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Water Balance and Residence Times in Stream Functional Units of Differing Scales

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Question

How is the water balance of a stream reach related to valley structure?

Hypotheses

- Gross reach gain is proportional to terrestrial contributing area due to hillslope watershed contributions.
- Gross reach loss is proportional to riparian contributing area due to channel-riparian hydraulic exchange.

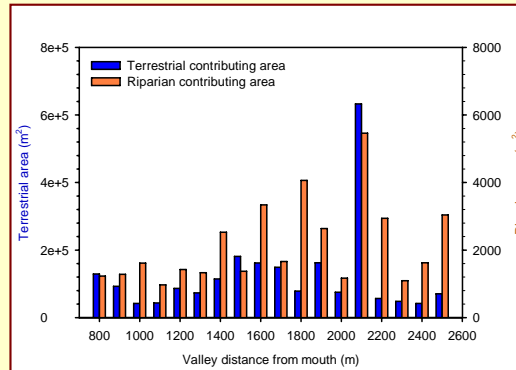
Site background



Tenderfoot Creek Experimental Forest, Montana, USA

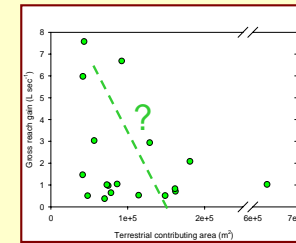
- Stringer Creek, study segment from 800-m base to 2600-m head in valley distance from mouth
- Tracer work completed 4-6 August 2005, low base-flow conditions
- Discharge was 22 L sec⁻¹ at the base and 3 L sec⁻¹ at the head of study segment

Contributing areas to stream reaches

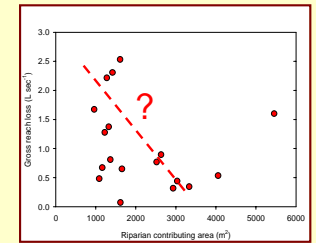


Comparisons

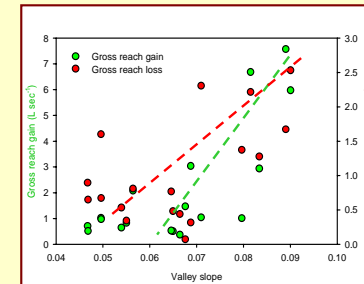
Gross reach gain vs. terrestrial contributing area



Gross reach loss vs. riparian contributing area



Gain & loss vs. valley slope



- Contributing area comparisons do not support hypotheses and are not an intuitive pattern.
- Valley slope may be an alternative predictor of gain or loss.
- Slope is from survey data because patterns are not evident using DEM data (not shown).

Measuring the water balance

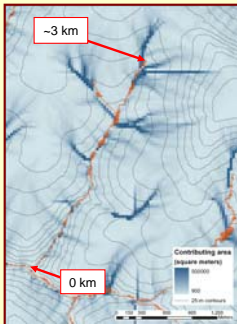
$$\text{DISCHARGE AT HEAD} + \text{NET GAIN} = \text{DISCHARGE AT BASE}$$

$$\text{NET GAIN} = \text{GROSS GAIN} - \text{GROSS LOSS}$$



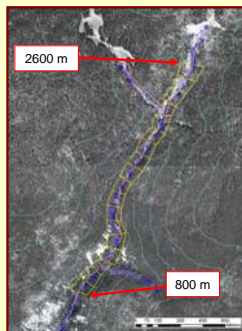
- Reach flow measured by dilution gauging with chloride tracer slugs
- Net gain calculated by upstream to downstream difference
- Gross loss inferred from upstream slug mass recovery at base of reach
- Gross gain calculated as net gain plus gross loss

Valley terrain analysis



Calculating terrestrial and riparian contributing areas

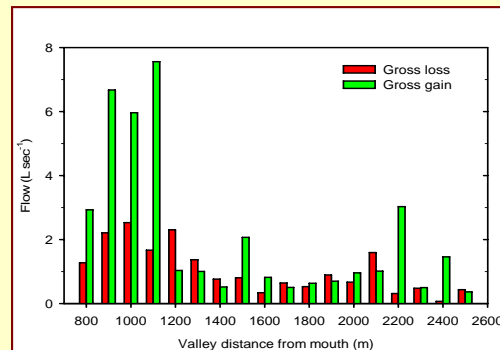
- Topographic analysis of digital elevation models (DEM)
- Blue is terrestrial contributing area, which excludes any upstream contributing area
- Orange is riparian area less than 1-m above channel elevation



Aggregating stream data

- Blue is total terrestrial contributing area for the stream channel
- Orange is riparian contributing area for the stream channel
- Yellow polygons represent reaches where water balance was measured
- Contributing areas were summed over these reaches

Gross reach gains and losses



Conclusions

- Terrestrial and riparian contributing area from this terrain analysis did not intuitively predict the gain and loss of the stream.
- Valley slope may have predicted gain due to channel intersection of longitudinal valley "underflow" flow paths.
- Valley slope may have predicted loss due to hydraulic gradients driving subsurface flow paths.

Future research

- Valley slope should be considered in future hypotheses
- Better quality DEM and spatial data from LIDAR are pending and may be necessary for these terrain analyses
- More stream gain/loss data at various hydrologic conditions
- Detailed analysis and modeling of stream solute transport in the valley context

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