# THE IMPACT OF PAST AND PRESENT LAND USE ON TWO GEORGIA PIEDMONT STREAMS

Leslie Edwards, Christopher Sturm, Joseph Charles and Candace Stoughton

*AUTHORS:* Graduate students, Department of Geography, The University of Georgia, Athens, Georgia 30602.
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**Abstract.** This study examined the influence of differing past and present land use practices on bankfull discharge and sediment patterns in two small Georgia Piedmont watersheds, one urban and one forested. It was hypothesized that the urbanizing watershed would have significantly higher bankfull discharge and non-gravel bedload levels than the forested basin. Bankfull discharge levels were estimated from stream cross section measurements, thalweg sediments were analyzed, basin morphometric parameters were calculated, and GIS-mediated aerial photography analysis was performed. The discharge hypothesis was validated. The sediment hypothesis was not validated, apparently because of past land use practices in the forested watershed. Thus, the most effective stream analyses will incorporate past and present land use and morphology at the basin scale.

## INTRODUCTION

The purpose of this study was to examine the influence of past and present land use on bankfull discharge and thalweg sediment patterns. By better understanding the role these variables play in flooding and aggradation patterns in streams, planners and land managers will be able more realistically to assess the potential success of stream restoration efforts.

## BACKGROUND AND RELATED WORK

Increased sediment and discharge levels are acknowledged problems in Georgia and throughout the country, causing destruction of wildlife habitat and increased recurrence of overbank flooding in urban areas (Faye et al., 1980). Changes in land use from forested to agricultural or urban are known to increase sediment and discharge levels dramatically (Wolman and Schick, 1967; Trimble, 1969; Faye et al. 1980). Antecedent land use has also been established as a factor still influencing channel morphology today in complex ways (Schumm, 1973; Knox, 1977; Trimble, 1993; Ferguson 1997; Jacobson and Primm 1997). Yet the role of antecedent land use is often not considered when assessing streams. How changes in land use affect a stream is predicated somewhat upon the watershed morphology, which can influence when flood peaks occur or how quickly sediment passes through a reach (Jacobson and Primm, 1997). By examining these three factors together, a clearer picture of stream dynamics will emerge.

## EXPERIMENTAL DESIGN

This study compared two small watersheds in the eastern Georgia Piedmont with differing land uses. The Middle Fork of the Broad is a forested watershed located in the Chattahoochee National Forest straddling Habersham and Stephens Counties. Cedar Creek is an urbanizing watershed in southeast Athens, Clarke County. Both watersheds are located in USGS region 2 (Stamey and Hess, 1993), with primarily Udult soils underlain by biotitic gneiss. Based on current land use, it was hypothesized that the urbanizing stream would have a significantly greater bankfull discharge and a higher proportion of non-gravel sediment levels than the forested watershed. To test the bankfull discharge hypothesis, a dimensionless variable was necessary because sub-basin areas did not correspond exactly between the two study areas. Channel cross sections were constructed throughout both watersheds to estimate bankfull discharge in sub-basins of varying sizes. Then the equation of Stamey and Hess (1993), $207A^{.654}$, was used to calculate the two year discharge of the average rural stream in the region with the same basin areas as those in the study. The following ratio was then derived for all cross-section sites:

$$\frac{\text{Bankfull discharge estimated from the cross section}}{\text{Two year discharge for the average rural stream of the same area, derived from the equation of Stamey and Hess.}}$$

For the discharge hypothesis to be validated, the ratios from the urbanizing watershed would have to be significantly different (larger) than those of the forested basin, using the Mann-Whitney U test.

Thalweg sediment samples were collected at each study site. To validate the sediment hypothesis, the sediments from the urbanizing watershed would have to have a significantly lower proportion of gravel than the forested basin, using the Mann-Whitney test.

## METHODS

Five sampling sites were selected in each watershed using USGS topographic maps to ensure a variety of sub-basin characteristics. Two to three cross sections were measured at each site using a level, stadia rod and measuring tape. Bankfull level was identified using the criteria of Leopold (1994). Cross sections were constructed on graph paper from the field data and used to estimate the area of the wetted perimeter, then the Mannings equation was used to derive bankfull discharge levels. Thalweg sediments were sieved to derive proportions of silt and clay, sand, and gravel. Digital USGS 7.5 minute topographic maps were transported into ArcView GIS and SigmaPlot to calculate area, stream length and slope for derivations of morphometric parameters.

Present land use patterns were mapped in ArcView GIS by interpreting ortho-photo-quarter-quadrants of 1993 aerial photographs. Past land use patterns were derived using Cedar Creek 1938 and Middle Broad 1941 1:20,000 aerial photographs from the University of Georgia map library. Land use features were traced on acetate, digitized and registered to the USGS 7.5 minute topographic map, and then transported to ArcView GIS for areal calculations and map production.

## DATA AND CONCLUSIONS

### Morphometric Parameters

The Middle Broad has a high drainage density compared to other streams in the region: 2.99 vs. 2.07 and 2.38 for representative streams (Faye et al. 1980). Cedar Creek is more elongated (a .74 geometric development exponent) than other regional streams, which average .58 (Faye et al. 1980). The Middle Broad is more rugged than Cedar Creek and possesses markedly longer second order streams (Table 1).

**Table 1. Morphometric Parameters**

| | Cedar Cr | M Broad |
|---|---|---|
| Stream Length | 7.94 km | 7.95 km |
| Basin Area | 14.1 km2 | 21.48 km2 |
| Drainage Density | 2.35 | 2.99 |
| Geometric Dev. | 0.74 | 0.58 |
| Ruggedness | 0.01 | 0.22 |
| # 1st Order Streams | 15 | 29 |
| Avg. Length 1st Ord. | 748.5 m | 881.1 m |
| # 2nd Order Streams | 5 | 6 |
| Avg. Length 2nd Ord. | 674.6 m | 1707.2 m |
| 1-2 Bifurcation | 3 | 4.8 |
| Length 3rd. Ord. | 6003 m | 6776.3 m |

### Land Use

Cedar Creek has changed from primarily agricultural to 40% urban (mostly residential), while the Middle Fork of the Broad River has become more forested and less cultivated (Table 2).

### Discharge Patterns

A scatterplot of the results (Figure 1) illustrates that Cedar Creek bankfull discharges tend to be above the two year discharges of the comparable average rural stream, while the Middle Fork of the Broad discharges are slightly below. The ratios of the bankfull discharges as estimated from the cross sections to the two year discharge for the average rural stream of the same area derived from the equation of Stamey and Hess (Table 3) did differ significantly between the watersheds (p=.05). The estimated bankfull discharges were also tested for significance differences from the two year discharge of the average rural stream as derived

**Table 2. Past and Present Land Use Percentages**

| | M Broad | M Broad | Cedar Cr | Cedar Cr |
|---|---|---|---|---|
| % Land Use | (1993) | (1941) | (1993) | (1938) |
| Forested | 90.2 | 82.6 | 45.6 | 24.8 |
| Cultivated | 0.25 | 11 | 4.4 | 54.9 |
| Pasture | 4 | 2.9 | 7.7 | 20.3 |
| Clear cut | 4.1 | 2.9 | 0 | 0 |
| Debris flow | 0 | 0.55 | 0 | 0 |
| Residential | 1.4 | 0 | 31.7 | 0 |
| Dense urban | 0 | 0 | 10.6 | 0 |

from Stamey and Hess. No significance differences were found (p=.44 for Cedar Creek; p=.71 for Middle Broad). Drainage basin area, then, was found to be a primary control of discharge, as noted by Stamey and Hess (1993), with land use acting as a secondary control of bankfull discharge levels for the two basins studied here. Further, overbank flooding is more frequent in the urban streams: bankfull flows fill or exceed the channel at all sites in Cedar Creek, but only one site in the Middle Broad.

Although the discharge hypothesis was validated in general, two sites in the Middle Broad experienced higher than expected bankfull discharge levels. Both sites (B2 and B4) are fully forested and were also forested in 1938 and 1941, so land use does not explain the higher levels. But both basins are draining fairly steep areas. Site B2 is fed by first order streams with 10% to 11% slopes; Site B4 is located between 18% slopes. Further, Site B4 is quite low on the trunk, so the high drainage density of the Middle Broad basin may be contributing to increased discharge levels at the site. Thus, basin morphology appears to an important influence on discharge levels at this site.

**Table 3. Discharge Results**

| | Area (km2) | Est. Bankfull (cfs) | Avg. Rural 2 Yr 207A $^{.654}$ | Ratio: Est. Bankfull to Rural 2Yr. |
|---|---|---|---|---|
| C1A | 0.2 | 79 | 66.9 | 1.2 |
| C1B | | 28 | 66.9 | 0.4 |
| C2A | 0.48 | 349.9 | 115.3 | 3.0 |
| C2B | | 130.1 | 115.3 | 1.1 |
| C3A | 1.18 | 222.7 | 201.7 | 1.1 |
| C3B | | 248.5 | 201.7 | 1.2 |
| C4A | 3.45 | 788.7 | 393.2 | 2.0 |
| C4B | | 981.4 | 393.2 | 2.5 |
| C5A | 5.45 | 393.8 | 522.5 | 0.8 |
| C5B | | 793.1 | 522.5 | 1.5 |
| B1A | 0.1 | 37 | 43.5 | 0.9 |
| B1B | | 25.1 | 43.5 | 0.6 |
| B2A | 0.35 | 107.1 | 94.7 | 1.1 |
| B2B | | 95 | 94.7 | 1.0 |
| B2C | 0.91 | 112.5 | 94.7 | 1.2 |
| B3A | | 169.2 | 171.6 | 1.0 |
| B3B | | 155 | 171.6 | 0.9 |
| B4A | 3.86 | 603.5 | 421.6 | 1.4 |
| B4B | | 449.8 | 421.6 | 1.1 |
| B5A | 8.29 | 442.6 | 678.3 | 0.7 |
| B5B | | 404.8 | 678.3 | 0.6 |

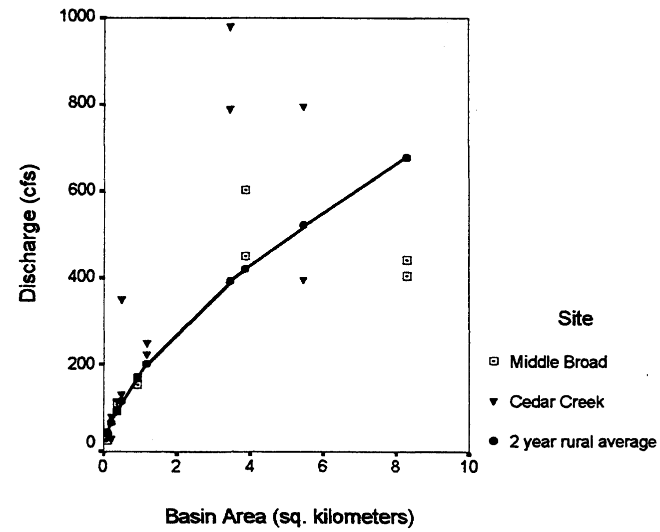


**Figure 1. Bankfull discharges at the study site cross sections in relation to the calculated two year discharge level of the average rural stream with the same basin area.**

**Sediment Patterns**

The hypothesis that the urbanizing basin would have a significantly higher proportion of non-gravel sediment than the forested basin was not validated. No significant difference in percent gravel (p=.33), sand (p=.62), or silt and clay (p=.22) was found between the two watersheds. Notably, Sites B3 and B4 have a lower proportion of gravel than other sites in the Middle Fork of the Broad River (Table 4). In addition, Site B5 is aggrading and has a bankfull discharge at the valley flat. The site has averaged one cm of deposition per year for the past 45 years. This was determined by coring a tree by the stream's side to derive its age, and dividing the amount of sediment covering the tree root by the age. Examination of past and present land use helps in interpreting the heavy sedimentation experienced at these sites. The 1941 aerial photographs show that clearing down to the stream for logging, cultivation and pasture, as well as a large debris flow, occurred rather extensively in these watersheds, and directly on all three sites. Nineteen percent of basin B4, 18% of B5 and 16% of B3 were non-forested. It is surmised that sediment from these antecedent activities (or even earlier events) is still passing through the basin. Although site B4 is remote, current practices are still contributing sediment to the other two sites. Site B3 remains pastured and partially cultivated, while Site B5 now has a parking area nearby.

**Table 4 Thalweg Sediment Texture**

| | % Fines | % Sand | % Gravel |
|---|---|---|---|
| B1 | 0.39 | 29.34 | 70.27 |
| B2 | 0.30 | 21.14 | 78.56 |
| B3 | 0.29 | 40.78 | 58.93 |
| B4 | 0.30 | 39.81 | 59.89 |
| B5 | 0.27 | 29.72 | 70.01 |
| C1 | 0.23 | 23.77 | 76.00 |
| C2 | 0.88 | 29.12 | 70.00 |
| C4 | 0.92 | 48.22 | 50.86 |
| C5 | 0.79 | 70.54 | 28.67 |

## DISCUSSION

In summary, Cedar Creek evidences the classic pattern of many urbanizing streams in the Georgia Piedmont, a pattern formed by past and present land use (Faye et al., 1980). The previous land use was heavily agricultural, causing stream aggradation and increased discharge levels. Subsequent reforestation (particularly in the southern portion of the basin) lowered discharges and sediment supply, enabling the stream to incise into the agricultural alluvium. Low density (single-family residential) urbanizing of the stream basin presumably has increased bankfull discharge levels once again. As the channels enlarge to accommodate the new flows, bank erosion is remobilizing the agricultural sediments stored in the valley. Discharge increases, except for site C4, are mild, probably because much of the new development is low versus high intensity urban. The elongation of the basin, promoting rapid flow into the trunk, may be exacerbating the more extreme conditions in C4 and C5, which are the furthest downstream..

The Middle Fork of the Broad evidenced the expected discharge patterns of a forested watershed. The streams are slowly incising, with well developed point bars below valley flat terraces. Above-expected discharge in two sites appears to be due to high relief. But the thalweg sedimentation patterns do not differ significantly from the urban watershed, presumably due to the continued impact of past land use, which involved clearing large areas down to the stream.

If this forested basin is experiencing disequilibrium, reference streams for third-order basins may not exist in the Georgia Piedmont due to past activities, making templates for stream restoration more difficult to devise. As Ferguson (1997) reported, in some instances streams will not return to equilibrium until some time in the future. Recognizing the relationships between past and present land use, basin morphometry, and stream discharge and sedimentation patterns will enable managers of stream restoration efforts to discern the causes of sediment deposition and flooding and so be able to set realistic goals.

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