Suburban stream erosion rates in northern Kentucky exceed reference channels by an order of magnitude and follow predictable trajectories of channel evolution

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Introduction

Conventional stormwater management amplifies erosive power in suburban streams.

Hypothesis

Suburban streams (> 5% Total Impervious Area, TIA) will experience greater rates of erosion than rural streams.

Methods

- ~Annually repeated surveys at 61 sites over ~10 years (Figures 1 and 2)
- Systematic measures of "bankfull" geometry
- Average rates of deepening and widening at each site via linear regression (Figure 3)

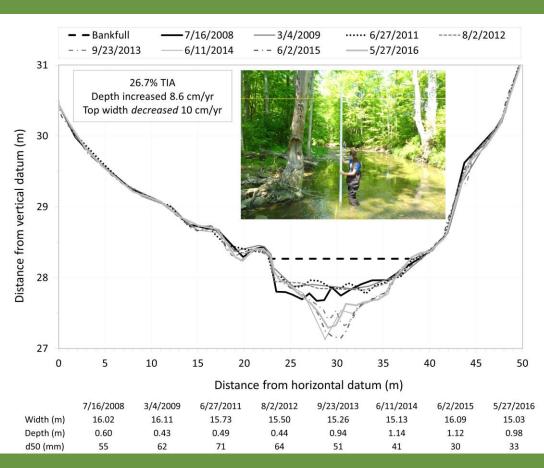


Figure 1 – Site experiencing incision (Stage 2)

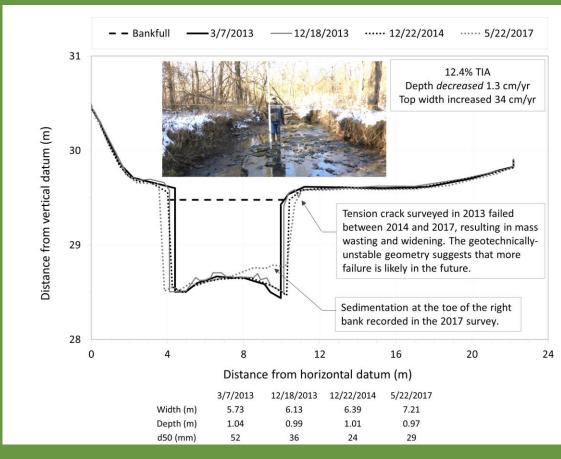


Figure 2 – Site experiencing widening and aggradation (Stage 4)

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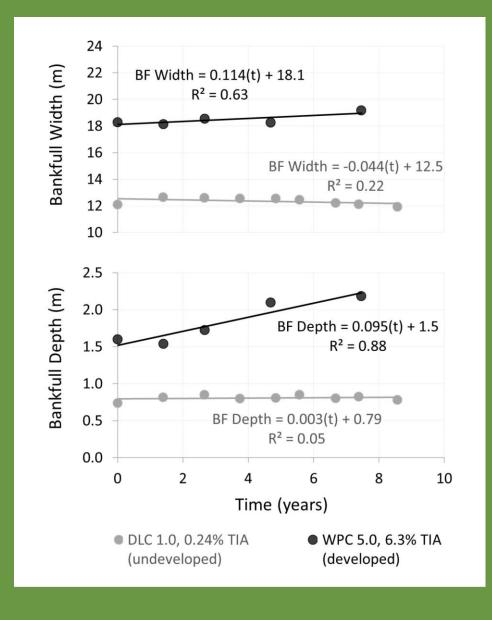


Figure 3 – Linear regression of changes in width and depth at two representative sites

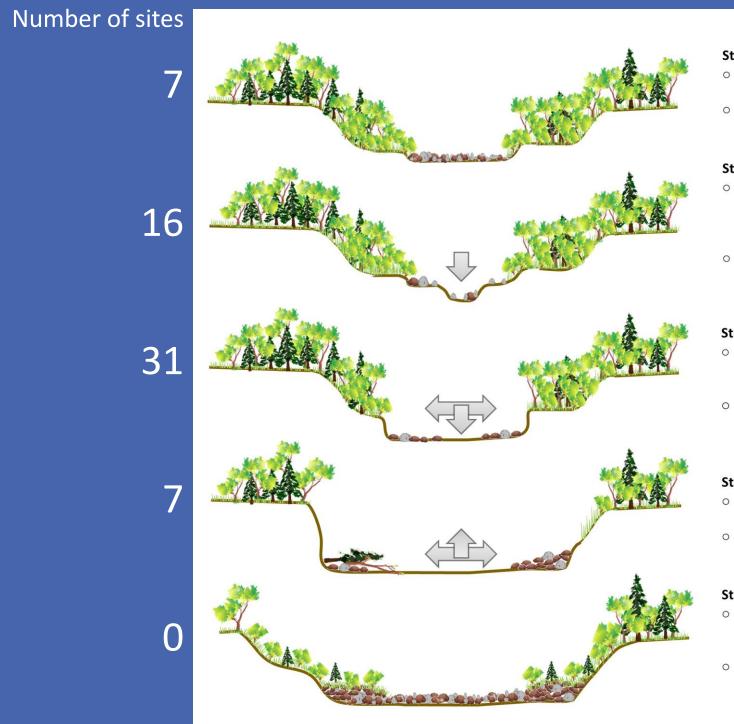




Erosion rates of suburban streams exceed rural streams by ~ 10x

Over a 10-yr study, the average widening rate of 45 suburban streams (>5% TIA) was 9.4 cm/yr compared to **1.0 cm/yr** for rural streams

Suburban streams follow predictable patterns of evolution, consistent with the "classic" Channel **Evolution Model** (CEM) of Schumm et al. (1984)



Only one suburban site showed signs of a potential recovery (transition from Stage 4 to 5), which was attributable to an upstream stormwater retrofit



Stable reference streams include a rocky mix of cobble/gravel bed material, gentle-sloped banks, and well-connected floodplains. The natural flow regime is in balance with the channel/floodplain geometry and bed material.

tage 2 – Bed Coarsening and Incising As documented by Hawley et al. (2013a), one of the initial phase channel adjustment to urbanization is bed coarsenin creased flows erode the small- and medium-sized bed particles which gradually makes the stream deeper. In some cases, this process continues until the streams have eroded nearly all of their gravels/cobbles, leaving streams with bedrock bottoms.

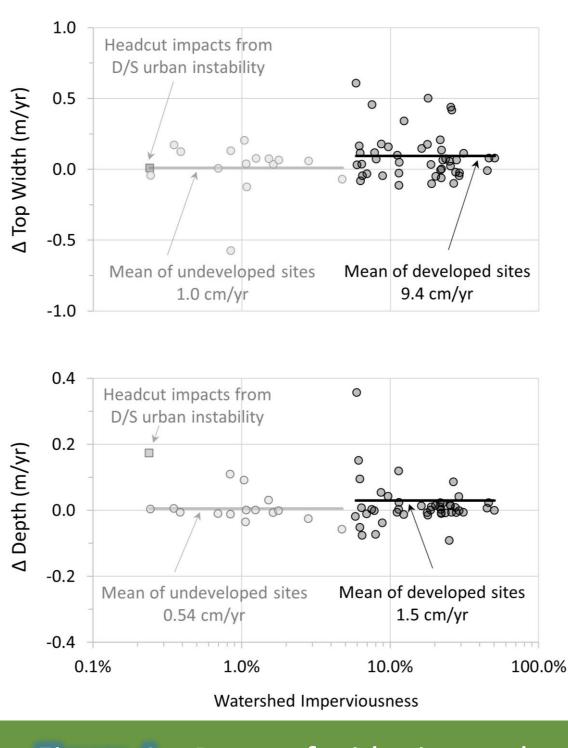
As incision makes the streams deeper, the taller banks become nore susceptible to erosion from both geotechnical failure and Stage 3b: In cases with bedrock bottoms, bank erosion can be exacerbated by excess erosive power being expressed on the banks as opposed to being used to transport gravels and cobbles

tage 4 – Widening and Sedimentation Continued bank erosion can create taller, steeper banks prone to o The over-widened channels can no longer transport the failed bank sediment leading to sedimentation.

Given enough time and space to adjust, streams will eventually form a new balance with the increased flows they receive from their watersheds. a recovered channel with gentle banks becomes re-established vithin the widened floodplain corridor

Results

- notable (p = 0.11)
- Widening rates between Stage 2 (-58 to 61 cm/yr, avg. 0.3 cm/yr) and Stage 4 (-10 to 50 cm/yr, avg. 17 cm/yr, Figure 5) were statistically different per an LSD test
- Deepening rates between Stage 2 (-5.8 to 36 cm/yr, avg. 5.2 cm/yr, Figure 5) were statistically higher than all other CEM stages except Stage 4 per an LSD test



Discussion

- **Historical data** (e.g. 21 to 34 cm/yr of widening at one suburban site over 44 years) are consistent with widening rates over that last decade
- Streams in suburban watersheds are also **significantly wider** than rural streams after accounting for drainage area (W = $7.18 * DA^{0.36} * TIA^{0.08}$) \rightarrow a stream with 30% TIA would be ~25% wider
- than a stream with 2% TIA
- Stormwater management that **restricts erosive discharges** can help to facilitate a geomorphic recovery (transition from Stage 4 to 5, Figure 6)



References

Take a picture to access the full paper • Widening rates between rural (-58 to 20 cm/yr, avg 1.0 cm/yr) and suburban (-11 to 61 cm/yr, avg. 9.4 cm/yr, Figure 4) were statistically



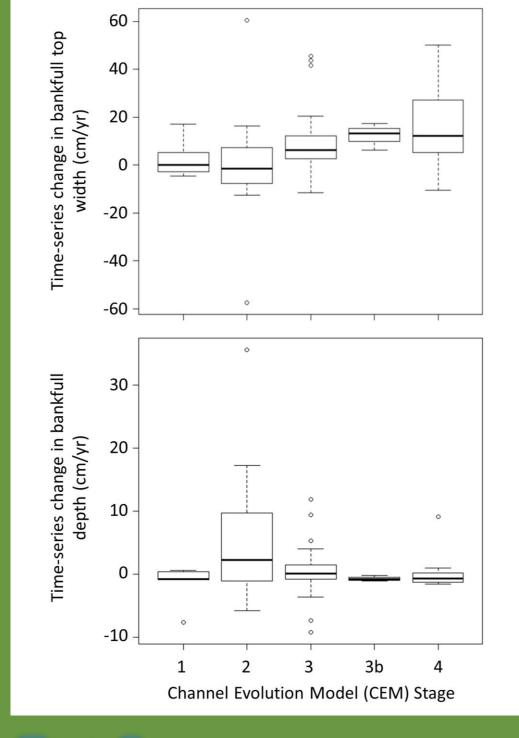


Figure 5 – Rates of widening and deepening by CEM Stage



Figure 6 – Looking downstream at the same site from Figure 2 in July 2019, ~5.5 yrs after a stormwater retrofit was installed upstream (see Hawley et al., 2017)

- Hawley, R.J., Goodrich, J.A., Korth, N.L., Rust, C.J., Fet, E.V., Frye, C., MacMannis, K.R., Wooten, M.S., Jacobs, M., and Sinha, R. 2017. Detention outlet retrofit device improves the functionality of existing detention basins by reducing erosive flows in receiving channels. Journal of the American Water Resources Association, 53(5): 1032-1047.
- Schumm, S.A., Harvey, M.D., and Watson, C.C. 1984. Incised Channels: Morphology, Dynamics, and Control. Water Resources Publications, Littleton, Colorado.