Watershed Structure and Stream Network Geometry: Implications for Water and Solute Transport

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How quickly do water and solutes move through a watershed?

- If a pollutant was spilled in a watershed, how long would it take to flush out?
- Redistribution in the uplands
- Routing in the channel network

How do watershed structure and stream network geometry combine to influence travel times to the watershed outlet?
So, what do we need to know to calculate travel time?

• How much water is entering where?

• How far does it have to travel?

• How fast is it traveling?
Study Watersheds
- Sawtooth Mountains, ID

Alturas
Area: 63 km²

Stanley
Area: 33 km²

Yellowbelly
Area: 27 km²

Pettit
Area: 23 km²

Hellroaring
Area: 15 km²

Bull Trout
Area: 14 km²
Watershed Structure
- Upslope Accumulated Area

- UAA - the watershed area draining to a point in the watershed

- Indicates areas of topographic convergence/divergence
How much water is entering where?
- Local Inputs

- The watershed area contributing directly to each stream reach/pixel

- Represents the distribution of water delivery to the stream network

Alturas, Stanley, Yellowbelly, Pettit, Hellroaring, Bull Trout

Ln(UAA) scale:
- 5 large
- 0 small
Stream Network Geometry
-Distance from Outlet

DFO- Stream network distance from the watershed outlet
How far does it have to travel?
- Travel Distance Distributions

**Alturas**

**Stanley**

**Pettit**

**Yellowbelly**

**Hellroaring**

**Bull Trout**
The effect of bifurcation on stream network distribution

As bifurcation increases, the pdf of stream network DFO approaches an exponential distribution.
Travel Distance Distributions

![Alturas](image1)

![Yellowbelly](image2)

![Percentage of Network](chart1)

Distance from Outlet (km)

Percentage of Network

Alturas

Stanley

Pettit

Yellowbelly

Hellroaring

Bull Trout
How fast is it traveling?

- $Q \rightarrow V$

Local inputs dictate increases in contributing area

Once we’ve estimated $Q$, we can calculate velocity for every stream reach
Calculating Travel Times
- Model Framework

• Weighted Inputs - how much water is entering where?

• Distribution of travel distances - how far does it have to travel?

• Variable Velocity - how fast is it traveling?

= Travel Time Distributions
Putting it Together
- Travel Time Functions

Proportion of Discharge vs. Travel Time (hours) for:
- Alturas
- Stanley
- Yellowbelly
- Pettit
- Hellroaring
- Bull Trout
Comparison of modeled travel times to distance from headwaters

- Steeper slope $\rightarrow$ slower velocity
- Main line = main stem
- A range of travel times at a given DFO

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<th>Blt</th>
<th>Bull Trout</th>
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<tr>
<td>Pet</td>
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<td>Hrg</td>
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How did we get those travel time distributions again?

• How much water is the network receiving and where?

• How far does it have to travel through the network to the outlet?

• How fast is it moving in the channel network?
Implications

• Describes network travel times of water and associated solutes
  • Nutrients
  • Pollutants
  • Sediment

• Can be coupled with other analyses

• Easy to apply to any watershed
Thanks everyone!
Questions?

**Related Presentations:**
Session 8, 10:30:

Session 8, 10:50:

**MSU Hydrology:**
watershed.montana.edu/hydrology