Behaviour of airport structures in permafrost areas…

that might not be permafrost in the future

SWIFT conference

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Presentation outline

- The context
- The problem
- Management of airport infrastructures in the context of degrading permafrost


THE CONTEXT


North ★ Pole
Norwegian Sea
Norway
Polar Ice
Greenland Sea
UK
Russia
Arctic Ocean
Quttinirpaaq
Bering Strait
Kalaallit Nunaat
(Grønland)
(Denmark)
Iceland
Alaska
(USA)
Ivvavik
Aulavik
Baffin Bay
Scale
300 0 300 600 900
km km
Vuntut
Tuktut Nogait
Simmilik
Auyuittuq
Davis Strait
Yukon Territory
Kluane
Northwest Territories
Nunavut
Labrador Sea
Atlantic Ocean
Nahanni
Ungava Bay
Newfoundland and Labrador
Pacific
Wood Buffalo
Hudson Bay
Gwaii Haanas
British Columbia
Alberta
Saskatchewan
Wapusk
Terra Nova
Gros Morne
Jasper
Elk Island
Manitoba
Mingan Archipelago
Glacier
Mount Revelstoke
Banff
Yoho
Kootenay
Prince Albert
James Bay
Quebec
(FR)
Forillon
Cape Breton Highlands
Pacific Rim
Ocean
Kouchibouguac
PEI
Prince Edward Island
Saguenay–St Lawrence
Fundy
NB
NS
Waterton Lakes
Riding Mountain
La Mauricie
Kejimkujik
Grasslands
Ontario
Pukaskwa
United States of America
Fathom Five
Georgian Bay Islands
Lake Superior
St Lawrence Islands
Bruce Peninsula
Lake Ontario
Lake Michigan
Lake Huron
Lake Erie
Point Pelee
Canada's National Parks
National Parks / National Park Reserves
National Marine Conservation Areas
NS = Nova Scotia
NB = New Brunswick
PEI = Prince Edward Island
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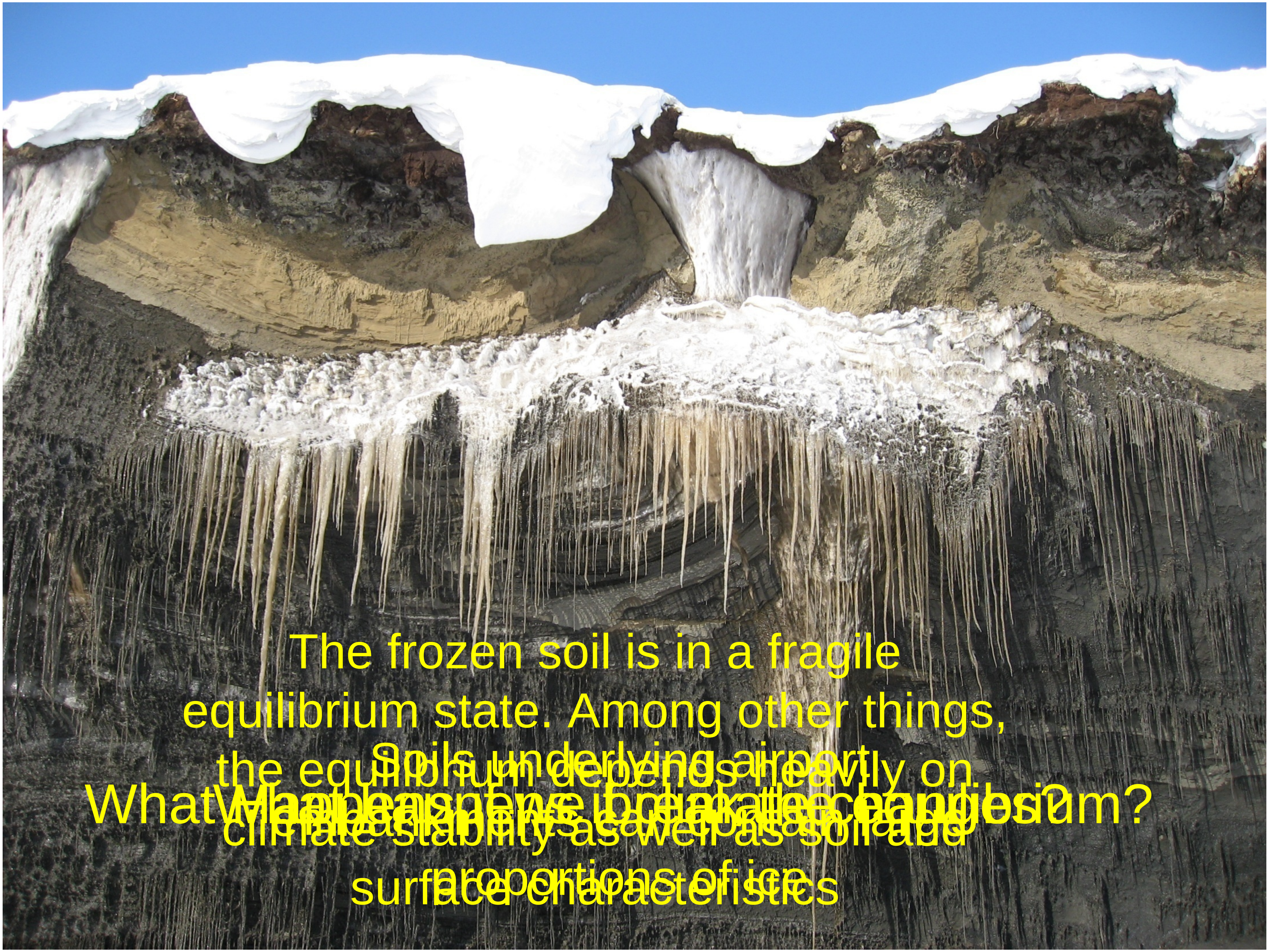
THE PROBLEM


The frozen soil is in a fragile equilibrium state. Among other things, the equilibrium depends heavily on:
climate stability as well as soil and surface characteristics
Soils underlying airport
proportions of ice

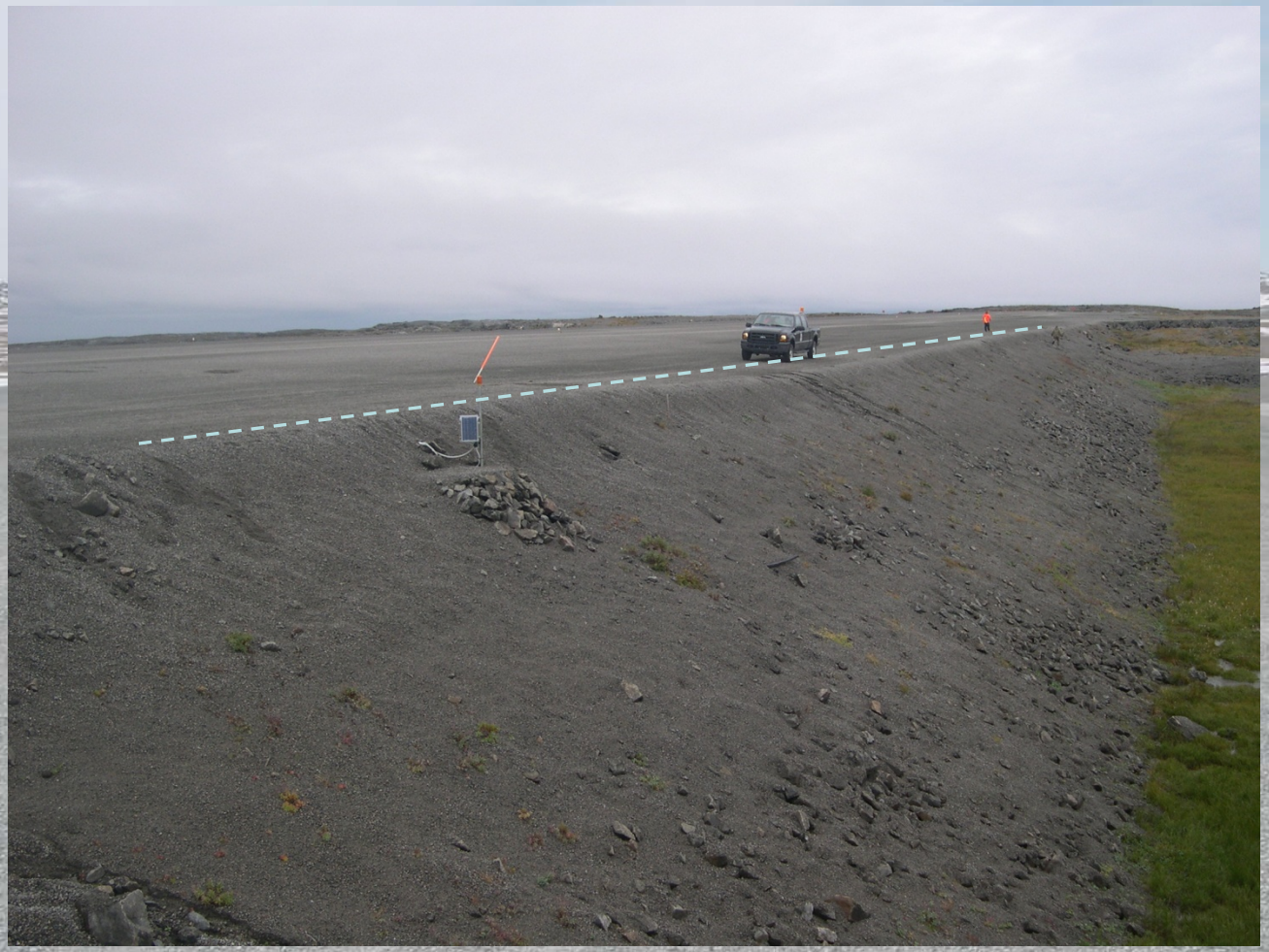
Development of thermokarsts

Thermal erosion

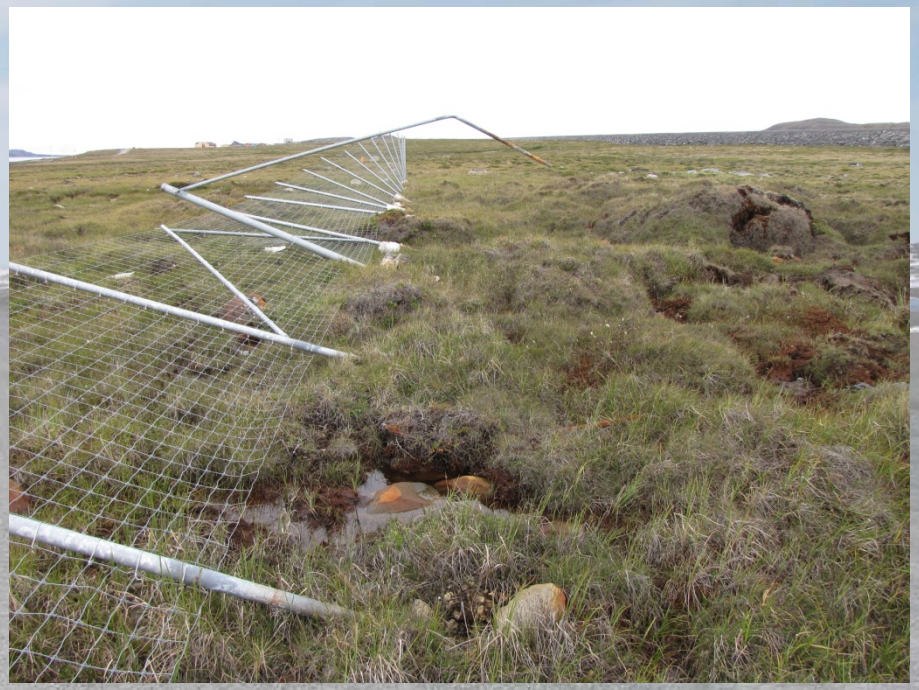
Differential settlements

Shoulder rotation

Creep in frozen soils



Frost heave



It is thus essential…

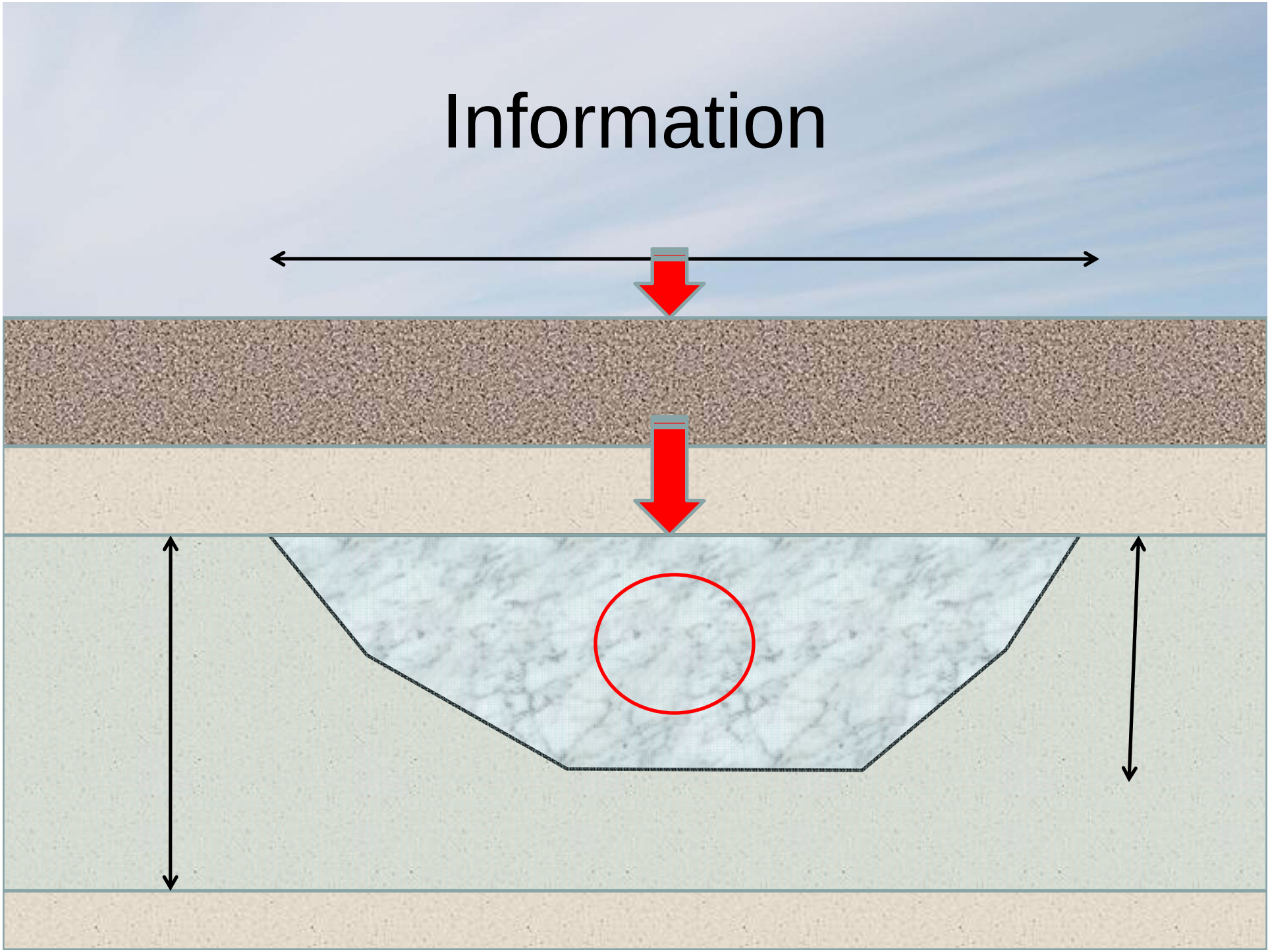
- To fully understand the context
- To know soil characteristics and properties
- To face the problem on a thermal stability angle first
- To account for climate warming over the design life of the embankment
- To rigorously apply thermal and mechanical principles in the design and the management of airport infrastructures

MANAGEMENT OF AIRPORT INFRASTRUCTURES

Adaptation strategy (management)

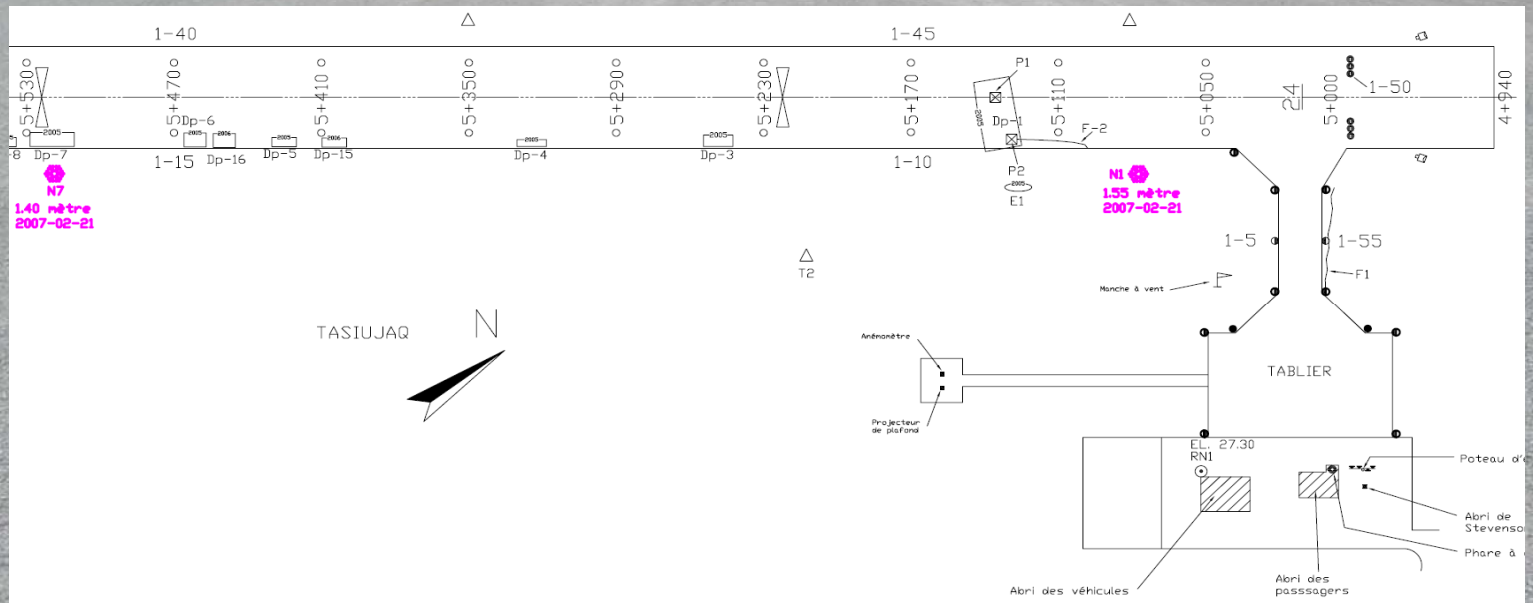
1. Information:
   a) Identification on thaw sensitive areas
   b) Characterization of thaw sensitive areas
      - Rate of settlement
      - Characteristics of thaw sensitive soils
      - Thickness of thaw sensitive soils
   c) Information management
2. Analysis of applicable solutions
      - Identify applicable strategies/solutions
      - Analyse applicable solutions
        - Cost
        - Expected performance
        - Cost/benefit
3. Selection and implementation of strategy

Information



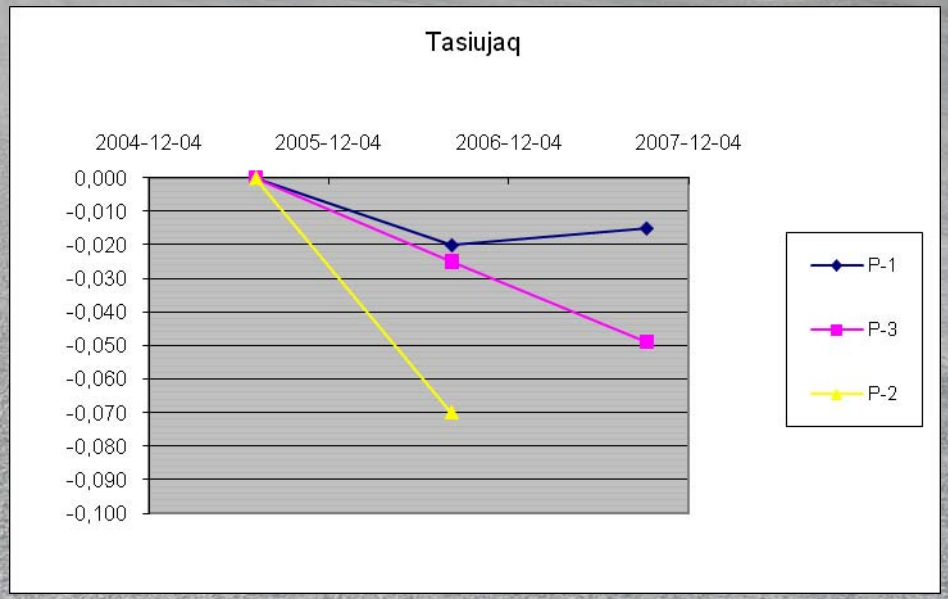
Information

- Identification of thaw sensitive areas
  - Areas showing indications of poor performance
    - Visual surveys
    - Profile measurements



Information

- Characterisation of thaw sensitive areas
  - Thaw and settlement rate
    - Thermistors
    - Elevation measurements (settlement plates)

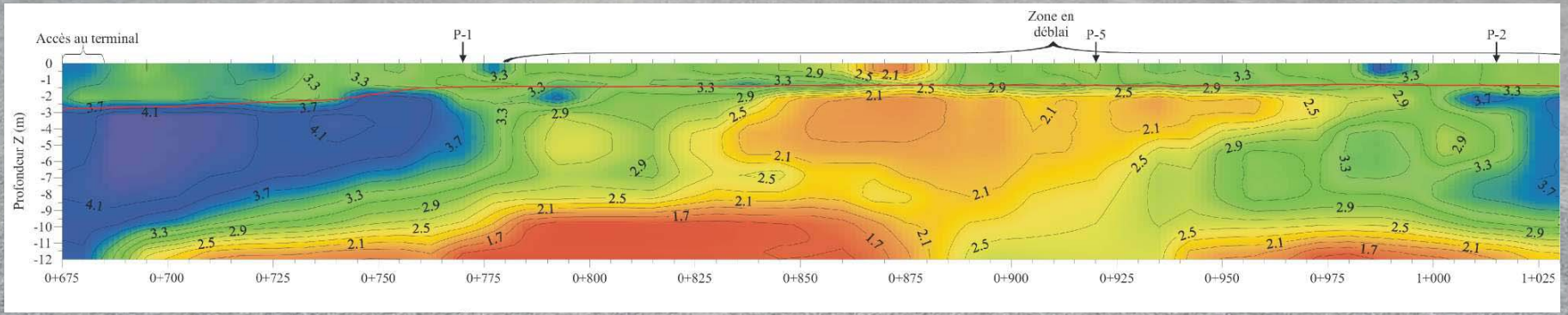


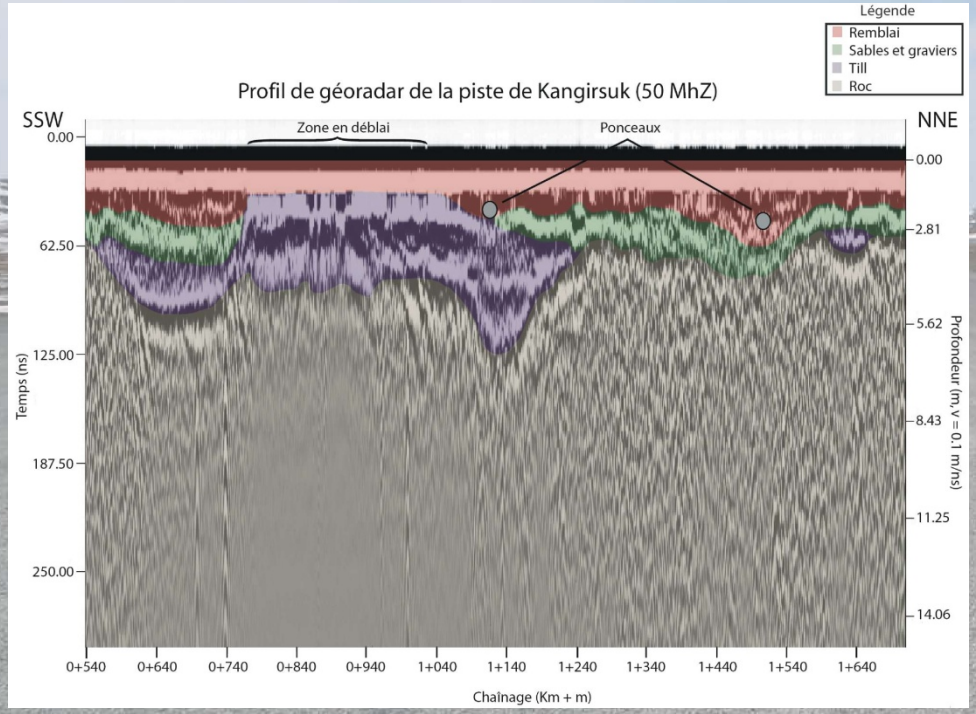
Information

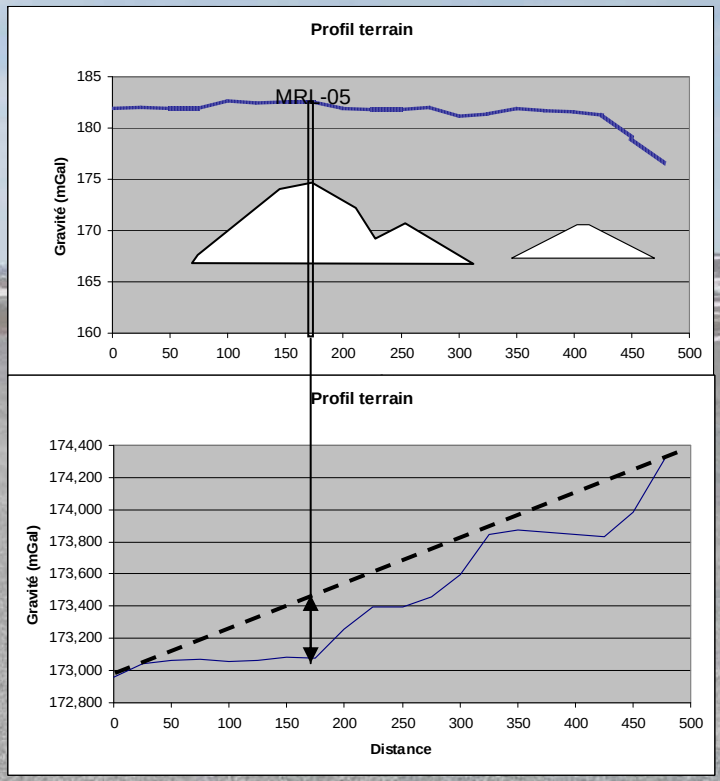
- Thickness of ice-rich soil
  - Geophysics
  - Drilling
- Characteristics of Ice-rich soils
  - Ice content
  - Thaw-settlement characteristics
- Prediction of climate evolution

Information

- Characterisation of thaw sensitive areas
  - Geophysical surveys
    - Ground penetrating radar
    - Electrical resistivity
    - Micro-gravimetry

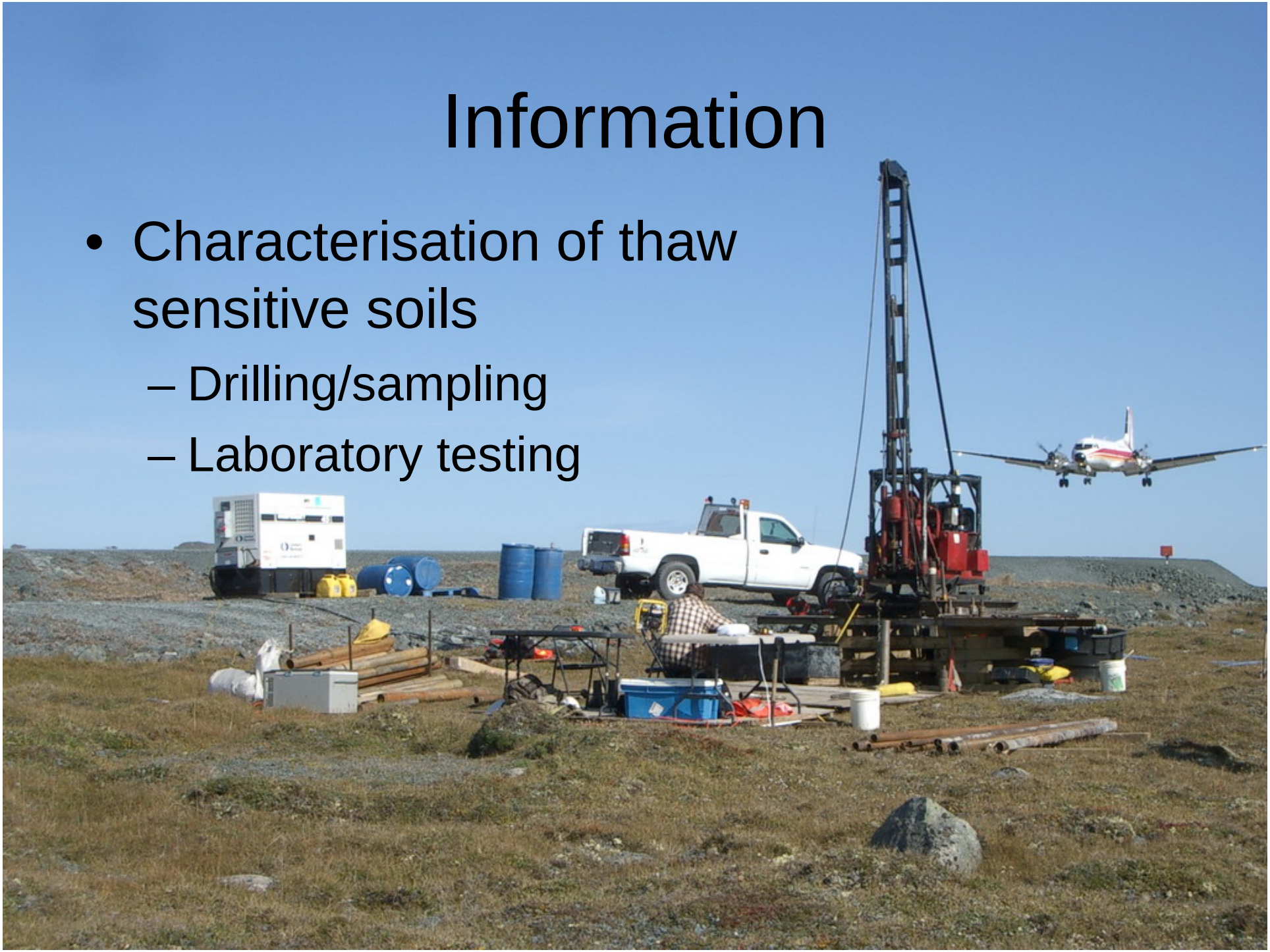


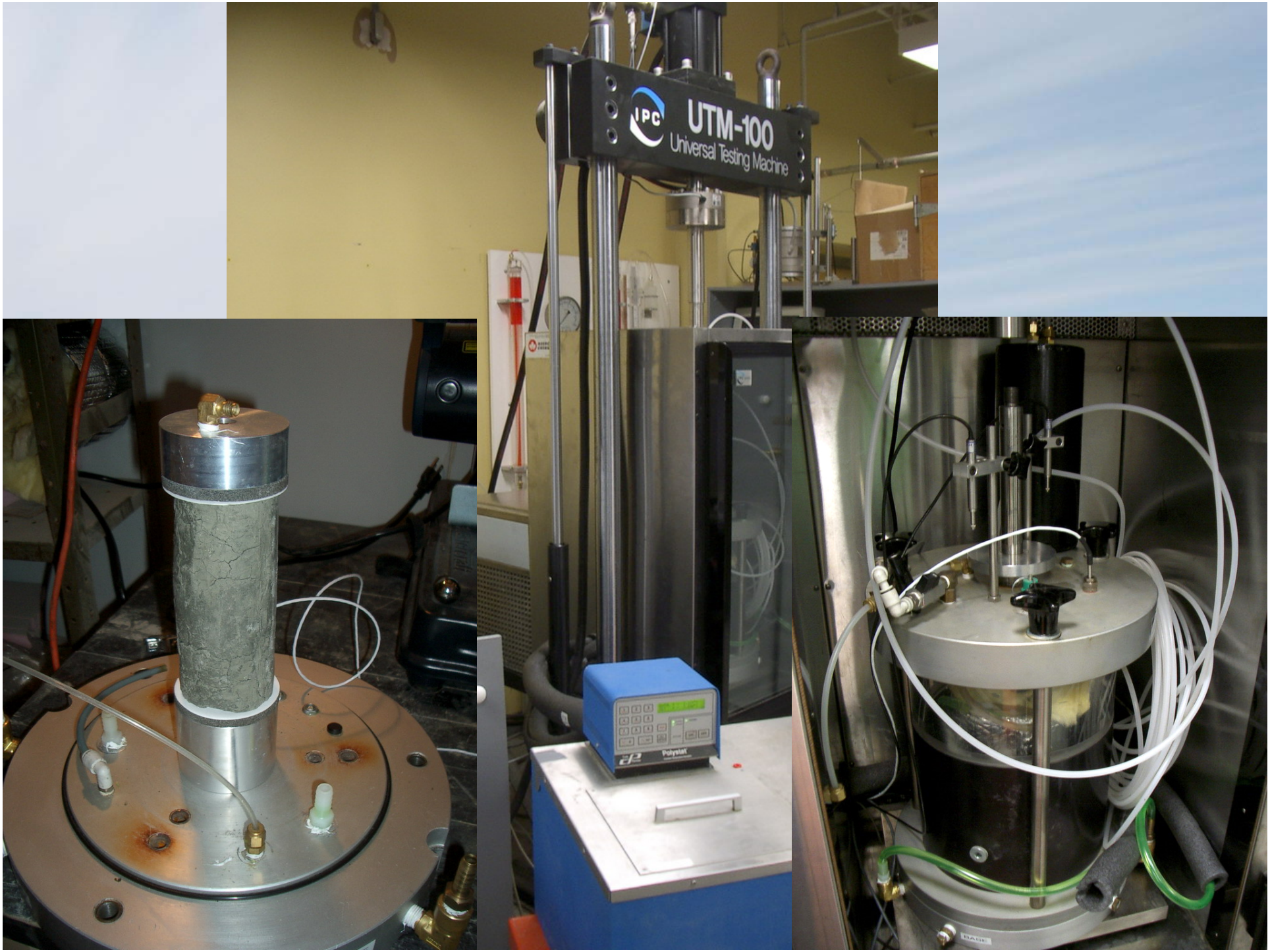

Légende
Remblai
Sables et graviers
Till
Roc
Profil de géoradar de la piste de Kangirsuk (50 MhZ)
SSW
NNE
Zone en déblai
Ponceaux
0.00
62.50
125.00
187.50
250.00
Temps (ns)
0.00
2.81
5.62
8.43
11.25
14.06
Profondeur (m, v = 0.1 m/ns)
0+540
0+640
0+740
0+840
0+940
1+040
1+140
1+240
1+340
1+440
1+540
1+640
Chaînage (Km + m)


Profil terrain
MRL-05
Gravité (mGal)
185
180
175
170
165
160
0
50
100
150
200
250
300
350
400
450
500
Profil terrain
Gravité (mGal)
174,400
174,200
174,000
173,800
173,600
173,400
173,200
173,000
172,800
Distance

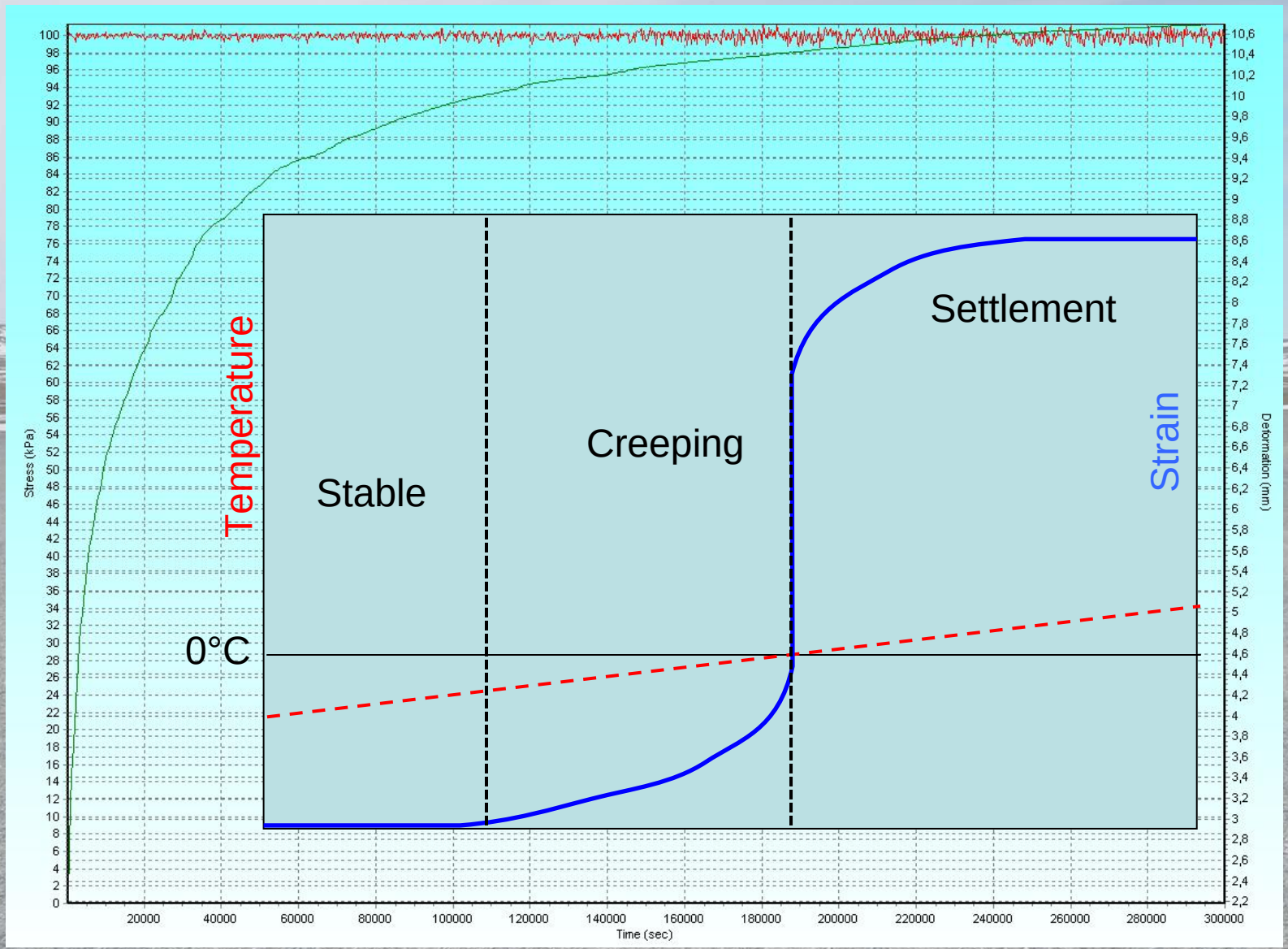
Information

- Characterisation of thaw sensitive soils
  - Drilling/sampling
  - Laboratory testing




IPC
UTM-100
Universal Testing Machine
Polystat

Mechanical behaviour of warming/thawing permafrost



Possible solutions

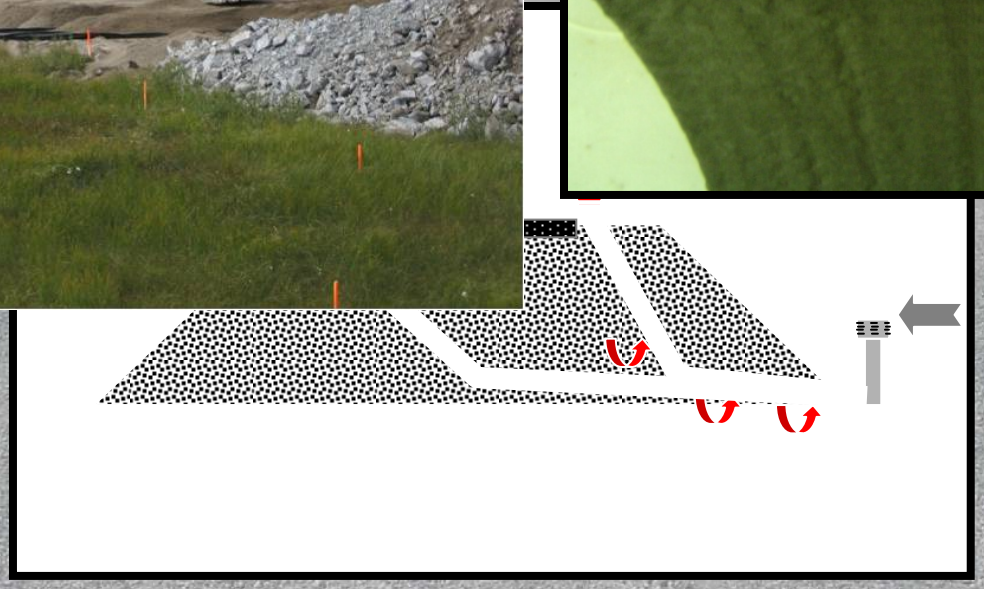
- Regular maintenance
- Intensive maintenance
- Controlled thawing/intensive maintenance
- Thermal stabilization
- Relocation of facility

Thermal stabilization

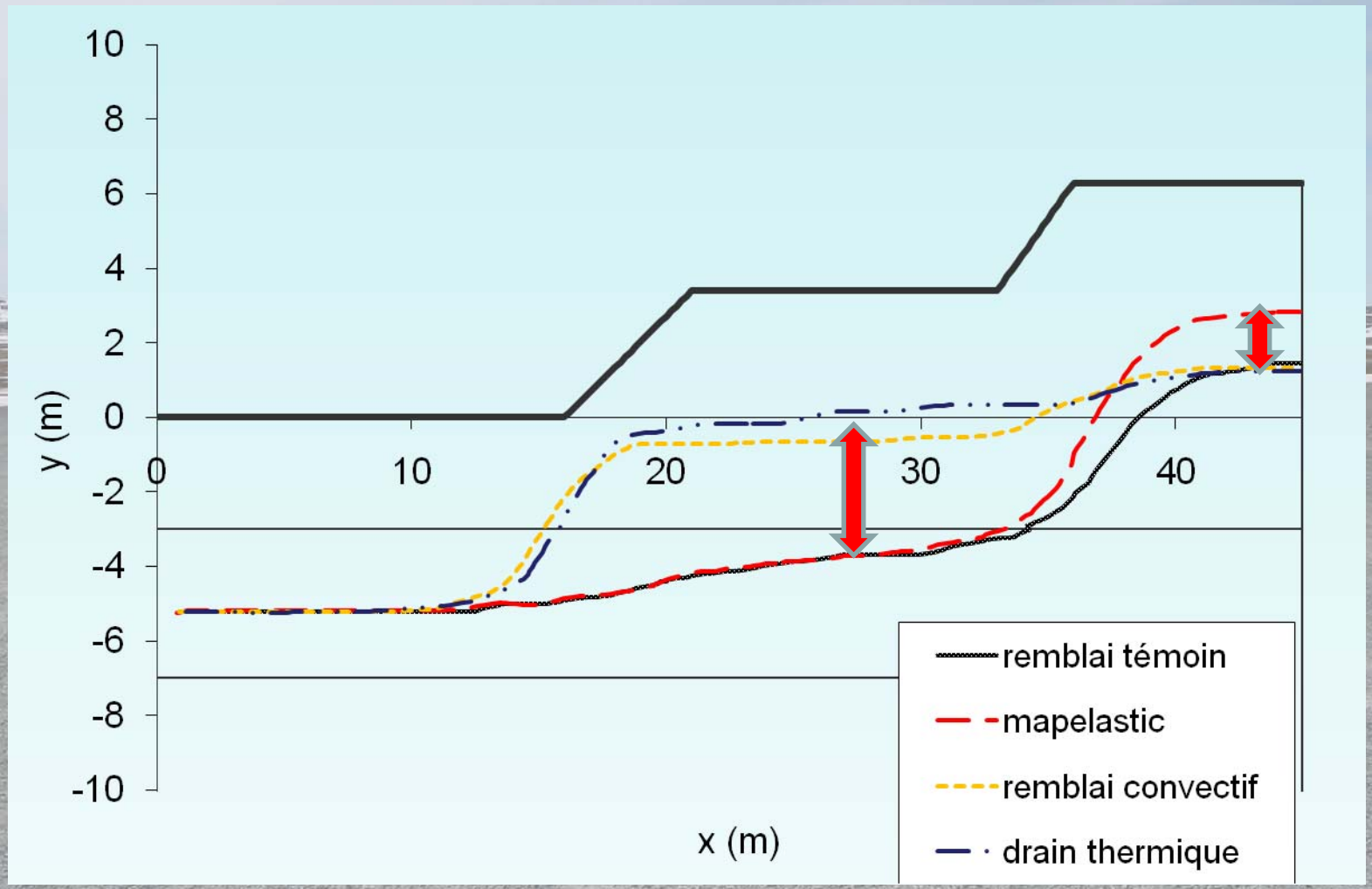
- Three possible approaches
  - Reduction of heat intake during summer
  - Increase heat extraction during winter
  - Embankment reinforcement

Reduction of heat intake: Clear coloured surfaces

Heat extraction: heat drain



Effectiveness assessment



Adaptation strategy

Gravel airstrip case

Settlement	Rate	Thaw Sensitivity	Position	Action
Yes	Slow	Low	Center	1
			Edge	1
		High	Center	1
			Edge	1 – 2 – 3 – 4
	Fast	Low	Center	1
			Edge	1 – 3 – 4
		High	Center	2
			Edge	2 – 3 – 4 – 5
No				1

1- Regular maintenance
2- Intensive maintenance
3- Slope correction
4- Drainage correction
5- Heat extraction (ACE / HD)

Conclusion

- Management of transportation infrastructures in Northern Canada is a challenge considering the rapid evolution of climate and permafrost condition
- Sound management requires information on the condition of infrastructure, on permafrost characteristics and on their evolution
- Cost effectiveness assessment of management strategies is difficult in the absence of reliable information on cost and effectiveness

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