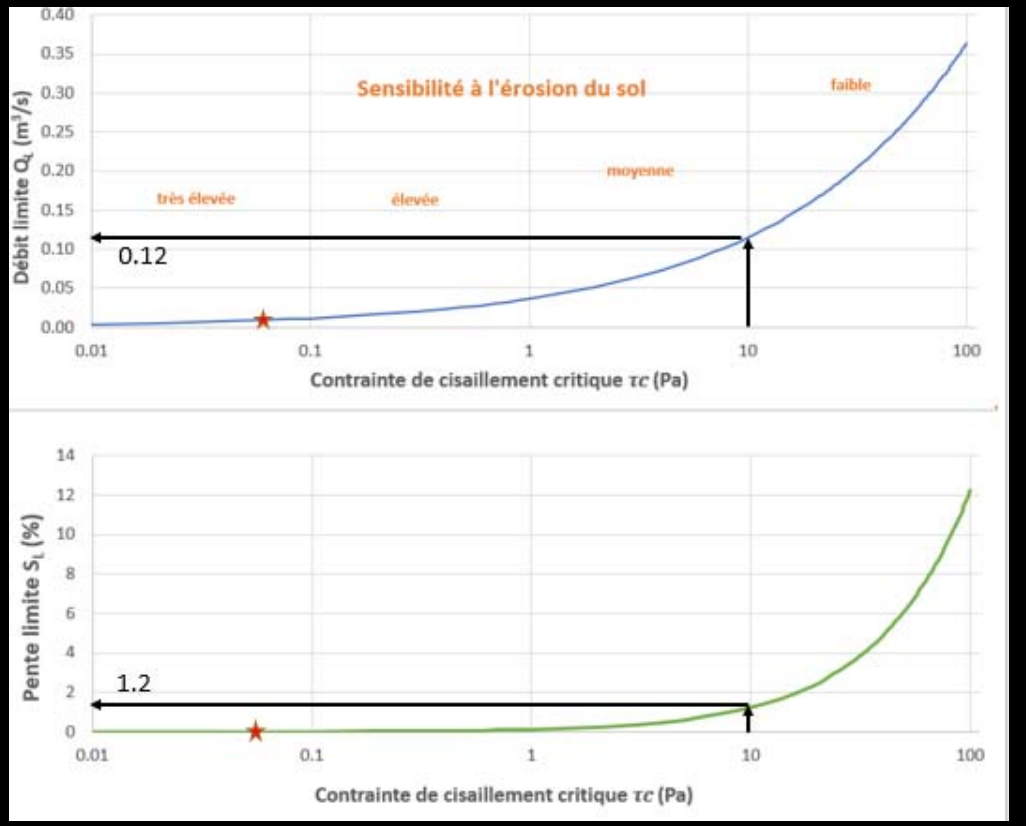


Step 1 - Preliminary results

Flow limit Q_L a function of critical shear stress

$$Q_L = \frac{1}{n}\sqrt{\frac{\tau}{\rho g}}\frac{A^{1.1}}{(W+2D)^{0.2}}$$

Only for W = 1 m
D = 0.1 m
A = 0.1 m²



Preliminary results – from Yukon test site

Step 3 - Data acquisition at experimental sites

ILULISSAT TEST SITE, GREENLAND

Study of the degradation of permafrost under a small stream in a natural environment (2014)

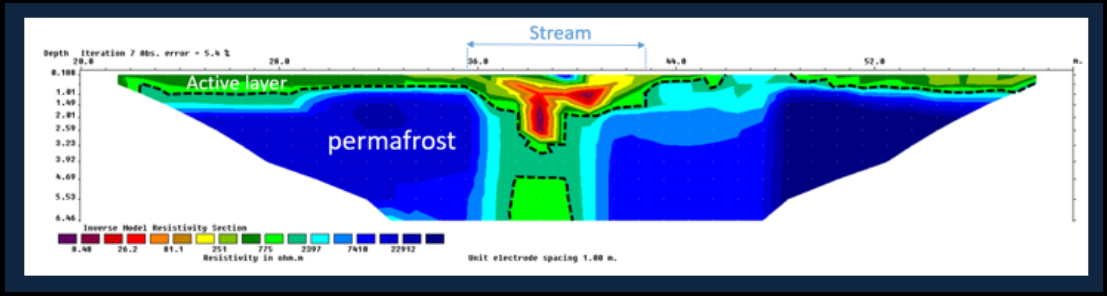
In collaboration with the DTU Technical University of Denmark

Step 3 - Preliminary results

ILULISSAT TEST SITE, GREENLAND

Electrical Resistivity Tomography (ERT)

- Degradation of permafrost due to water flow is easily observed (low resistivity values in orange and red)
- An increase in thaw depth is observed from upstream to downstream
- Electrical resistivity has the potential to become a useful and cost-effective tool for the design of any permafrost drainage system



Ilulissat

Step 3 - Data acquisition at experimental sites

KM 1894 ALASKA HIGHWAY, YUKON (2014-2017)

Study of permafrost degradation following the construction of an interceptor ditch (2014-2017)

Step 3 - Data acquisition at experimental sites

KM 1894 ALASKA HIGHWAY, YUKON

Topography and active layer thickness measurements

Electrical Resistivity Survey

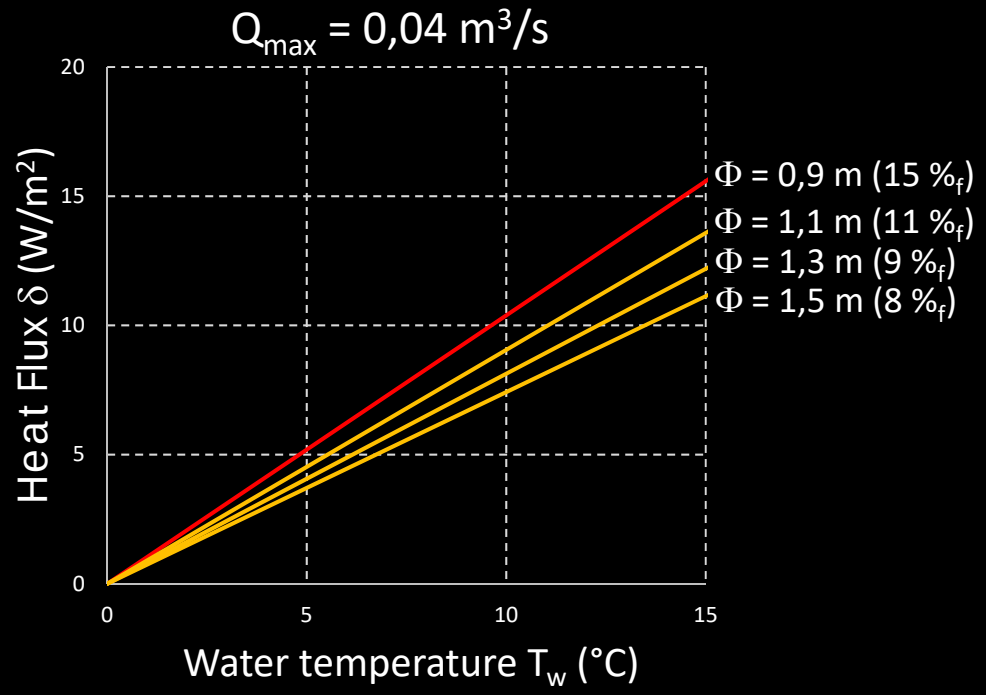
Flow rate measurements

Cohesive Strength Meter

In collaboration with Yukon Research Center

Step 3 - Results

Thermal regime around culvert – Loriane Périer M.Sc. project



Heat flux is smaller for larger diameter

Several figures for various flow

Step 3 - Data acquisition at experimental sites

SALLUIT, NUNAVIK (northern Québec)

Study of the impacts on permafrost
of the construction of a new drainage ditch

Watershed study

In collaboration with the climate change adaptation monitoring project
of the Salluit access road, MTMDET (Loriane Périer and Vincent Lamontagne)

Arquluk
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