Quantifying Measurement Error for Accurate Testing of Channel Cross-section Change

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Introduction

Channel change over time is frequently assessed using cross-section variables like area or hydraulic depth. Despite the popularity of this approach, there is little guidance available on how to statistically test whether the measured change for a given variable is real or the result of imprecision in the measurement process (a.k.a., "measurement error").

Conceptual Approach

If the measurement error can be estimated, then a t-test can be used to determine whether the observed change is sufficient to conclude that it is not just the result of measurement error.

$$t = \frac{(x_2 - x_1)}{sem}$$

where x_2 = the cross-section variable measured at some later time; x_1 = the value at some earlier time, and *sem* is the standard error of the mean associated with the measurement process used.

If a cross section was surveyed twice during a visit (producing "replicate" samples), then the *sem* for each cross section can be estimated from

$$sem_i = \frac{s}{\sqrt{n}}$$

where n = 2 for two replicates; and s = the standard deviation based on the two measures of the given variable at each cross section, i.e.,

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

where x_i = the ith value of the cross-section variable; and $\bar{x}$= the mean of the two measurements.

If several replicate surveys are done, then for each variable of interest, the *sem* values can be summed for all paired cross sections and a mean *sem* computed. The mean *sem* would represent the measurement error for that variable as determined using the same survey method in channels with similar geometry and bed material characteristics.

Objectives

•Quantify the measurement error (*sem)* associated with the rod-and-level survey method (Harrelson and others 1994) using the approach described above.

•Assess how measurement error is affected by the number of measurements made and the cross-sectional area of the channel.

•Demonstrate how the method can be applied.

Methods

Data were obtained from three headwater channels within the Ouachita Mountains of Arkansas. Cross-section widths varied from 3 to 23 m, channel gradients varied from 3 to 13 %, and typical bed material D_{50} was about 90 mm. Flows are ephemeral to intermittent with $Q_{2.33}$ for the one gauged basin being 560 L/s (20 cfs).

Twelve cross sections within each channel were randomly selected. The selected cross sections were surveyed twice, with the second survey being done immediately after the first.

Cross-section Measurement Specifications

•Equipment used: autolevel, telescoping survey rod, rod level, and 30-m nylon tape.

•Measurement precision: nearest 3 mm (0.01 ft).

•Nylon tape stretched taught across the section (no sag correction was used).

•All depths measured vertically against the tape on the upstream side.

•Depths measured at each "significant" slope change within the cross-section (rod person choice).

•After the first survey, the tape was left in place, crew members changed jobs, the survey was repeated, and depth locations were chosen independently of what positions were used previously.

Cross-section variables were computed using WinXSPro (West Consultants 1996). The variables chosen were cross-sectional area, wetted perimeter, and hydraulic depth. These were computed relative to the lower of two permanent steel pins marking the cross-section ends.

Results

The *sem* values are not normally distributed; rather there is a predominance of small values and just a few relatively large values. Log-transformation of the data produces a distribution closer to normal, but still somewhat skewed right (see Fig. 1).

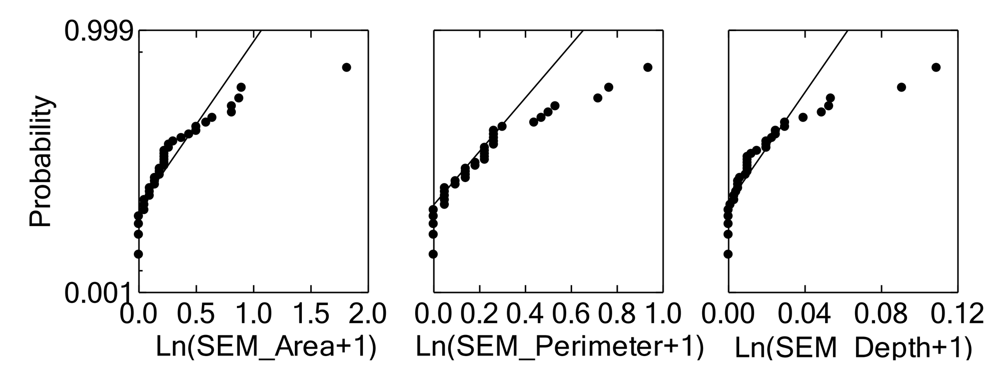

Figure 1. Normal probability plots of *sem* values for cross-section variables.

Results (continued)

Effect of Number of Measurements

The magnitude of the *sem* value is not correlated to the number of measurements made during the surveys. The apparent relationships are plotted in Fig. 2, but the weakness of these relationships is evident in the correlation statistics.

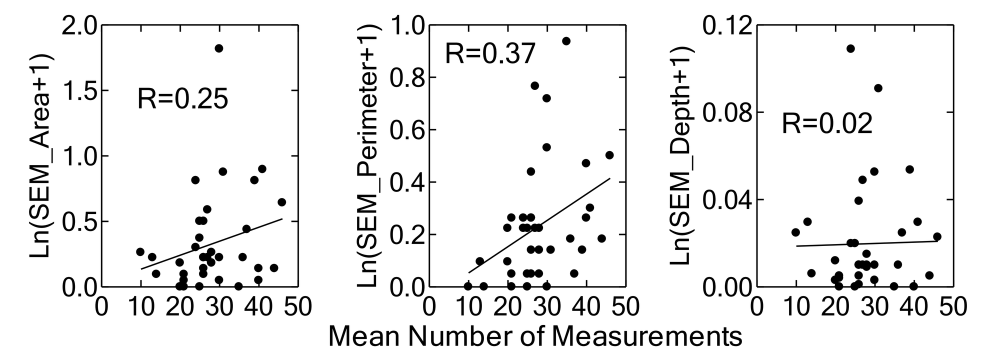

Figure 2. Relationship between number of measurements per cross-section and sem values for cross-section variables.

Effect of Channel Conditions

The magnitude of the *sem* value is not correlated to channel size, either (see Fig. 3). Cross-sectional area is used as an index of channel size.

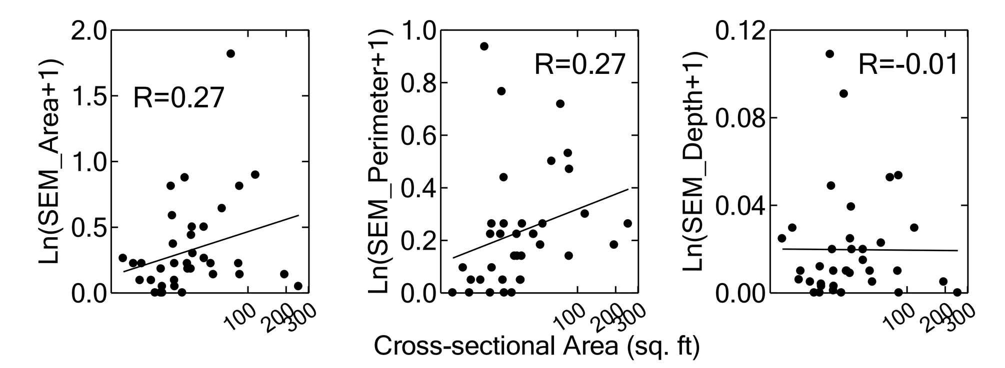

Figure 3. Relationship between cross-sectional area and *sem* values for cross-section variables.

Discussion

• Given the lack of correlation between *sem* values and channel size or number of measurements, it is reasonable to pool all data together and use one location estimate of *sem* to represent measurement error for each variable.

• Given the *sem* values are skewed, use of the mean values based on transformed data is appropriate (Table 1).

Table 1. Mean *sem* values derived from $\log_e$-transformed means.

Mean *sem*		
Area (m^2)	Wetted Perimeter (m)	Hydraulic Depth (mm)
0.036	0.081	6.1

Application Example

Using artificial streamflows (Marion and Weirich 1997), five peak-flow events with return periods of 1.0- to 1.6-yr were simulated in Toots Creek, a nearby stream similar to those described above. The *sem* values derived above are used to determine if area, wetted perimeter, or hydraulic depth changed between consecutive events (e.g., Event 1 v. 2) at three cross sections.

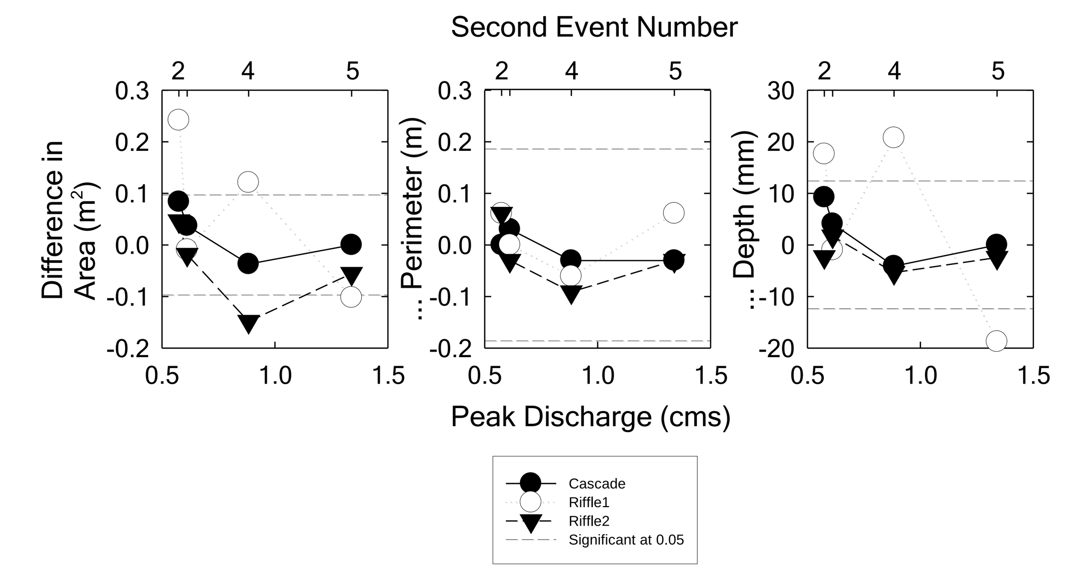

Figure 4. Changes in cross-section variables after consecutive peak-flow events at Toots Creek.

While most variables changed relative to the previous event, statistical testing indicates that only a small number of these changes were significant at the α = 0.05/2 level.

Conclusions

- Cross-section measurement error can be quantified using data from randomly selected, replicate surveys to compute the *sem* for variables of interest.
- The *sem* values do not vary with measurement number or cross-sectional area.
- Changes in cross-section variables over time can be statistically tested using a t-test and *sem* values representing the measurement error.
- These *sem* values should be applicable in testing cross sections measured at different locations if survey methods are the same, and channel geometry and bed material are similar.

Acknowledgements

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