Hydraulic Controls on Streambank Sediment Grain Size

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I. Background

The Rouse-Vanoni suspended sediment transport equation is used to predict sediment concentration as a function of distance above a streambed. Sediment suspension is governed by the ratio of particle fall velocity, ω_s, to stream turbulence, which is estimated with stream shear velocity, u* (Rouse, 1939). An increase in shear velocity will result in the suspension of larger grains and higher sediment concentrations at a given height (van Rijn, 1984). Suspended sediment modeling can be compared to field observations to assess controls on grain size of overbank suspended sediment deposits.

II. Hypotheses

Hypothesis (Hydraulic Controlled): The maximum grain size in overbank deposits increases with bankfull stream shear velocity.

Null Hypothesis (Source Controlled): The maximum grain size in overbank deposits decreases or does not show a systematic relationship with bankfull stream shear velocity.

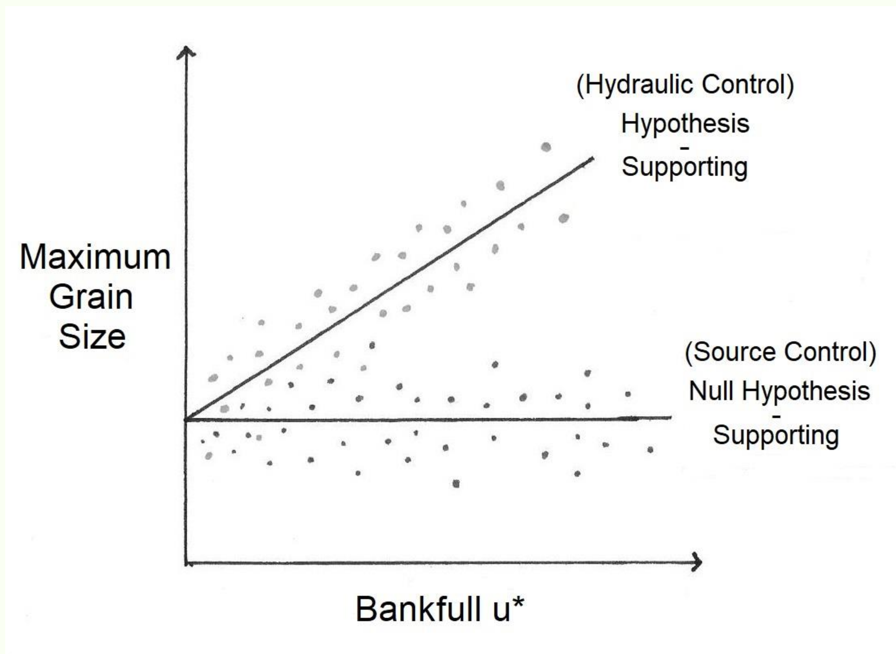


Fig. 1: Schematic diagram of datasets supporting hypothesis and null hypothesis

III. Methodology

1. Twenty-four MD streams selected to create Rouse-Vanoni suspended sediment profiles
2. USGS hydraulic geometry data collected, determine bankfull depth
3. Collect water surface gradient data using MD iMap LiDAR, gradient surveys
4. Create Rouse-Vanoni suspended sediment profiles
5. Select ten non-urbanized streams to sample overbank sediment
6. Obtain overbank sediment samples
7. Perform sieve analyses on overbank samples, determine relationship between maximum grain size and shear velocity

Selection of Study Sites

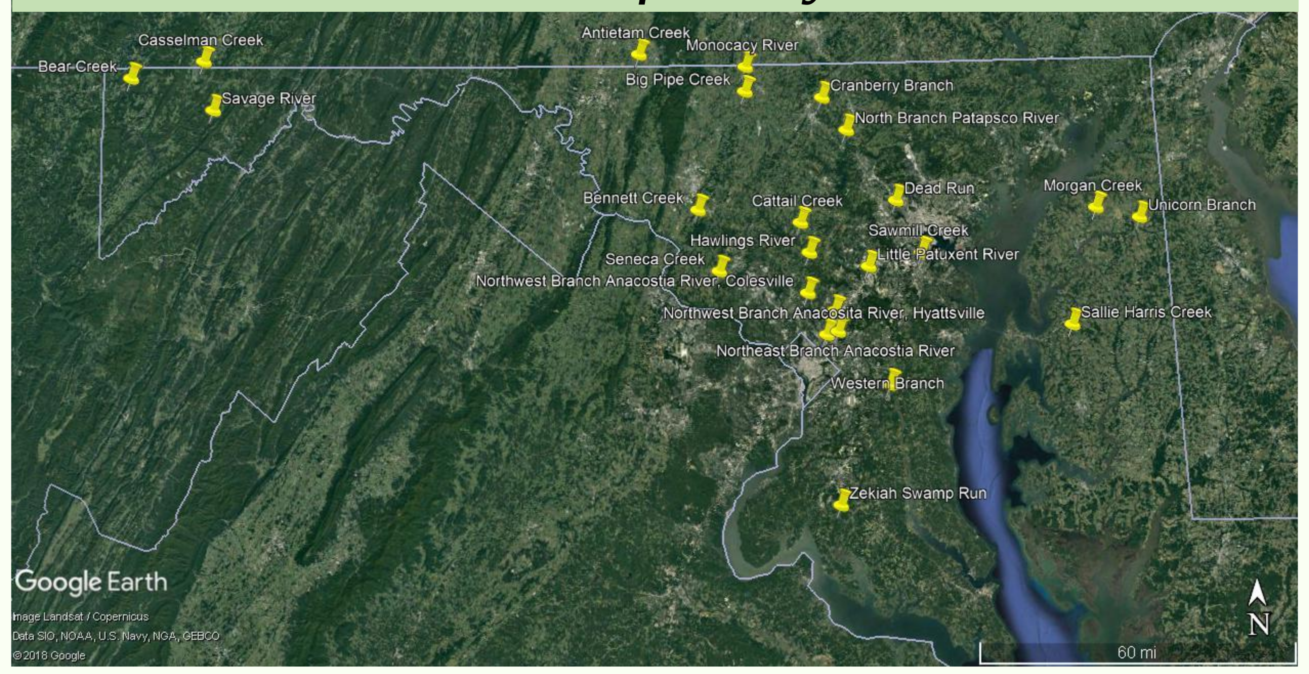


Fig. 2: Locations of selected sites plotted on Google Earth

IV. Sensitivity Analysis

Stream shear velocity, u* = $(gHS)^{0.5}$, where g is gravitational acceleration, H = depth, and S is stream gradient. Probable ranges of stream gradient and bankfull depth are estimated for the selected sites to determine the sensitivity of shear velocity values to these two variables. Given the expected range of values, gradient exerts the greatest control on shear velocity.

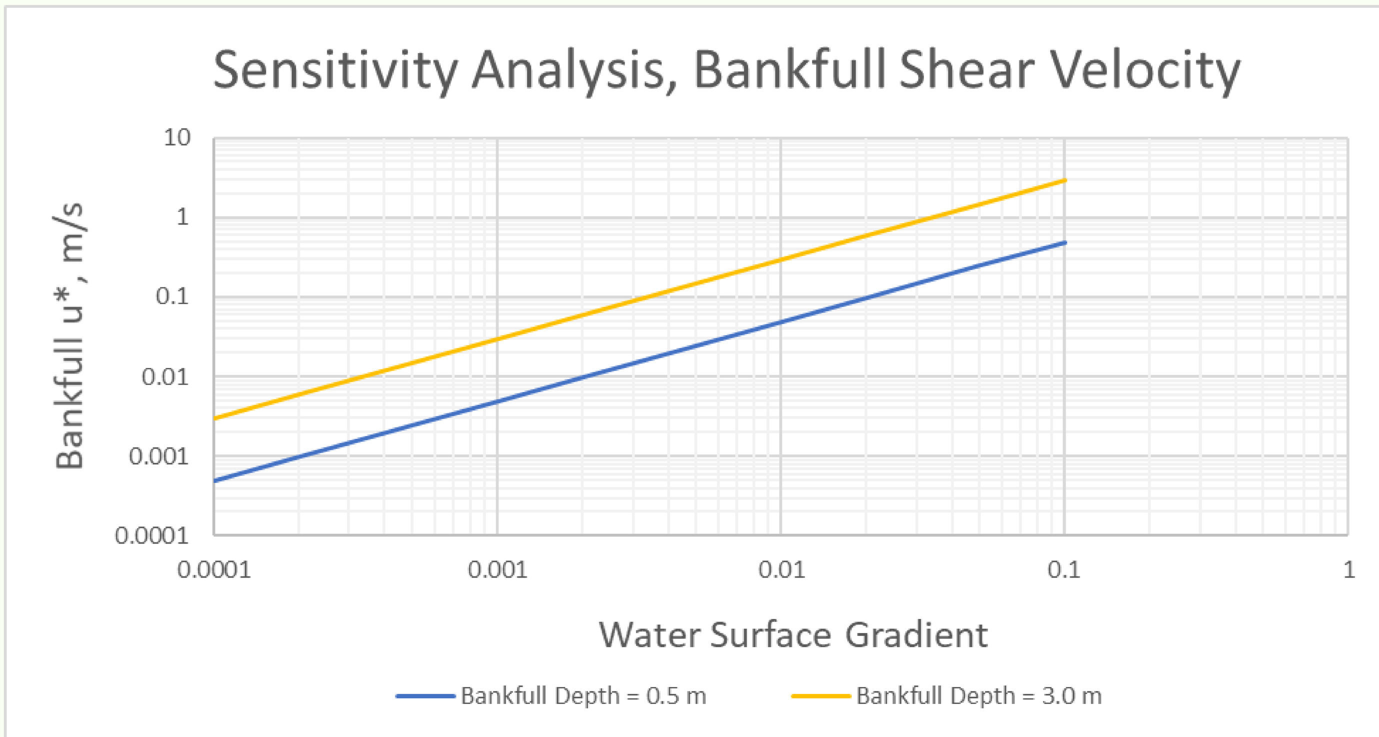


Fig. 3: Bankfull shear velocity, u*, as a function of expected range of water surface gradient for upper and lower estimates of bankfull depth for the selected sites

V. Measurements and Calculations Example: Zekiah Swamp Run

Zekiah Swamp Run near La Plata, MD has been selected for preliminary data collection. This is done in order to determine feasibility of this project as well as error associated with sieve analysis.

Hydraulic Geometry

USGS stream measurement data were used to construct At-a-Station Hydraulic Geometry graphs of width, depth, and velocity as functions of discharge (fig. 4). These data were used to determine bankfull depth.

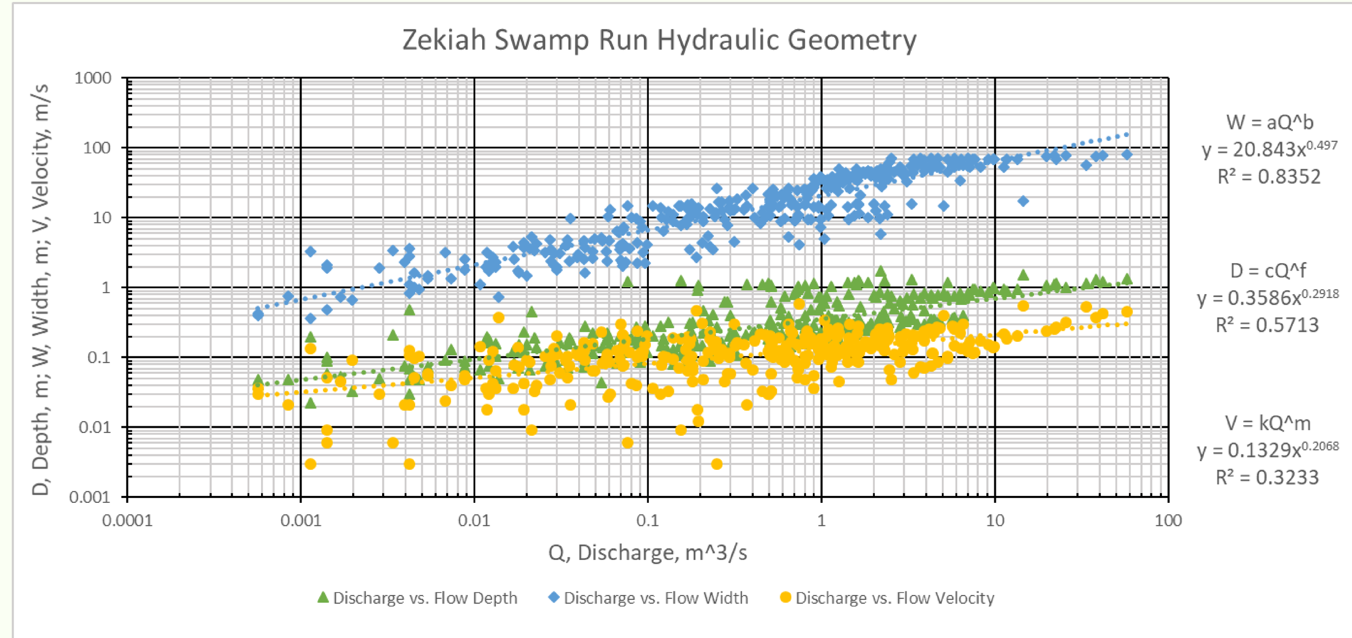
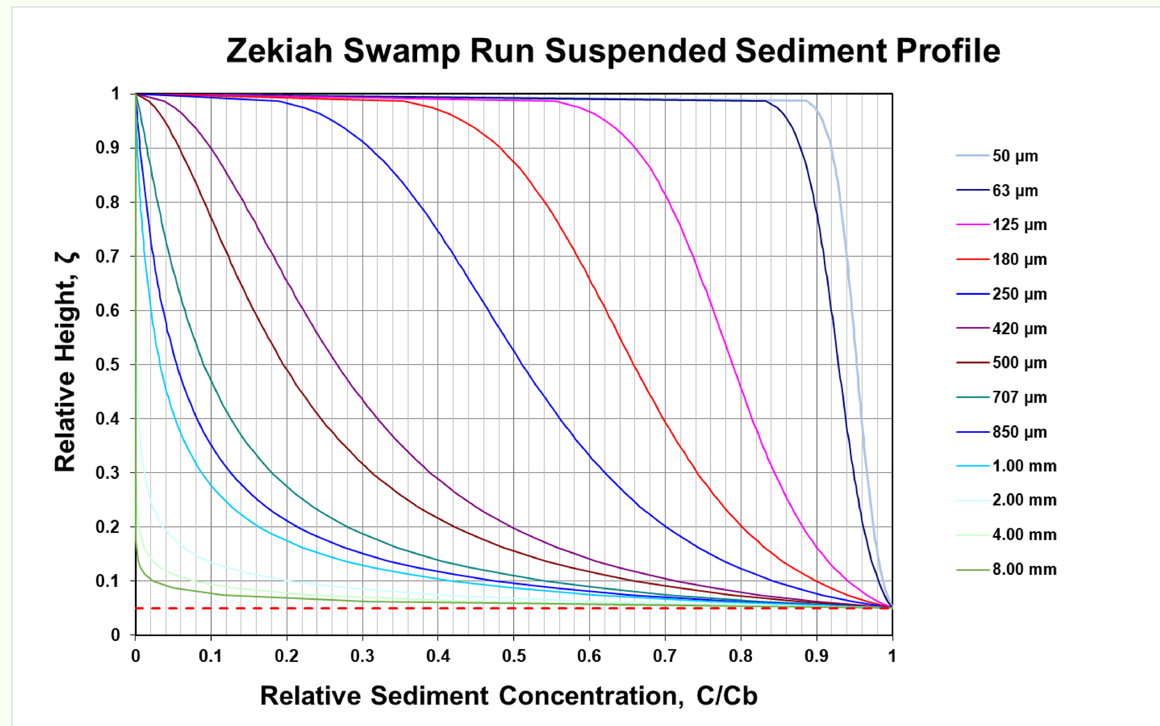


Fig. 4: Hydraulic geometry plot of stream discharge vs. flow depth, width, velocity; Bankfull values are maximum values; Data: USGS

Rouse-Vanoni Suspended Sediment Profile

Using values of bankfull depth of 1.75 m and bankfull water surface gradient of 0.00065 m/m, Rouse-Vanoni suspended sediment profiles were determined for Zekiah Swamp Run. Concentration profiles indicate that sand between 0.5 and 0.85 mm will likely be transported overbank. 1.0 mm sand can be transported near the bank top.



Rouse-Vanoni Equation:

$$\frac{C}{C_b} = \left[\frac{\left(\frac{1-\zeta}{\zeta}\right)}{\left(\frac{1-\zeta_b}{\zeta_b}\right)}\right]^Z$$

Where $Z = \frac{\omega_s}{ku^*}$

Fig. 5: Rouse-Vanoni suspended sediment concentration profile of Zekiah Swamp Run; Relative concentration (C/Cb) is calculated for changing relative height above the bed for each grain size

Overbank Sampling at Field Site

Fig. 6: Three sampling sites of recently-deposited material along streambank edge at Zekiah Swamp Run; Locations of sampling outlined in red

Overbank sediment samples were collected on banks of Zekiah Swamp Run anabranches downstream of the USGS gaging station near Rt. 6 (fig. 6). Sediment deposition on vegetation in overbank deposits and adjacent high flow indicators suggest material was recent deposited recently from suspension.

Sieve Analysis

Seven overbank samples were sieved. Sample 1B was divided into three sub-samples in order to assess sample uncertainty. These data indicate a modal grain size of 0.5 mm (2ϕ) and a maximum grain size between 1 and 4 mm. The modal grain size of overbank sediment is very similar to predicted maximum overbank grain size predicted using the Rouse-Vanoni equation.

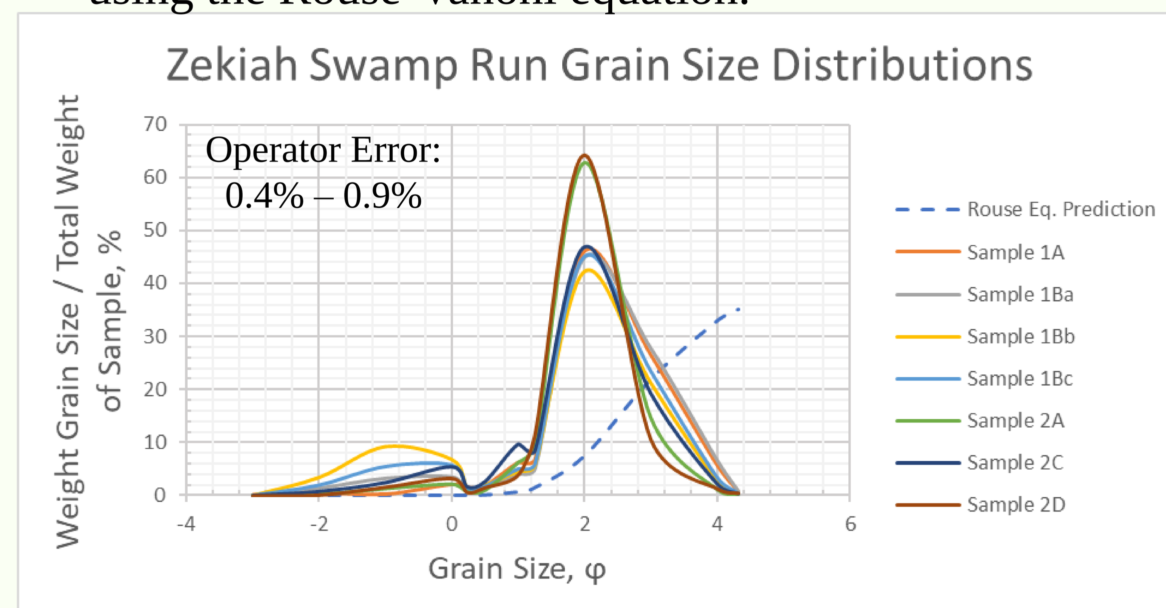


Fig. 7: Grain size distributions of Zekiah Swamp Run samples; Samples 1Ba,1Bb,1Bc taken from same location for sieve error

Preliminary Observations

From the preliminary data, it can be suggested that the Rouse-Vanoni equation predicts sand-sized grains that are similar to the grain sizes found in overbank deposits at this site, suggesting hydraulic control for Zekiah Swamp Run.

VI. Future Work

Rouse-Vanoni profiles will be created for streams using bankfull depth and gradient data. Overbank samples will be collected from ten streams, sieved, and compared to grain sizes predicted from bankfull stream shear velocity values.

VII. References

Rouse, H. (1939). An analysis of sediment transportation in the light of fluid turbulence. *United States Department of Agriculture Soil Conservation Service*. 1-25.

Van Rijn, L. (1984). Sediment Transport, Part II: Suspended Load Transport. *Journal of Hydraulic Engineering*, *110*(11). 1613-1641.