Effects of Urbanization on Stream Hydrology and Geomorphology

7 February 2013
Pigeon House Creek, Raleigh NC
USGS Discharge record for Pigeon House Creek

Drainage area = 0.75 km²
Contributing Drainage area = 0.70 km²

--- Provisional Data Subject to Revision ---

△ Median daily statistic (16 years)  ★ Measured discharge

Discharge, cubic feet per second

Graph courtesy of the U.S. Geological Survey
Lag to peak: 35 minutes, 75 minutes, 115 minutes
What controls hydrologic response to urbanization?

Watershed properties:
- Soils – how fast do they infiltrate water? How quickly do they saturate?
- How big is the watershed?
- How steep is the watershed?
- What is the precipitation regime?
- What is the drainage network like?

Land cover properties:
- What is the land cover/use?
- What is the agricultural management?
- What is it’s hydrologic condition?
- How much impervious surface is there?
- How connected is it?
- What is the variability of watershed land cover and imperviousness?
Those questions are basis for the NRCS curve number method (in TR-55)

\[ Q = \frac{(P-0.2S)^2}{P + 0.8S} \]
Effects of urbanization on stream channels

Photo by Jefferson
Streams within Riparian Zones

Benefits of riparian zones:

- Reduced flooding and erosion
- Decreased velocity and increased filtration of water runoff
- Shaded streams
- Increased habitat
- Recreation opportunities
- Increased property values?
Lane sediment balance
Braided, Meandering, or “Straight”

Leopold and Wolman, 1957. “River Channel Patterns: Braided, Meandering, and Straight, USGS Prof. Pap. 282-B.

http://www.geology.ohio-state.edu/~vonfresse/gs100/lect12/xfi12_28.jpg
http://www.fgmorph.com/fg_4_5.php
http://pages.uoregon.edu/millermd/Dep-33.jpeg
Pools and Riffles

http://fishwild.vt.edu/afs/pages/Stream%20riffle-pool%20sequence.jpg.htm
Pools and Riffles

- Alternating deeps and shallows characteristic of gravel-bed streams
- Spacing = ~5-7 widths

Bottom: Adapted from North Carolina Cooperative Extension Service, 1999
Why pools and riffles are important

- Stable, equilibrium channel form
- Particles move downstream, form stays fixed
- Way for stream to adjust to changing $Q$ and $Q_b$ & develop meanders
- Primary framework for aquatic habitat
- Important for macroinvertebrates and fish species
- Aerate the water
Breakneck Creek, near Kent

- Meandering stream
Meander anatomy

- Erosion occurs on the outside of the bend, forming cut banks.
- Deposition occurs on the inside of the bend, forming point bars.
- Riffles form at cross-over points between meanders.

Peffer Park, near Miami University

http://www.ecbarranch.com/adeq%204004/rrip/meander.htm
Geomorphic effects of urbanization

- Sediment yields usually increase during construction, but are low afterwards
  - Why?

- Watershed sediment yield: depends on relative decrease in erodibility due to impervious surfaces versus increase in peak flows → so channel is often main point of adjustment
Geomorphic effects of urbanization

A wide range of changes to geomorphology have been reported:

- **Massive bank erosion during construction**
  - Constriction due to construction sediment
- **Channel enlargement and incision after construction**
  Enlarging upstream channels can supply sediment to downstream reaches
- **Increasing pool depth**
- **Decreasing complexity of channel form**
- **Changes to bed sediment sizes are inconsistent**
  - Coarsening of stream bed sediment, as fine sediments are scoured
  - Increasing percent of sand and silt in stream bed
Person is standing in the same spot


During active urbanization → 20 m³/m/year bank erosion = 2/3 of total sediment yield in Orange County watershed.
This was attributed to the fact that much of the urban development in the region was more than 20 years old and bridges, infrastructure, and large woody debris helped promote aggradation. As pointed out by Leopold (1973), the aggradation response may be spatially and temporally variable and time periods of several decades or more would be needed to observe the complete urban response cycle [68].

In an Appalachian V alley and Ridge setting (Knox Co., TN), Gallery and Harden (2006) studied the geomorphic response to urbanization [74]. They found that although erosion was the dominant response to urbanization, aggradation could also occur and channel response patterns were complex late to the temporal and spatial variability of urban development and infrastructure. Urban infrastructure and channel alteration could prevent the propagation of channel responses upstream (i.e., upstream migration of erosion alluvial kinks). In addition, increases in channel sediment size and particles of anthropogenic origin were noted.

The inputs of anthropogenic particles were geomorphically significant, as they comprised up to 21% of channel sediment.

Figure 6. A comparison of the annual hydrographs of rural (Phillippi Branch, 4% TIA) and urban (Fornes Branch, 37% TIA) streams in the Coastal Plain of NC (Greenville, NC) and the stream channel cross-sections, indicating the channel incision and enlargement response to urbanization documented in the region [38,71]. Photo of Phillippi Branch is courtesy of Dr. Mark Brinson.