Imaging the Subsurface: The Effect of Logjams on Groundwater-Surface Water Exchange

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1. Introduction

Initiate: Analyze the effect of logjams on the extent of groundwater-surface water exchange for the first time in a field-setting, using electrical resistivity imaging, a two-dimensional geophysical technique.

1.1. Hyporheic Exchange

Hyporheic exchange (HE): the mixing of groundwater and surface water under and around a stream that contributes to water quality and ecosystem health. (Fig. 2)

Natural stream features alter the extent of HE: logjams increase hydraulic resistance, driving water deeper in subsurface

- sudden formation (floods, beavers) -> rapid stream alteration
- discharge (flow rate of water) may affect time spent in subsurface or residence time, RT

Low-flow may increase RT.

Longer residence time allows water to be processed by hyporheic exchange longer, increasing water quality.

1.2. Electrical Resistivity Imaging

Electrical Resistivity Imaging (ERI): geophysical surveying method that used to obtain two dimensional (2D) subsurface profile.

How it works:
- Electrodes placed across reach -> resistivity-meter sends current through cable (Fig. 5)
- Solution is injected in stream as a tracer -> subsurface data collection
- Raw resistivity is collected and used to calculate bulk/apparent resistivity, ρₐ:

  \[ \rho_a = \frac{R}{R_{resistivity}} \]

  Bulk resistivity: average resistivity of soils and rocks influencing current flow
  - Electrode spacing accounted for in geometric factor, K

  \[ K = \frac{2h}{3d} \]  
  \[ \rho_a = K \cdot \rho_{apparent} \]

  - Bulk vs. Fluid Conductivity: bulk measures heterogeneous subsurface while fluid represents homogeneous surface water.

2. Methods

Site Location: Northern Colorado, Little Beaver Creek

Salt used as tracer because it is conservative and conducive, making it easy to detect on a graph.

Equipment:
- Point-measurement: HOBO logger in stream
- ERI: Iris Syscal Pro (Fig. 6)
- Discharge: Velocity Flow Meter

Measurements taken at two reaches (logjam and control):
- Fluid Conductivity: point-measurement
- Discharge: Flow of June and July test date (Fig. 7)

Data processing: MATLAB

3. Results

Fluid vs. Bulk Electrical Conductivity (EC):
- Fluid has minimal tailing (Fig. 8A1)
- Bulk has substantial tailing (Fig. 8A2)
- Noise from fluid EC measurement

Control vs. Logjam:
- Logjam tailing slower return to background (Fig. 8B3)
- Control has slight bump after tracer ends (Fig. 8C4)

Flow:
- Low-flow injection slower return to background (Fig. 8B3 vs. Fig. 8D5)

4. Discussion

June high-flow due to snow-melt

Due to increase in hydraulic resistance, logjam reach implies slower movement in the subsurface.

Results show flow rate influences rate of solute discharge.

Low-flow and logjam: may indicate longer residence time, meaning more filtration.

5. Conclusions

- Logjams increase the extent of hyporheic exchange due to an increase in hydraulic resistance. Longer residence times may occur when flow is low and in the presence of logjams.

- ERI is demonstrated to show a more accurate representation of the subsurface, unlike fluid EC, where noise was abundant.

Acknowledgements:
Thank you: ABSTRACT, Melissa Weber, Nadine Reitman, Rolf Nagaard, Emily Fairfax, Megan Brown, UNAVCO employees and UNAVCO interns for their guidance, encouragement, and support.

REFERENCES
3. Teodora Mitroi, Teodora Mitroi, Jackie Randell, Megan Doughty, Kamini Singha, UNAVCO employees and UNAVCO interns for their guidance, encouragement, and support.
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