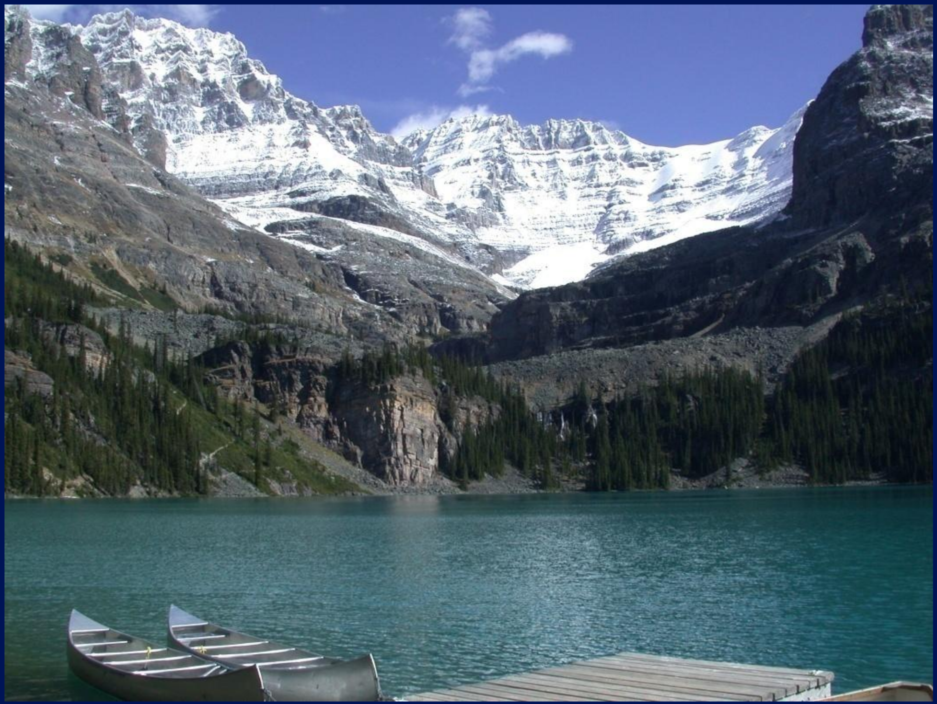
Alpine Hydrogeology: Storage and Flow of Groundwater in Moraine and Talus Deposits



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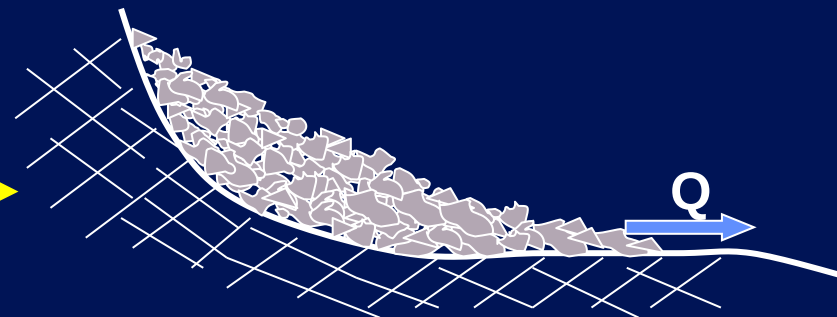
Dept. of Geoscience, Univ. of Calgary, Canada

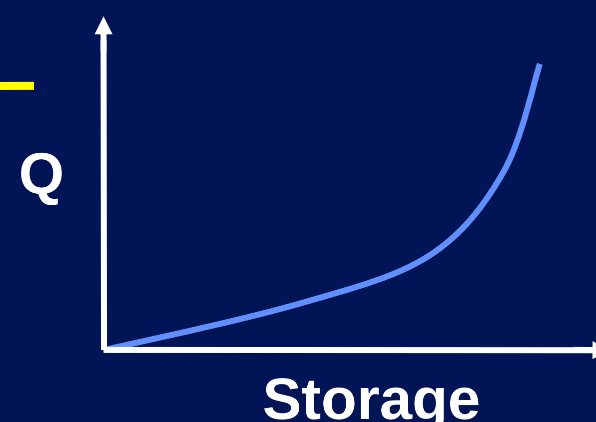
From Processes to Parameterization

field observation

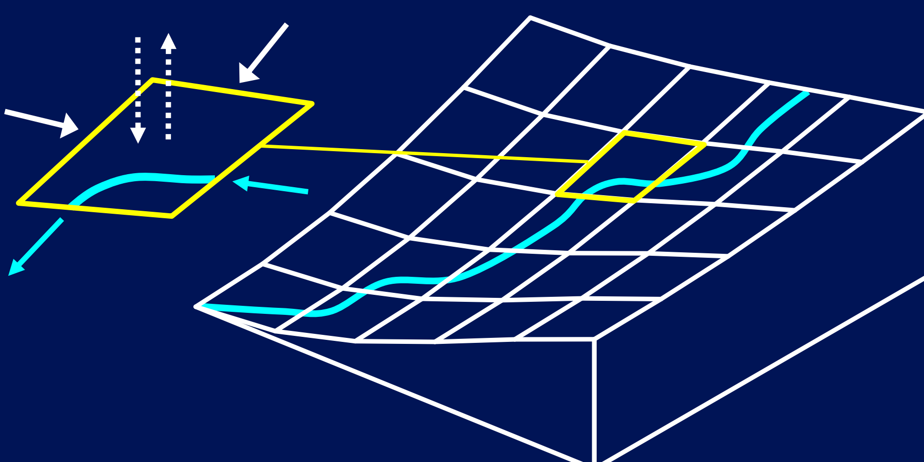
physically-based model



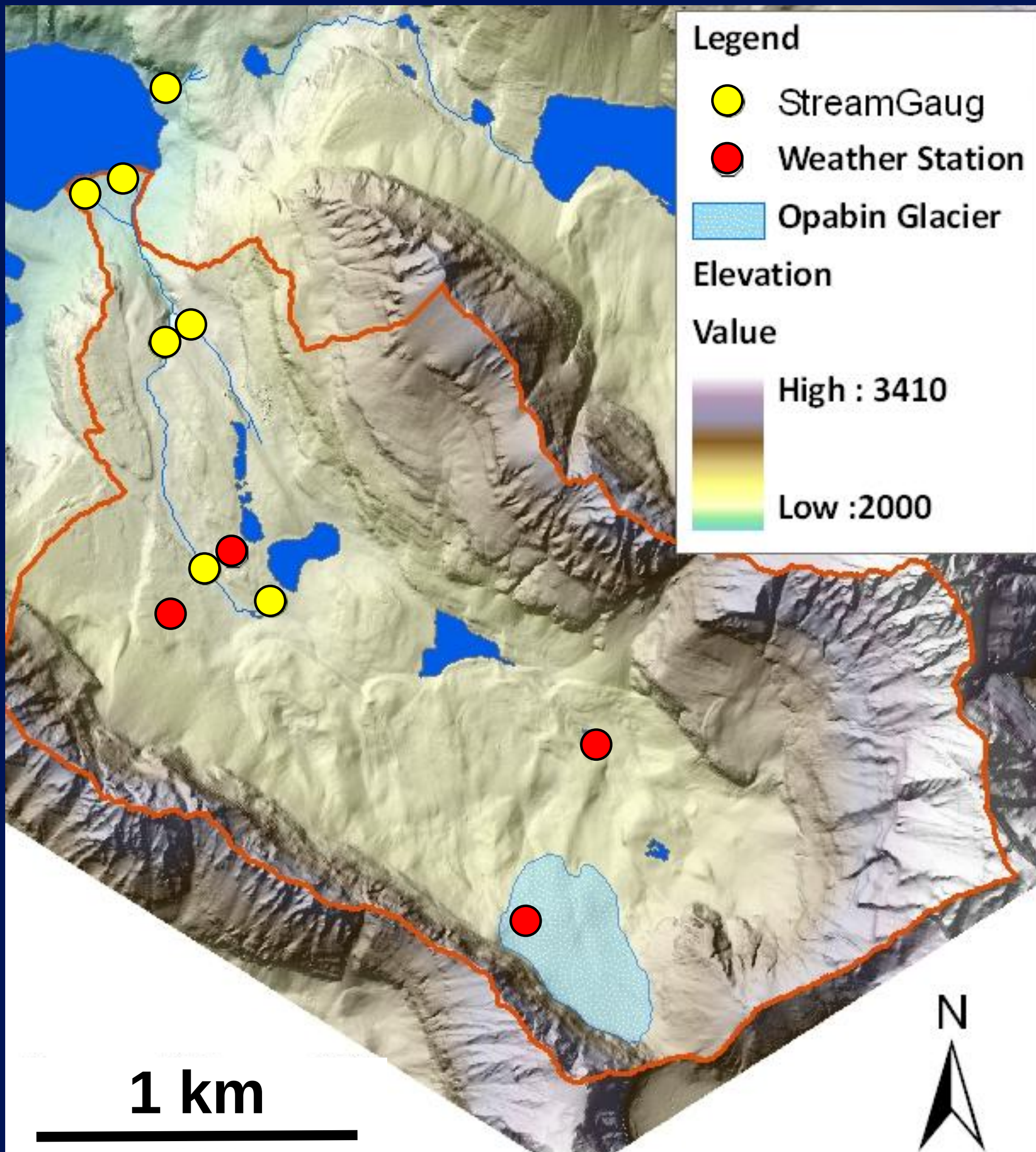
grid-scale function

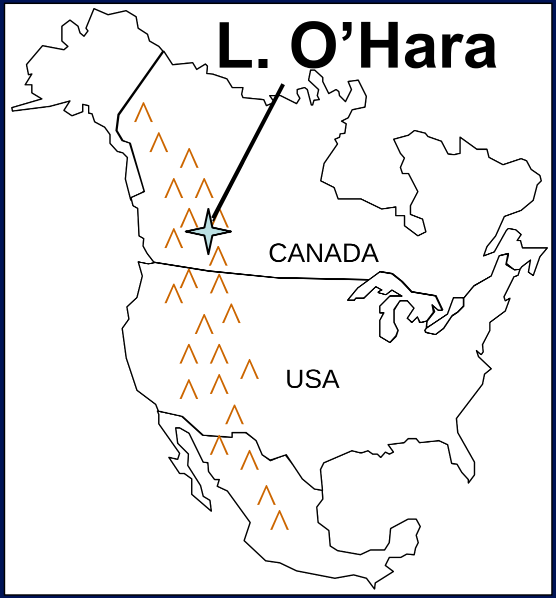


river-basin model



Opabin Sub-Watershed in Lake O'Hara Basin

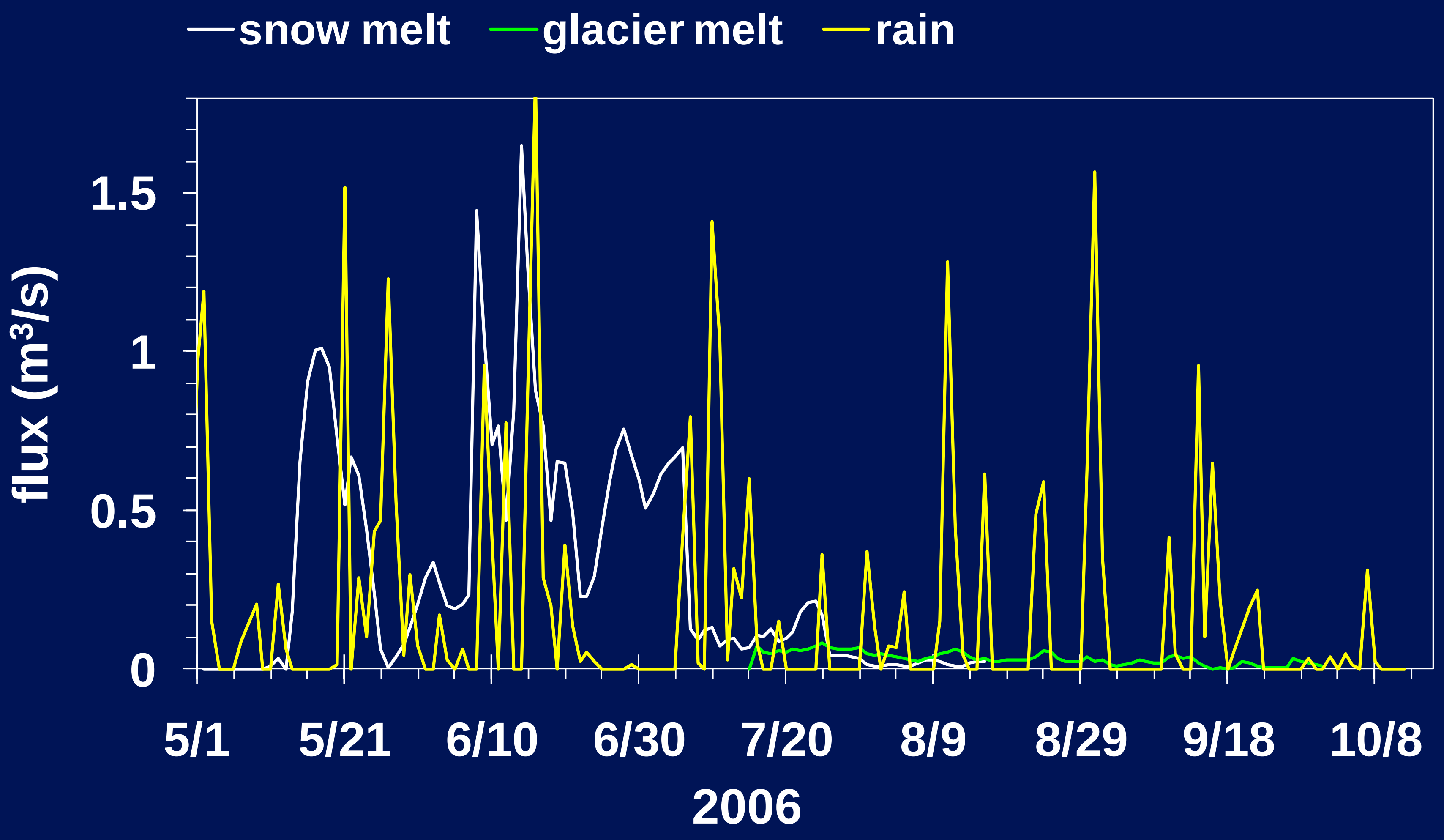




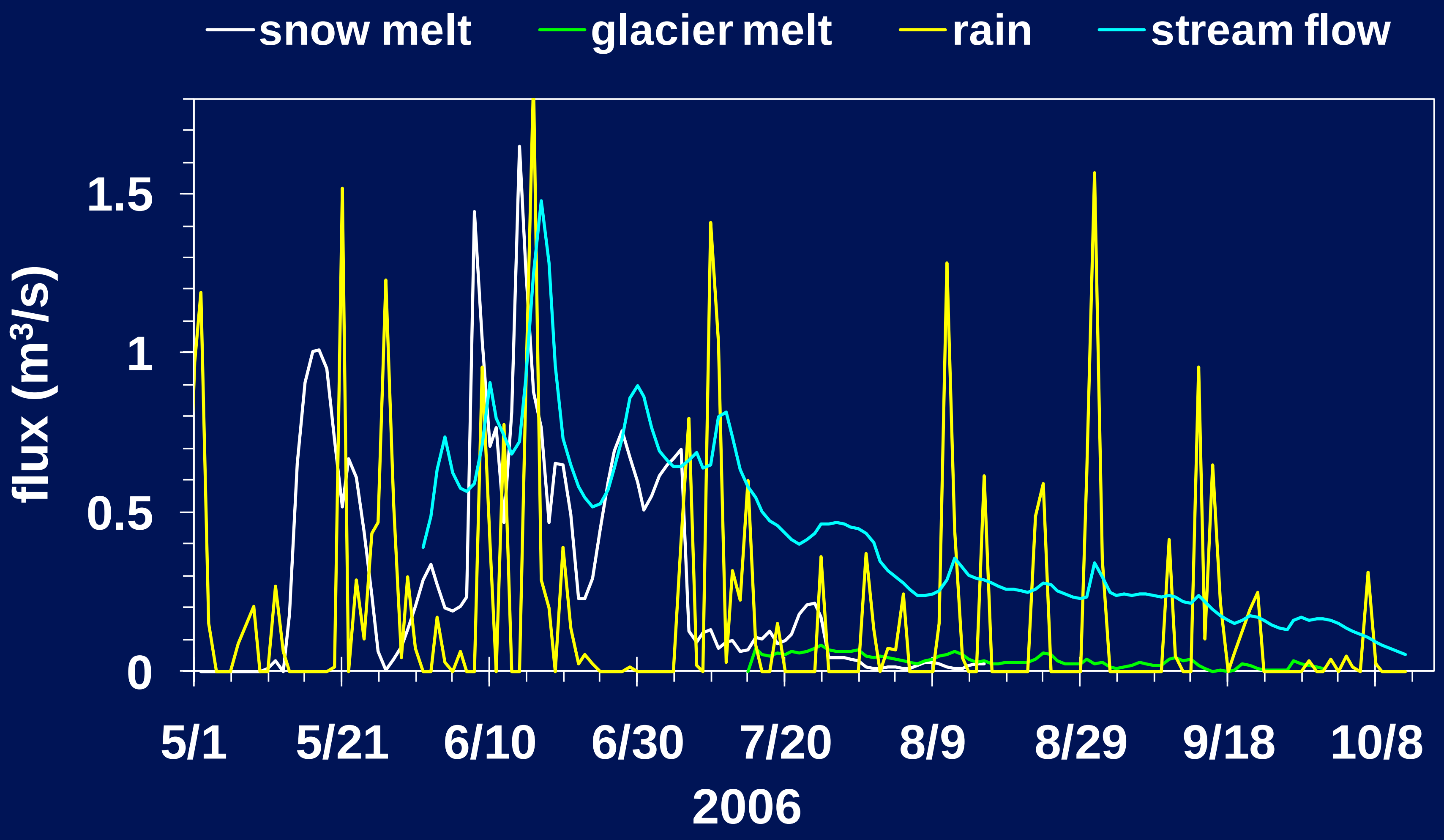
Hydro-meteorological instrumentation

Annual snow survey at peak accumulation

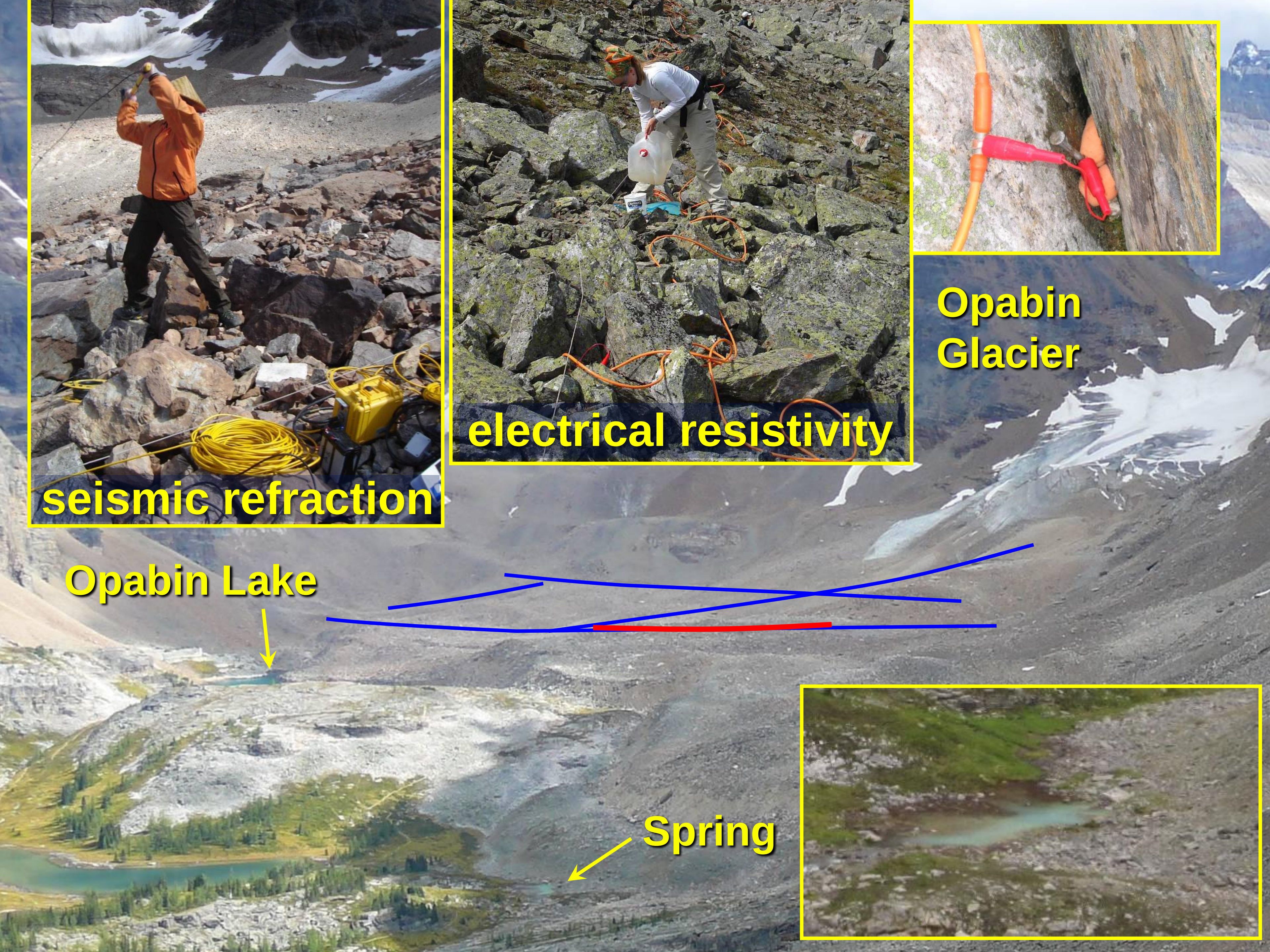
Water Input to the Opabin Watershed

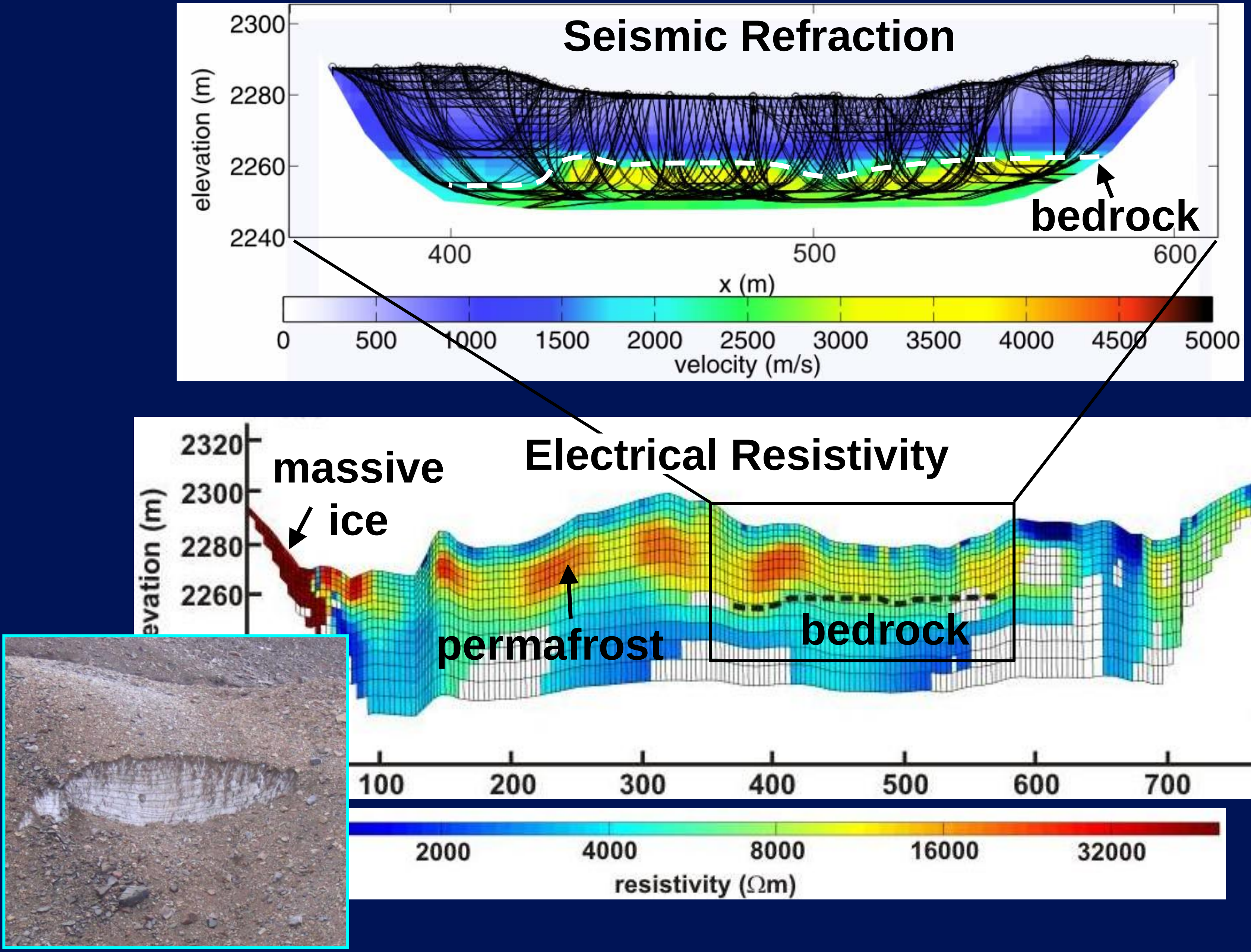


Water Inputs and outputs



Opabin Plateau

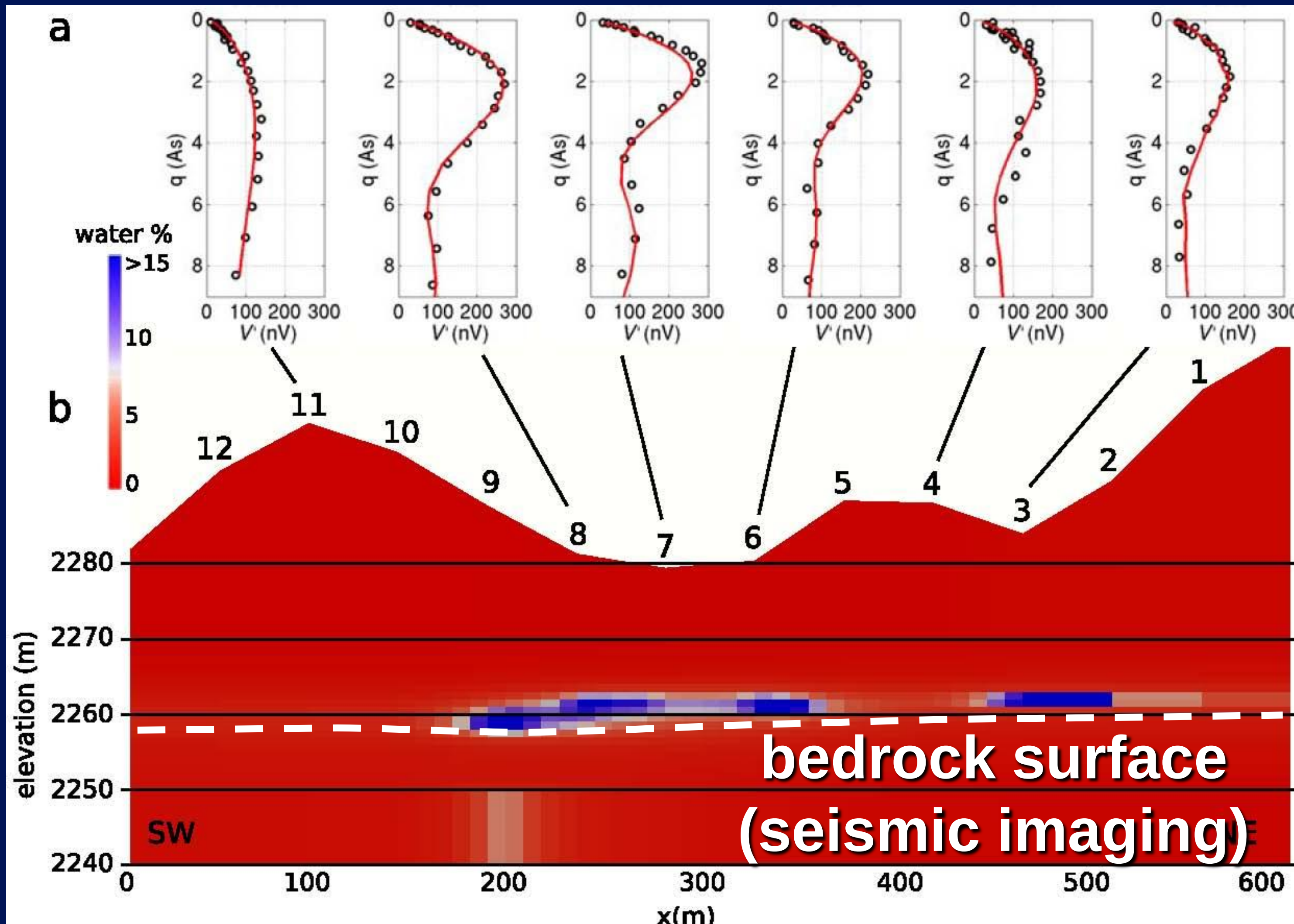

seismic refraction
electrical resistivity
Opabin
Glacier
Opabin Lake
Spring



Seismic Refraction
2300
2280
2260
2240
elevation (m)
400
500
600
x (m)
bedrock
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
velocity (m/s)
Electrical Resistivity
2320
2300
2280
2260
massive
ice
permafrost
bedrock
100
200
300
400
500
600
700
2000
4000
8000
16000
32000
resistivity (Ωm)

Nuclear Magnetic Resonance Imaging

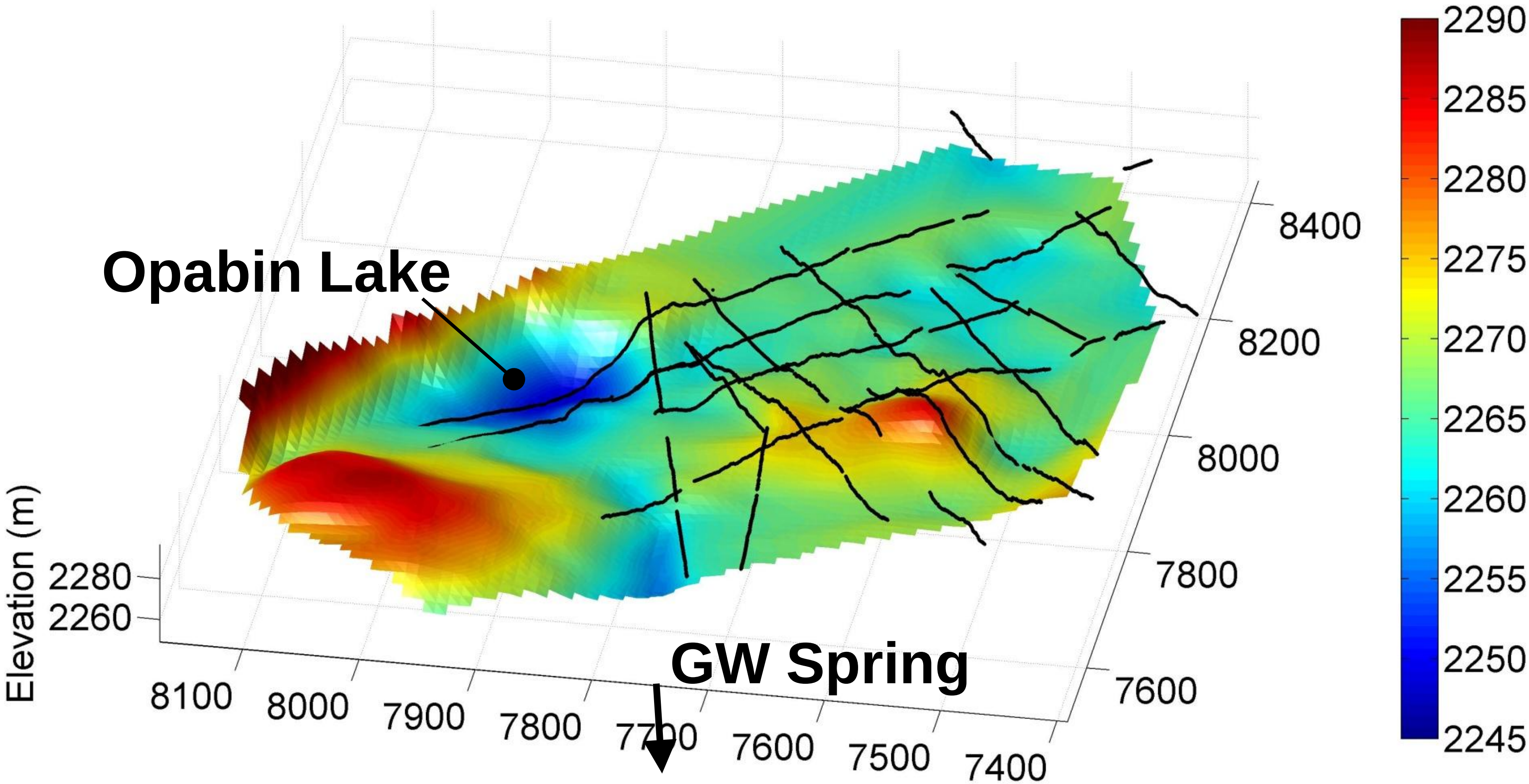
Blue colour indicates water molecules



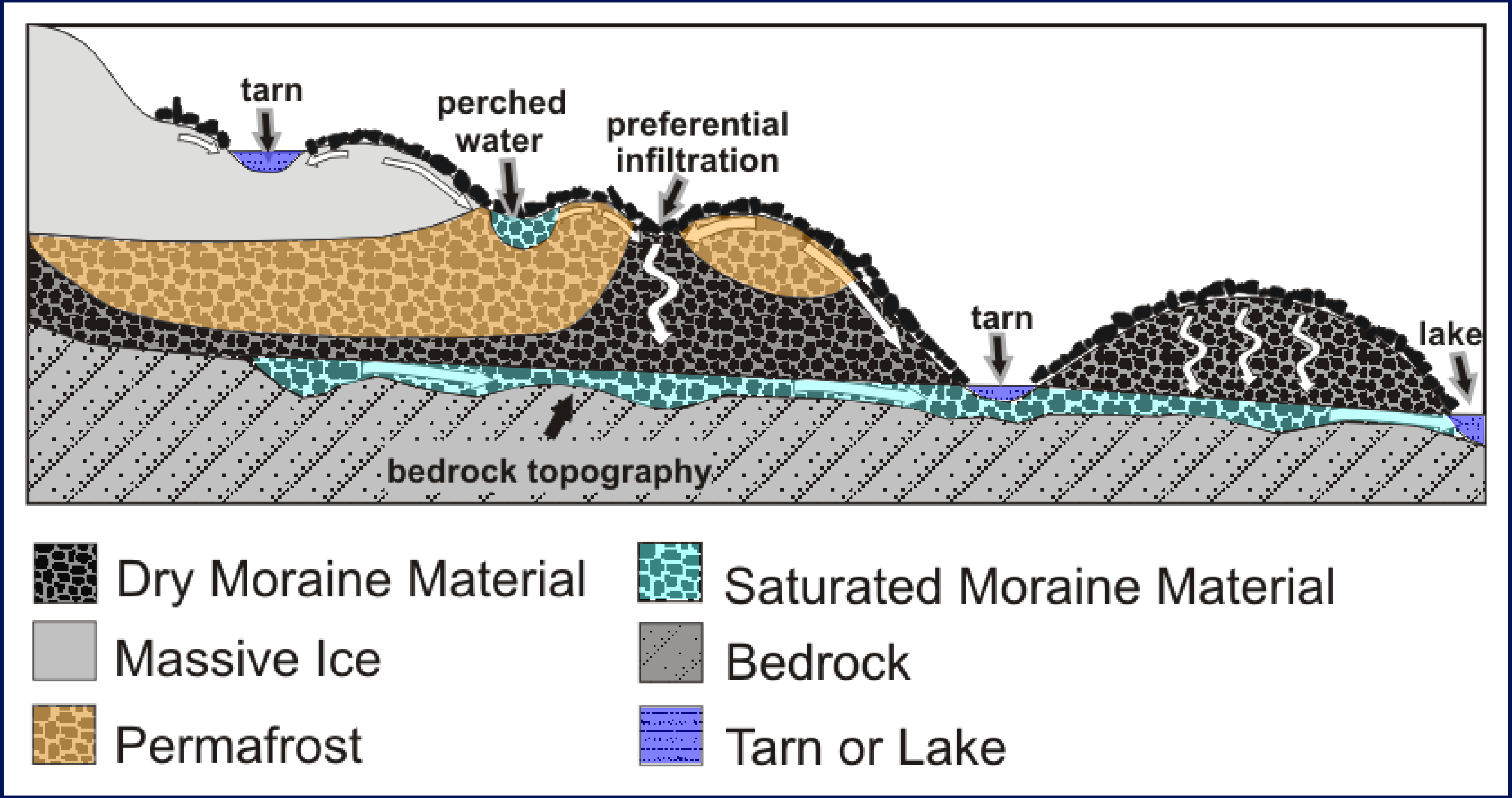
Lehmann et al. (2011. *J. Geophys. Res.*, in press)


Ground-Penetrating Radar
Opabin Glacier
Opabin Lake
Spring

Bedrock Surface Map from Radar Data

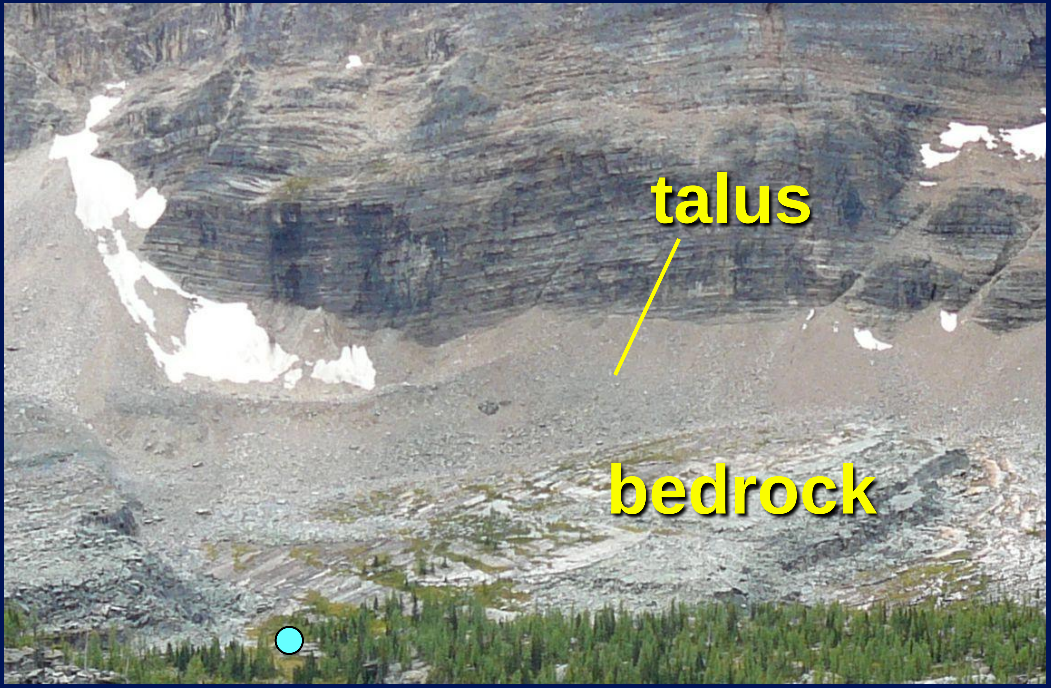


Emerging Conceptual Model



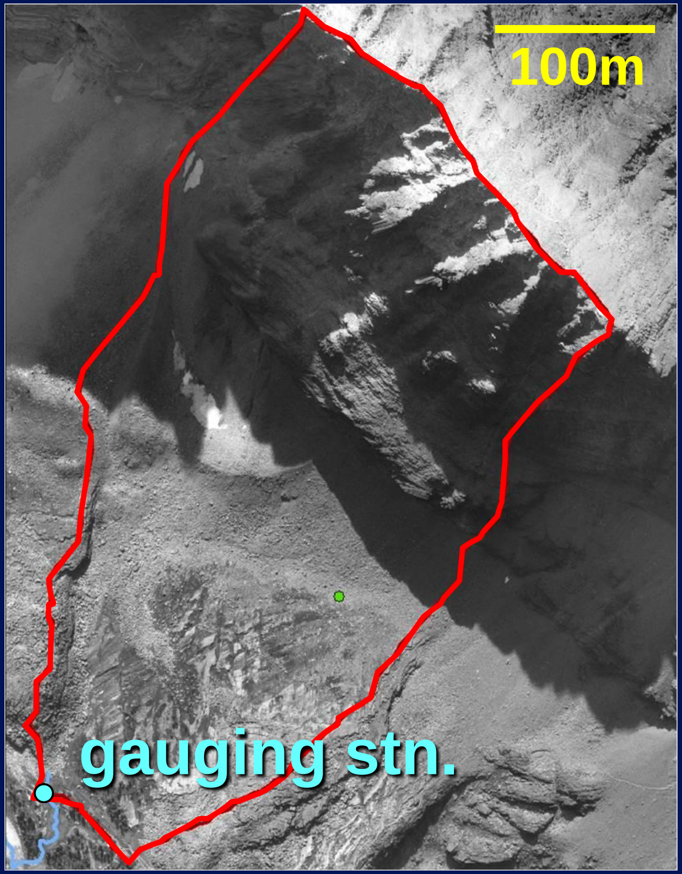
Langston et al. (2011, *Hydrol*. Process. 25: 2967)

Talus Covers 25 % of Opabin Watershed.



Gauging Station

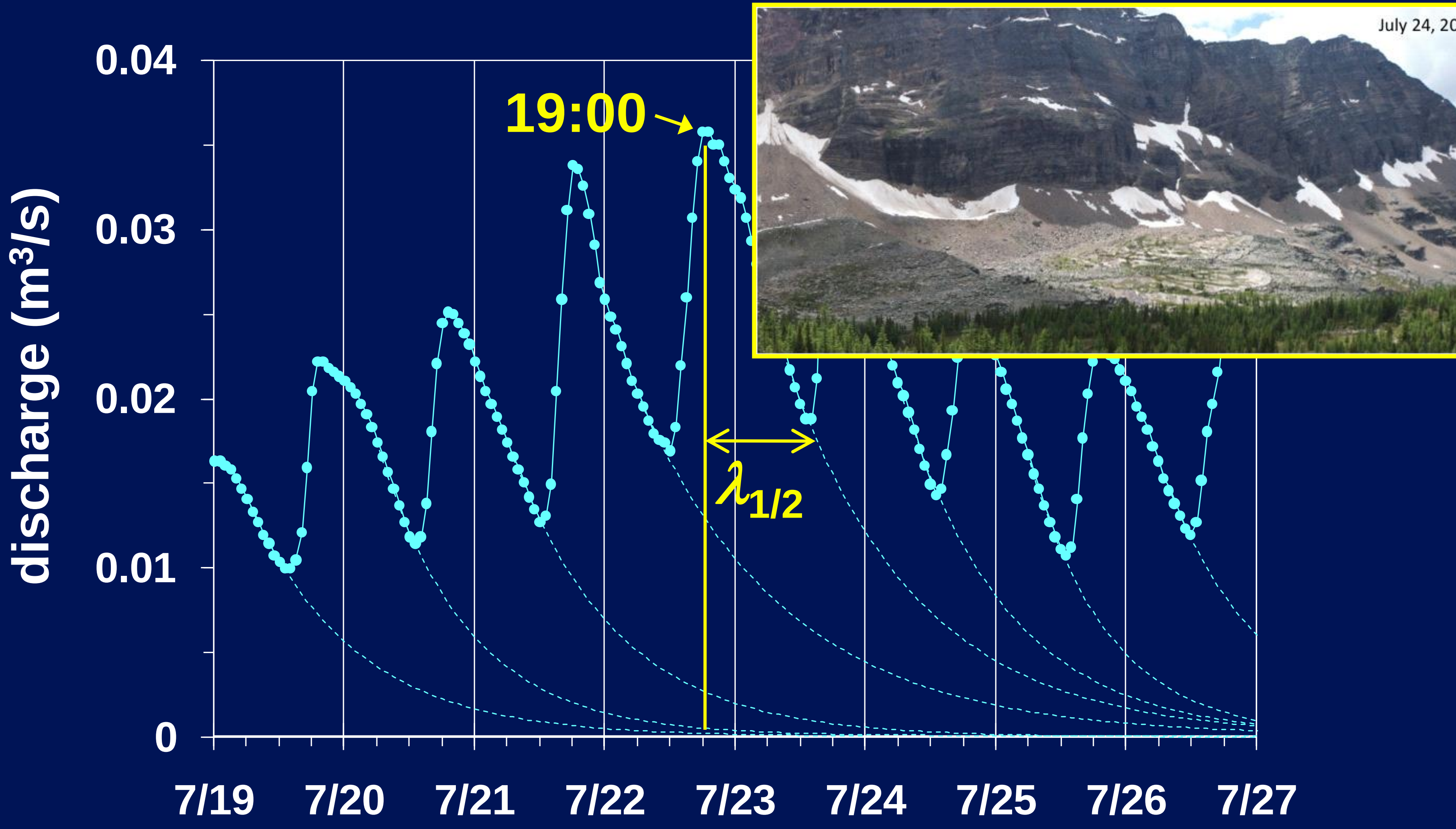
Babylon Catchment



Babylon Creek Discharge, 2008

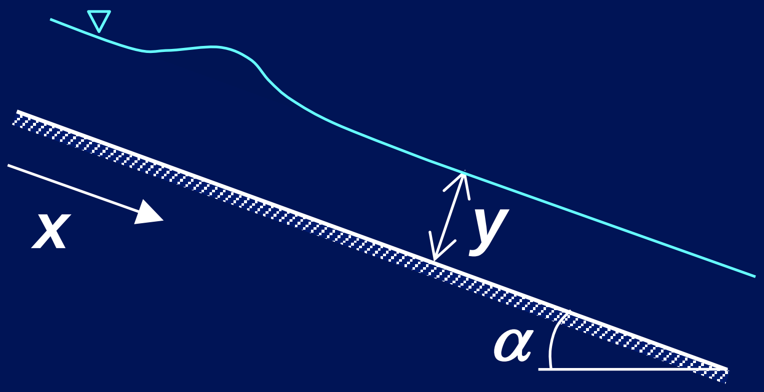
Diurnal fluctuations, peaking in early evening.

Half life ($\lambda_{1/2}$) of exponential decay < 1 day.



Hillslope Flow in Unconfined Aquifers

Brutsaert (2005) Approximation: Kinematic Wave



$$Q = Ky\left(-\frac{dy}{dx} + \sin\alpha\right) \cong Ky\sin\alpha$$

Q: flow per unit width (m^2/s)

K: hydraulic conductivity (m/s)

The pulse of water table travels like a wave.

$c = K \sin\alpha \,/\, n_e$

c: velocity of wave propagation (m/s)

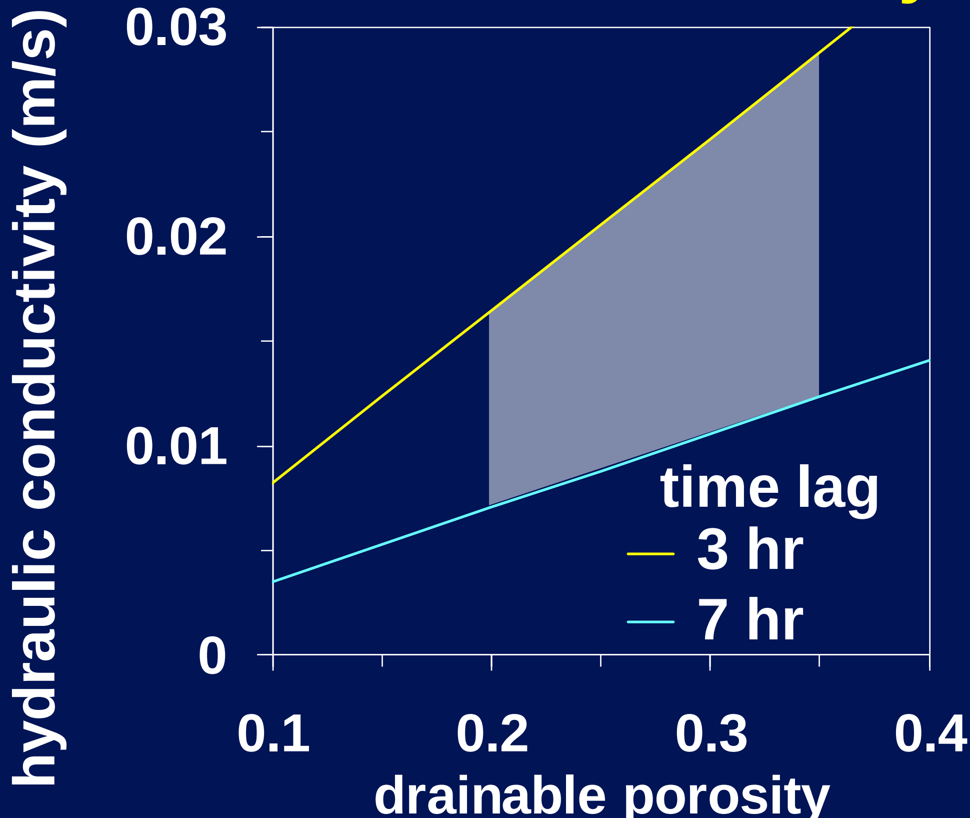
n_e: drainable porosity

Analysis of Babylon Hydrograph

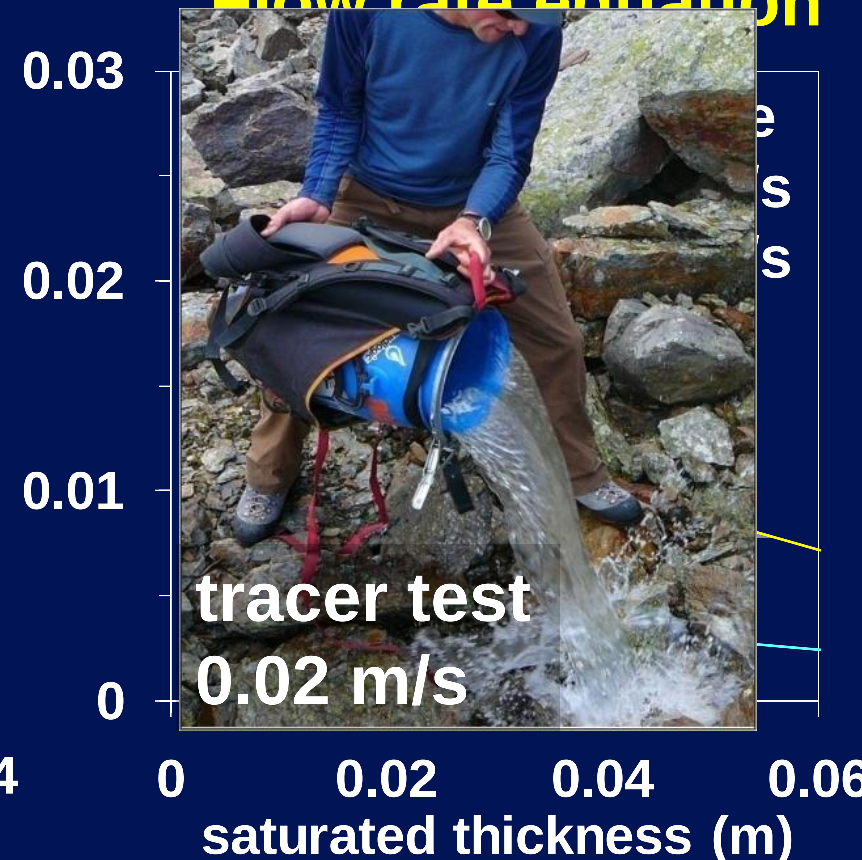
Peak discharge – peak snowmelt = 3 to 7 hrs

Flow rate ranged between 0.01 and 0.03 m^3/s

From wave velocity



Flow rate equation

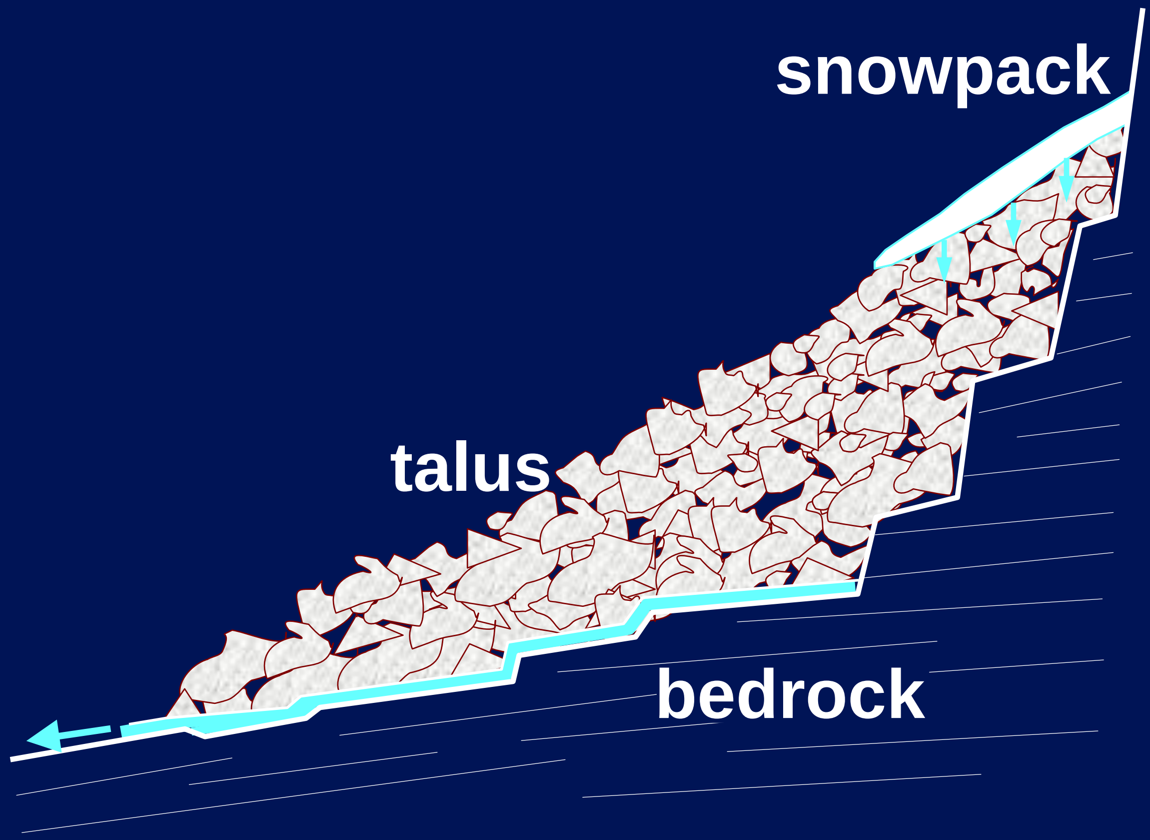


Conceptual Model of Talus Groundwater

Fast hydraulic response time (< 1-2 days).

Flow through a thin (< 0.1 m) saturated layer.

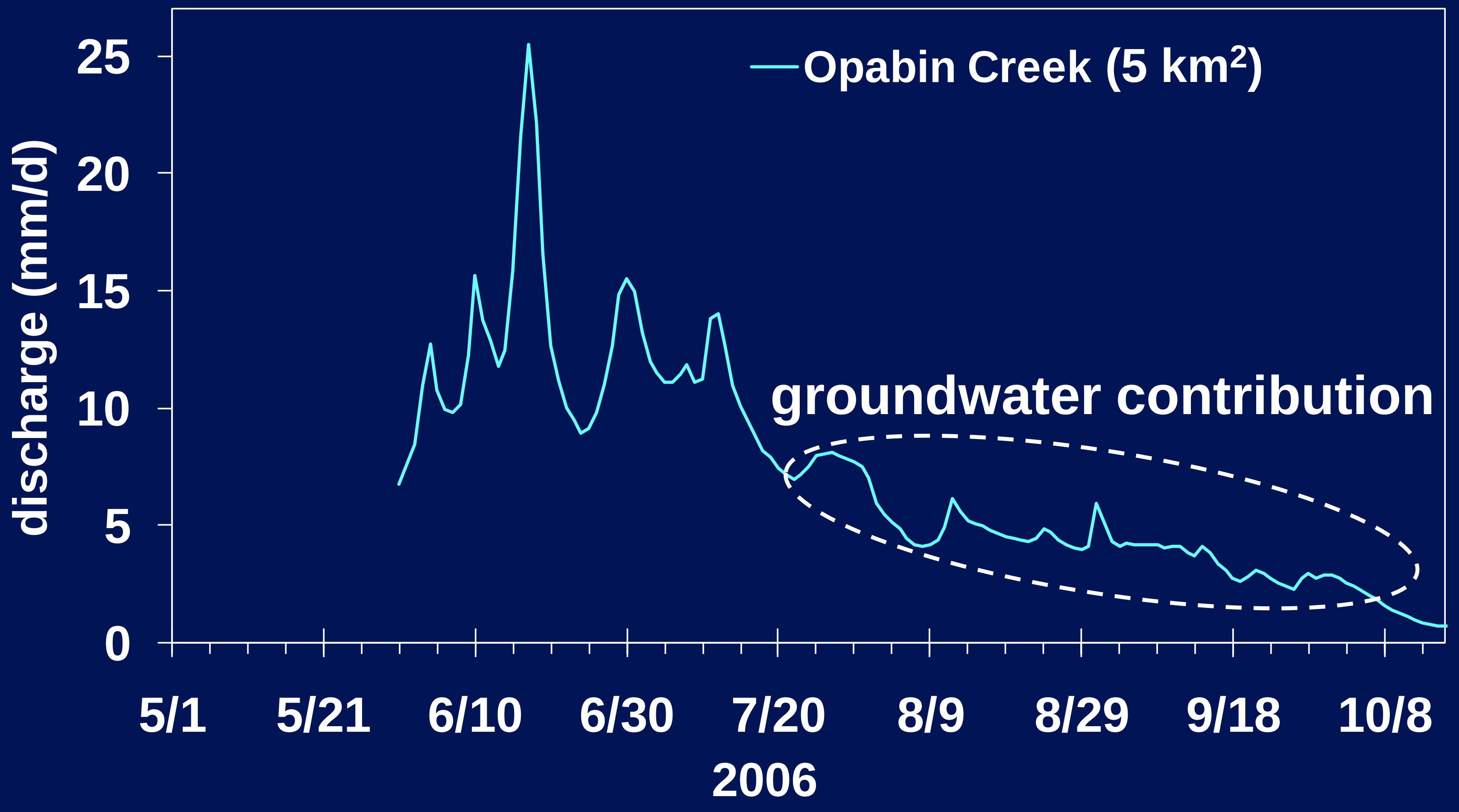
Late-lying snowpack – importance water source.



Muir et al. (2011, *Hydrol*. *Process*. 25: 2954)

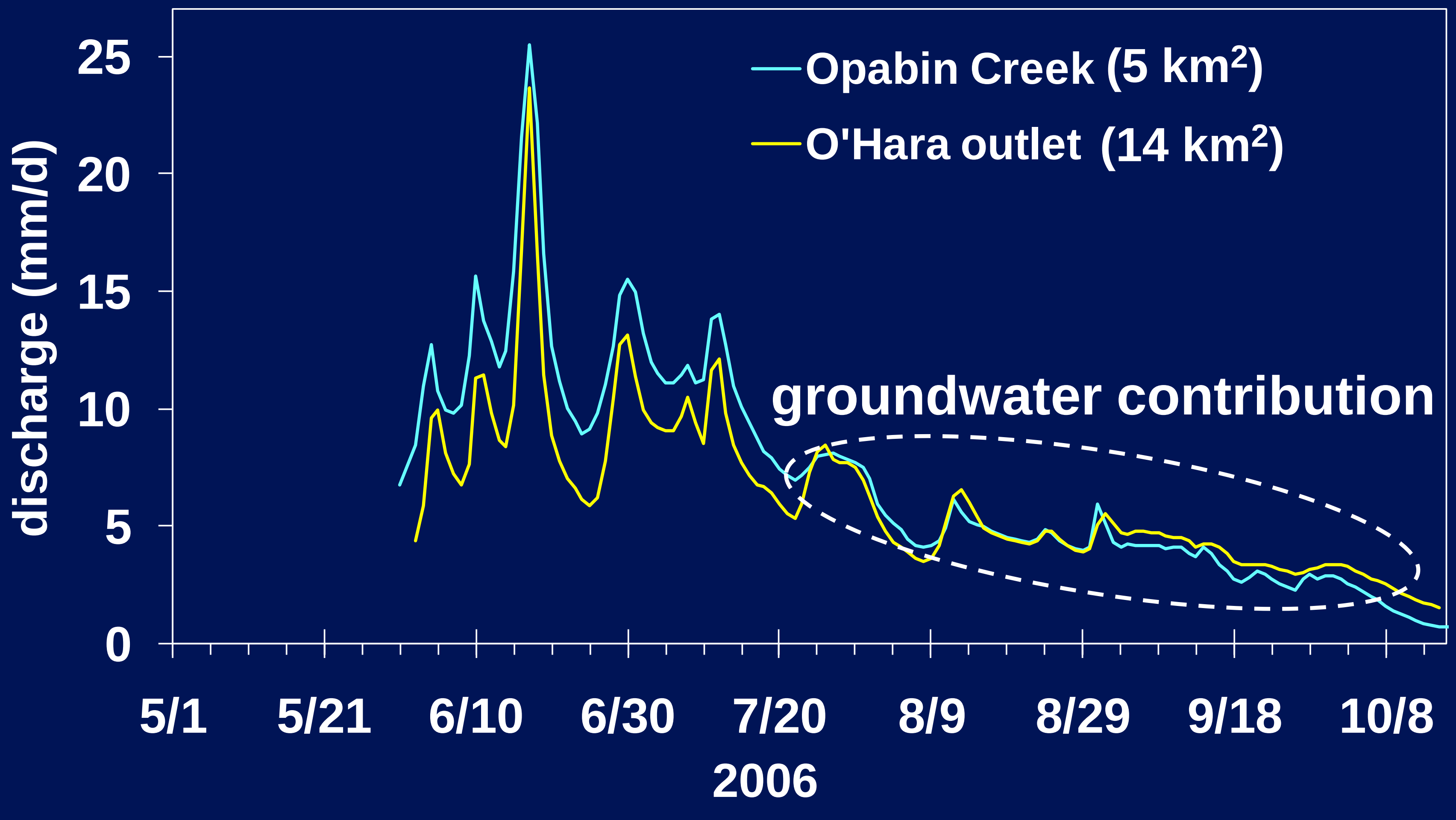
Normalized Stream Discharge

volumetric discharge / drainage area



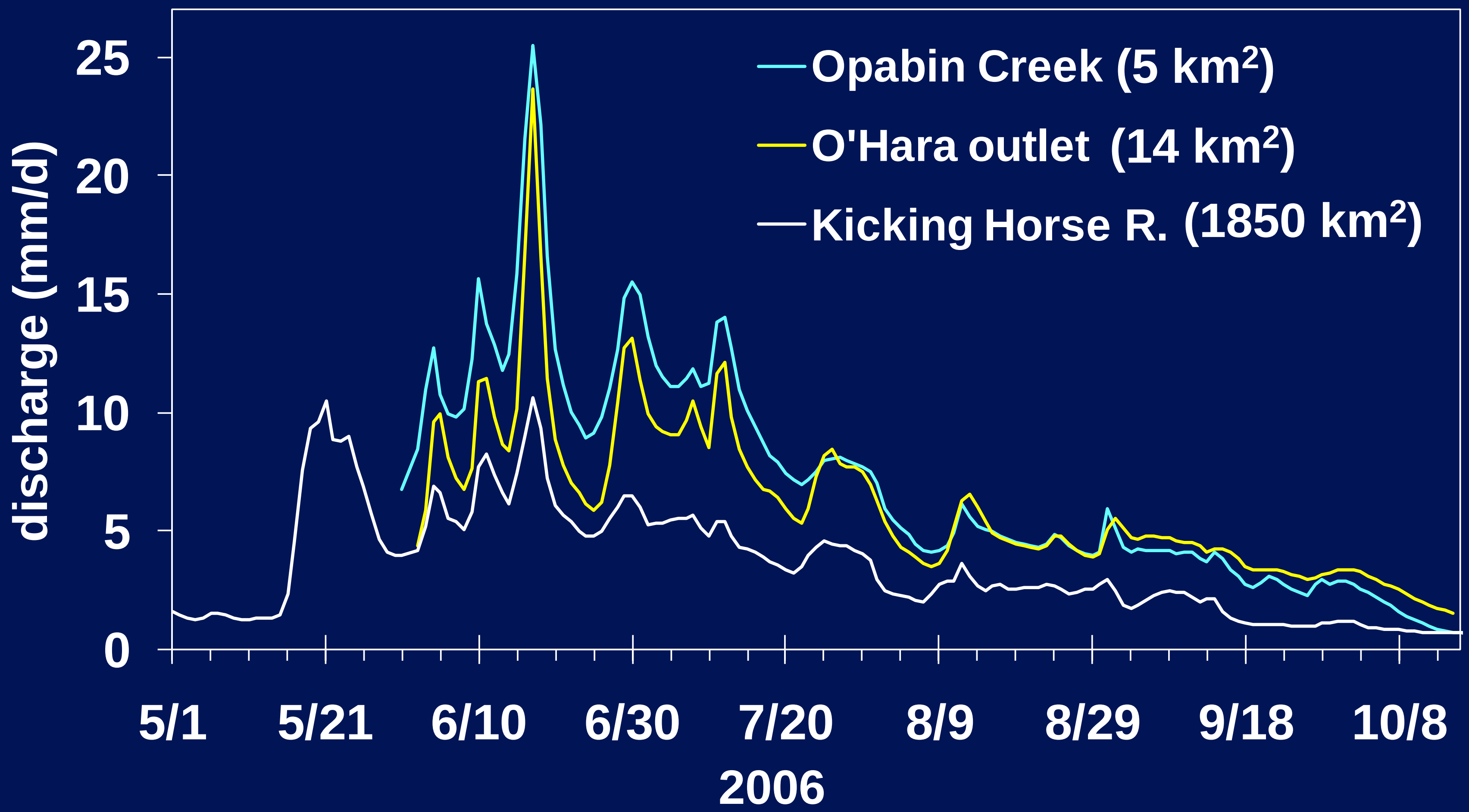
Normalized Stream Discharge

volumetric discharge / drainage area



Normalized Stream Discharge

volumetric discharge / drainage area



Challenges and the Way Forward

1. Turn the conceptual models into process-based numerical models (e.g. finite-element flow model).
2. Determine grid-scale (i.e. 10 km) parameters for river basin model (e.g. MESH).
3. Test the concepts and models in other basins.

IP3 Legacy

1. Lake O'Hara research basin for alpine studies
2. First Canadian study on alpine groundwater hydrology.
3. Hydro-meteorological database.

Acknowledgements

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