Hydrological Storage and Pathways in Alpine Headwaters: Lake O’Hara Study Update

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Unanswered Questions in Alpine Hydrology

• Where is groundwater stored?

• How large is groundwater storage?
  10 mm?  100 mm?

• How long is groundwater stored?
  days?  weeks?  months?

• How can these be represented in basin hydrology models?
Opabin Sub-Basin in Lake O’Hara Basin
Annual Snow Survey, April 16-21

1,200-1,500 depth measurements.

300-500 density measurements.
Snow Water Equivalent (SWE) Distribution

2009 SWE (mm)

1174

293

2007 SWE

0 250 500 Meters

2075 2125 2175 2225 2275 2325 elev. (m)
Remote Survey of Steep Slopes
Laser Range Finder: Poor man’s LiDAR

Validation Procedure
“Model” the depth distribution using Laser data. Measure the depth using conventional probes.

Results
Average measured snow depth = 1.74m
RMS error of modeled vs measured = 0.27m
SW Radiation: ArcGIS Solar Radiation Tool

Opabin AWS

E Tarn

Glacier

Babylon AWS

April 14, 11:00

Clear-sky radiation
Jul. 14, 11:00

SW Radiation 11:00 MDST
High: 1078
Low: 15
W/m²

July 14, 2008

Clear sky total
Observed
Diffuse

Radiation (W/m²)

0:00 6:00 12:00 18:00 0:00
Validation of SW Radiation: Babylon Site
Electrical Resistivity Results

Ice ridge

Tarn

Permafrost
Emerging Conceptual Model

- Dry moraine material (MM)
- Debris covered massive ice (MI)
- Degrading Permafrost (PF)
- Saturated Moraine Material (GW)
- Bedrock (BR)
- Wet Moraine Material (WMM)
Tracer Dilution Experiment, Aug. 2008

- 44 kg of NaCl released
- Concurrent energy-balance study
Estimation of Hydraulic Conductivity

- Use a 3D groundwater flow model, MODFLOW.
- Simulate the steady-state exchange of groundwater with the pond.
- Inverse determination of best-fit conductivity.

\[ K_{\text{sat}} = 2 \times 10^{-4} \text{ m/s} \]
Groundwater Storage and Flow in Talus

Gauging Station

Tracer tests

Babylon Creek

tracer tests
rain gauge
gauging stn.
Groundwater Storage and Flow in Talus

Preliminary Analysis

- Storage time in the talus is in the order of < 1 week.
- High hydraulic conductivity ($10^{-2}$ m/s) for loose sediments.
- Moderate conductivity ($10^{-5}$ m/s) for a second "reservoir" – fractured bedrock??
Coupled Surface-Groundwater Model

Daily snowmelt (mm) June 6, 2008

Hydrologic landscape units

Distribute water inputs.
Couple with GW flow model.
Simulate basin outflow.
HBV–MODFLOW for this example.
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