Effects of Urbanization on Stream Equilibrium in the Northwest Branch Anacostia River

Alli Stavely
Advisors: Karen Prestegaard, Jennie Jin-Mullen

DEPARTMENT OF **GEOLOGY**

DEPARTMENT OF **GEOLOGY**

Statement of the Problem

Urbanization alters both water and sediment discharge of streams, causing channels to adjust – perhaps reaching a new equilibrium state. Channel responses can vary significantly even with similar urbanization levels and basin areas, suggesting sediment characteristics are also important. For example, the two streams below have similar basin areas and amounts of urbanization but are very different in size.

Fig. 1:
Left: Batchellor's Run ~ 10 m wide
Right: Nursery Run ~ 4 m wide

Background

Channels that are mobile at bankfull or higher flows are termed thresholds channels, which can be defined as:
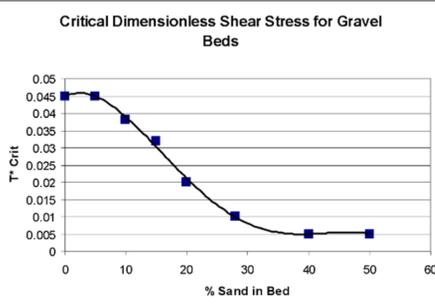
$$\tau^*_{bankfull} \approx \tau^*_{crit}$$

Where τ^* is defined as:

$$\tau^* = \frac{\rho g d S}{(\rho_s - \rho) g D_{84}}$$

Where ρ = fluid density, g = gravitational acceleration, d = depth, and S = gradient. These terms define fluid shear stress. Grain resisting forces are sediment density (ρ_s), g, and D = grain size.

Critical Dimensionless Shear Stress for Gravel Beds

Urban construction can increase sand supply. Sand content in the bed can lower τ^*_{crit}, increasing bed mobility.
Fig. 2: Relationship between critical dimensionless shear stress and percent sand in the bed (from Wilcock and DeTemple, 2005).

Hypotheses

Null: All stream sites are threshold channels, with dimensionless bankfull shear stress equal to the critical dimensionless shear stress to move the sediment.
Alternative: Streams with percent sand in the bed > 15% are mobile at bankfull stage, they are not threshold channels, and their $\tau^*_{bankfull}/\tau^*_{crit}$ ratios will be > 1. Streams with low percent sand in the bed will be threshold channels.

Study Sites

Study sites were selected in upper NW Anacostia, mainly in streams smaller than 5 km^2. Most of the selected sites were previously studied in the 1960s-70s by the USGS during a period of suburban expansion. Gauging stations have been re-established at these sites by Dr. Prestegaard and Jennie Mullen and these gauge data can be used for this study. Study sites are shown in fig. 2.

Fig. 2: Study site maps
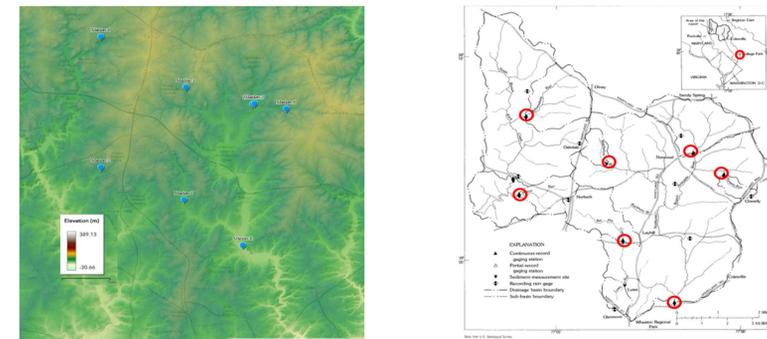
Table I: Site characteristics

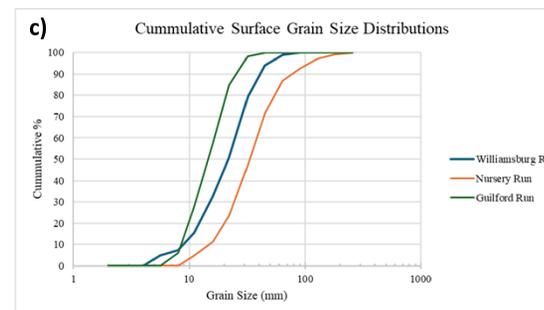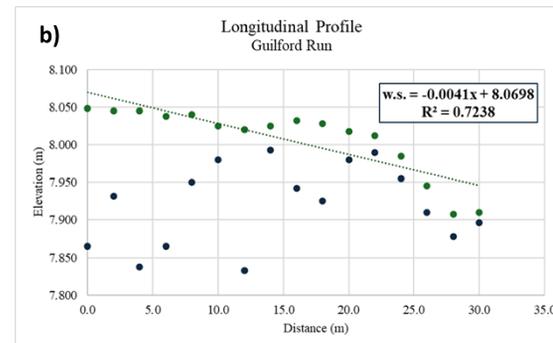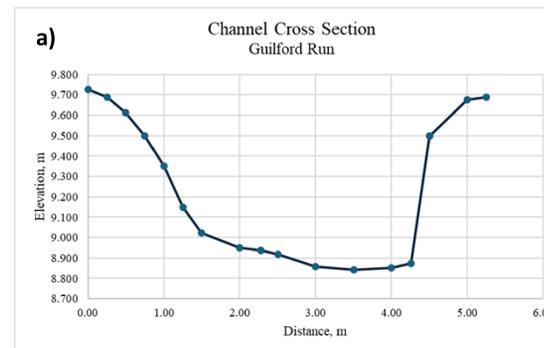| Site Name	% Urban Area (2019)	Basin Area (km^2)	Gauge in 2025
Batchellor's Run	14%	1.2173	UMD
Guilford Run	79%	0.4403	UMD
Manor Run	76%	2.6159	UMD
Nursery Run	16%	0.9065	UMD
Williamsburg Run	84%	5.8275	UMD
NWB Norwood	22%	6.3455	UMD
NWB at Colesville	58%	54.649	USGS
Bel Pre Creek	89%	4.3771	UMD

Methods

Field Data Collection:

a) **stream morphology measurements:** bankfull channel cross sections, surface grain size measurements, and longitudinal profile surveys

b) subsurface sediment sampled for sieve analysis to obtain **sand content**

c) **continuous flow data:** time of series of gauge heights used to calculate shear stress and τ^*

Analysis of Field Morphology Data: Channel cross section measurements are analyzed to determine surface width, bankfull depth (A/W). Longitudinal profiles are analyzed to obtain average water surface gradient, used for bankfull gradient. Surface grain size data are used to construct cumulative probability graphs, used to obtain D_{84}.

Fig. 3: a) Guilford cross section **b)** Guilford longitudinal profile **c)** surface grain size distribution

a) Channel Cross Section Guilford Run

b) Longitudinal Profile Guilford Run
w.s. = -0.0041x + 8.0698
R^2 = 0.7238

c) Cummulative Surface Grain Size Distributions
— Williamsburg Run
— Nursery Run
— Guilford Run

Time Series Analysis

Shear stress and τ^* can be calculated from continuous gauge (depth) data. An example is shown in fig. 4, January 2025 through February 2025. Calculations of τ^* are shown in fig. 4. These can be compared with values of τ^*_{crit} for various sand contents.

Fig. 4: Guilford Run dimensionless shear stress over time

Guilford Dimensionless Shear Stress
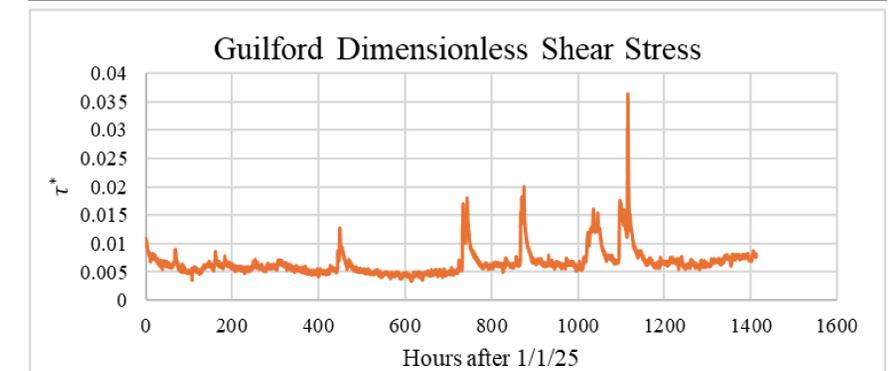
Preliminary Results

Bankfull characteristics for the Guilford Run Channel are listed below. The initial time series data are shown above.
Table II: Bankfull channel characteristics of Guilford Run

Width	Avg. Depth (A/W)	D50	D84	Gradient	% Sand	τBF	τ*crit (Wilcock)	τ*	τ*BF/τ*crit
5.25 m	0.40 m	15 mm	21 mm	0.0041	20%	16.1 N/m^2	0.02	0.047 N/m^2	1.0 (gravel) 2.36 (Wilcock)

Completed and Future Work

➢ Cross sections of Batchellor's Run, Manor Run, and Nursery Run, as well as surface grain size distributions for Williamsburg and Nursery Run have been completed.
➢ Subsurface samples of Batchellor's Run, Guilford Run, Nursey Run, and Williamsburg Run have been put through the 2 mm sieve to determine bed sand percentage. Further sieve analysis will be completed to create a full subsurface grain size distribution for each site.
➢ Complete sets of geomorphic data will be collected for all eight sites, and bankfull shear stress calculations will be made from these data.
➢ All sites are being gauged.

Acknowledgements and References

Wilcock, P.R., DeTemple, B.T., 2005. Persistence of armor layers in gravel-bed streams. *Geophysical Research Letters* 32. doi:10.1029/2004gl021772