Technical Note #92 from Watershed Protection Techniques 2(4): 503-506

Comparison of Forest, Urban and Agricultural Streams in North Carolina

Recent stream research has frequently demonstrated that stream quality indicators decline from baseline conditions as impervious cover in the contributing watersheds increases. The baseline for measuring this decline is usually a non-urban reference watershed. Although it is often impossible to find a totally undisturbed watershed, most studies have used watersheds that are mostly forested and are not actively disturbed as a reference.

Some argue, however, that a forested watershed is not the best baseline to measure changes in stream quality indicators for many regions of the country. This is due to the fact that prior land use in many urbanizing watersheds is often dominated by agriculture and not forest. The choice of a reference land use can have important implications for urban watershed managers. Will the same dramatic decline in stream quality indicators occur if an agricultural watershed is converted into a suburban one? Or have agricultural activities already degraded or impaired stream quality so that little if any decline is noted?

There are a number of good reasons to suspect that agriculture can degrade stream quality. Agricultural areas, for example, produce more runoff, greater soil erosion and higher nutrient loads than forested watersheds. In addition, current or past agricultural practices often modify natural drainage patterns, alter the riparian zone and drain wetlands. On the other hand, agricultural watersheds have little or no impervious cover, and produce only a fraction of the destructive storm flows of an urban watershed. Where, then, do agricultural watersheds fit in?

A paired watershed study conducted by Crawford and Lenat (1989) sheds some light on this issue. The investigators intensively monitored three small watersheds in the North Carolina piedmont over a two-year period (Figure 1). The dominant land uses in each watershed were forest, agriculture and urban, respectively. Riparian condition was generally good in all three watersheds, and point sources were not a factor. Other key watershed characteristics are compared in Table 1.

In each watershed, Crawford and Lenat sampled suspended sediments, water quality, bottom sediments, macroinvertebrates and fish populations. At each study site, instantaneous suspended sediment discharge was statistically correlated with stream discharge. Annual suspended sediment loads were then calculated using daily discharge values. In addition, the particle size distribution and sediment chemistry of stream substrates were sampled at randomly selected intervals in each stream.

Findings: Water Quality and Stream Substrate

The three watersheds had contrasting water quality and substrate conditions (Table 2). Sharp differences, for example, were noted in their nutrient levels. The agricultural stream had the highest phosphorus and nitrogen concentrations, whereas nutrients were present at low and possibly limiting levels in the forested stream. The urban streams had an intermediate level of nutrients, but did exhibit the highest level of dissolved nitrogen. With respect to stream temperature, the forested stream was the coolest, whereas the urban stream was the warmest.

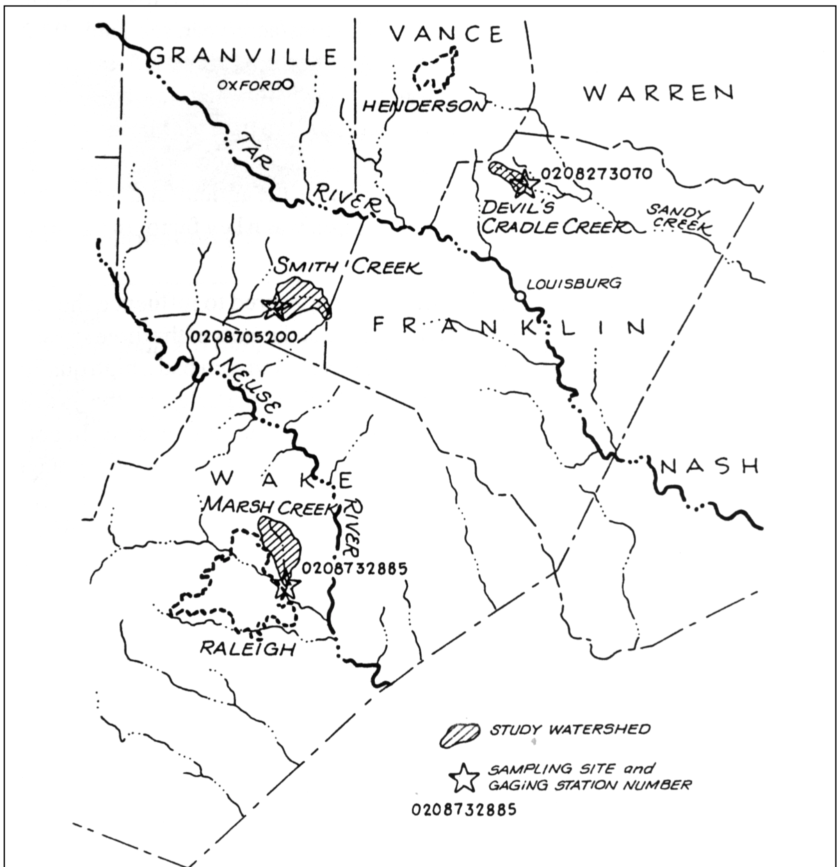

Figure 1: Location of Three Paired Watersheds in North Carolina

Table 1: Comparison of Watershed Characteristics in North Carolina Watershed Study

Characteristic	Forest Watershed	Agriculture Watershed	Urban Watershed
Name	Smith Creek	Devil's Cradle Creek	Marsh Creek
Area (square miles)	6.2	2.9	6.8
Forest Cover	75%	31%	24%
Agricultural Cover	21%	53%	5%
Urban Cover	4%	13%	71%
Riparian Cover	forested	mostly forested	mostly forested
Stream Order	Second	Second	Third
Point Sources?	None	None	None
Other Influences	upstream beaver dam may have trapped sediment	no stormwater practices were used to treat agricultural runoff	no stormwater practices were used to treat stormwater runoff

The three streams also sharply differed in their annual suspended sediment load. As might be expected, the forested stream had the lowest annual sediment loading (0.13 tons/acre/year, see Table 2). The agricultural stream exported about 2.5 times more suspended sediment than the forested stream, while the urban stream discharged more than four times as much (0.59 tons/acre/year). Soil erosion appeared to the major source of sediment in the agricultural watershed, while streambank erosion was a key factor in the urban one.

Sediment discharge appeared to influence the size distribution of the bottom sediments of the three streams (see Table 3). The forested stream had a high quality substrate, with a third of all particles in the gravel category, and virtually no silt or clay present. In contrast, the agricultural stream had the highest percentage of sand (85%) and silt-clay (7.7%) sized particles. The urban stream, despite its high sediment load, had a surprising amount of gravel-sized particles (25%) and relatively little silt and clay (1.4%). Scour caused by higher stormwater flows may explain the substrate pattern found in the urban stream. The researchers also examined metal levels within the finer-grained sediments of the stream bottom. Surprisingly, the forested stream had the highest sediment metal levels of any of the three streams (but these did not approach any level of concern).

Findings: Stream Biota

The biota of the three streams was quite different, as measured by various indicators of aquatic macroinvertebrates (see Table 4). The forested stream had the greatest overall species richness, the most sensitive taxa, and the least number of pollution tolerant species. The three aquatic insect families, collectively known as E-P-T (Ephemeroptera–mayflies, Plecoptera–stoneflies, and Trichoptera–caddisflies), were most numerous in the forested stream. The forested stream had a large number of filter feeders, collector/gatherers, and shredders, but had relatively few scrapers that feed on periphyton.

In contrast, the urban stream had low diversity in its aquatic insect community. It had the lowest taxa richness, the least taxa and abundance of EPT insects, and the greatest number of pollution tolerant species (86%). Unlike the forested stream, the urban stream had few filter feeders and no shredders, and was dominated by scrapers and collector/gatherers. The major components of the urban stream macroinvertebrate community were *Oligochaetes* and *Dipterans*, both of which tend to indicate poor water quality and soft substrates.

The agricultural stream also had a fairly poor aquatic insect community, although it was not as poor as the urban stream. The poor stream substrates present in the agricultural stream may have been a cause of the reduced taxa richness, low EPT scores, and large abundance of pollution tolerant species. The feeding groups in the agricultural stream were sharply different from the forested stream, with fewer shredders and collectors, and more filter feeders and scrapers.

Fish surveys, however, told a different story. Both the forested and agricultural streams had fish communities that could be characterized as "good," according to several indicators. Both streams had the same species richness and about the same Index of Biotic Integrity (IBI) score. The enriched agricultural stream had more unit biomass and a greater number of individual fish collected than the forested stream. By contrast, the forested stream had more sensitive fish species. Both streams were clearly in much better shape than the urban stream. The poor quality of the urban fish community is attested to by its low species richness, poor

IBI score, complete absence of pollution intolerant species, small fish population and low unit biomass.

Summary

The North Carolina study reinforces the paradigm that forested streams exhibit much higher quality than urban streams, as defined by a rather broad range of stream indicators (Table 5). The study is more ambiguous in regard to where agricultural streams fit in. By some indicators, the agricultural stream was as bad or even worse than the urban stream (e.g., nutrient enrichment, high sediment load, poor substrate quality and macroinvertebrate diversity). According to other indicators, however, the agricultural stream was hard to distinguish from the high quality forested stream, particularly in regard to fish diversity and IBI scores. The divergence among these indicators underscores the need to measure multiple indicators when analyzing watersheds. In a narrow context of the North Carolina study, it appears that agricultural streams occupy a middle ground between high quality forested stream and lower quality urban ones. Despite its high nutrient and sediment load, the agricultural stream monitored in this study clearly supported a diverse fish community.

More stream indicator research is needed before we can determine where agricultural streams really fit in. While it may be tempting to generalize from a single study, many more agricultural streams need to be sampled before we can truly compare the dynamics of urban and agricultural streams. Indeed, the term "agriculture" encompasses a bewildering variety of crops, rotations, livestock, management practices and other factors. Until this knowledge is obtained, watershed managers will probably need to use forested watersheds as the baseline from which to measure change in urban watersheds.

—***TRS***

Reference

Crawford, J. K., and D. R. Lenat. 1989. *Effects of Land Use on the Water Quality and Biota of Three Streams in the Piedmont Province of North Carolina.* U.S. Geological Survey. Water- Resources Investigation Report 89-4007. Raleigh, NC. pp. 67.

Table 2: Comparison of In-Stream Water Quality in Study Watersheds (Crawford and Lenat, 1989)

Stream Water Constituent [a]	Forested Watershed	Agricultural Watershed	Urban Watershed
Total Phosphorus [b]	0.09	0.27	0.10
Dissolved Phosphorus	<0.01	0.05	0.02
Total Nitrogen	1.70	2.11	1.42
Dissolved Nitrogen	0.08	0.59	0.41
Total copper (µg/L)	7.9	5.0	12.5
Total lead (µg/L)	5.1	6.6	14.4
Total zinc (µg/L)	31	23	39
Mean Stream Temp. [c]	57	58.9	60.1
Max Stream Temp.	72.5	73.4	77.0
Sediment Discharge [d]	0.13	0.31	0.59

[a] Mean of 12-14 baseflow samples.
[b] Nutrient units are mg/l.
[c] Degrees Fahrenheit.
[d] Summed product of daily flow and watershed-specific suspended sediment discharge regression equation for one year (tons/acre/year).

Table 3: Analysis of Bottom Sediment in Study Watersheds (Crawford and Lenat, 1989)

Size Distribution (%)	Forested Watershed	Agricultural Watershed	Urban Watershed
Gravel *(greater than 2.0 mm)*	35.0%	7.5%	27.0%
Sand *(2.0 mm to 0.63 mm)*	64.6%	84.8%	71.6%
Silt-Clay *(less than 0.63 mm)*	0.4%	7.7%	1.4%
Metals Levels in Bottom Sediments[a]	high	low	moderate

[a] Metals were elevated in forest watershed, but did not exceed standards.

Table 4: Comparison of Stream Biota in Three North Carolina Watersheds

	Forested Watershed	Agricultural Watershed	Urban Watershed
Macroinvertebrates Indicators			
Total Taxa Richness (species)	202	169	101
EPT (% of all Taxa) [a]	22%	11%	5%
EPT (% abundance)	65%	24%	10%
Tolerant Species (% abundance) [b]	26%	71%	86%
Feeding Category [c]			
• **Filter Feeders**	46%	47%	10%
• **Scrapers**	4%	16%	21%
• **Shredders**	4%	0%	0%
• **Collector/Gatherer**	34%	19%	46%
Number of unique taxa [d]	75	42	9
Fish Indicators			
Species Collected	19	19	9
Game Fish Species	6	6	3
Insectivorous Cyprinids	8%	0%	1%
Intolerant Fish Species	3	2	0
Number of Individuals	305	755	75
Biomass (grams)	3,766	8,494	503
Index of Biotic Integrity	50 / Good	48 / Good	34 / Poor

[a] EPT = Ephemeroptera, Plecoptera and Tricoptera insect groups, which include mayflies, stoneflies and caddisflies, are often considered intolerant of pollution.

[b] Pollution tolerant species were defined as Dipterans, Oligochaetes, and others.

[c] Proportion of taxa within each of the major feeding strategies.

[d] Unique taxa are defined as the number of taxa that occur solely within one stream (not found in the other two watersheds). Grossly tolerant species were excluded.

Table 5: Overall Summary of Stream Indicators

Stream Indicator	Forested Watershed	Agricultural Watershed	Urban Watershed
Nutrients	Good	Poor	Fair
Sediment Discharge	Good	Fair	Poor
Temperature	Good	Fair	Poor
Stream Substrate	Good	Poor	Fair
Macro-invertebrates	Good	Fair	Poor
Fish Diversity	Good	Good	Poor