ASSESSMENT AND ESTIMATION OF STREAMBANK EROSION RATES IN THE SOUTHEASTERN PLAINS ECOREGION OF MISSISSIPPI.

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Abstract: Sediment loads from watersheds located in the Southeastern Plain Ecoregion can have contributions from stream channel degradation as large as 90%. Monitoring and modeling techniques to assess the contribution of channel sediment to overall sediment load are needed to determine the reductions necessary to meet water quality standards. A study is performed with the main objective to evaluate streambank erosion rates and generate empirical correlations for estimating streambank surface erosion involving physical and geomorphic variables influencing this process for streams in the Southeastern Plains Ecoregion in Mississippi. Focusing on the Town Creek watershed in this ecoregion the study used a combination of methods including field reconnaissance and detailed data collection, surveying, and channel modeling. Watershed characterization and preliminary reports showed increased rates of sediments emanating from the northern headwaters of the watershed. Incised streams with unstable active streambank profiles near agricultural lands and limited or no riparian vegetation are common in the northern headwaters. Streambank failure events tend to be periodic and mainly occur during runoff season. Channel morphology changes from incised V-shaped channels to wide U-shaped channels with an accompanying increase in riparian vegetation density along the middle 20-km of the principal channel. Streambank erosion pin data along the middle 20-km of the principal channel showed negative average erosion depths (i.e., deposition) at most of the erosion pin plots. Although, jet tests showed streambank soils to be highly erodible. Preliminary results of watershed characterization and field observation show that streambank erosion and deposition rates are largely seasonal and depend on channel morphology.

INTRODUCTION

Accelerated streambank erosion is a major cause of non-point source pollution associated with increased sediment supply (Rosgen, 2001). Sedimentation is a significant environmental problem, with estimated mitigation costs of $16 billion annually in North America (Wynn and Mostaghimi, 2006). Increased streambank erosion results not only in accelerated sediment yield, but also destabilizes streams with associated changes in stream type. These adverse impacts can be observed in the Town Creek watershed, northeastern Mississippi. Sediment loads from watersheds located in the Southeastern Plains Ecoregion can have contributions from stream channel degradation as large as 90% (Simon et al., 2002).

The Town Creek watershed is located in the Southeastern Plains Ecoregion in Mississippi (Figure 1). Its total area covers 1,769 km^2 and represents approximately 50% of the upper Tombigbee River basin area contributing to the Aberdeen Pool on the Tennessee-Tombigbee Waterway. The sediment yield from the watershed greatly attributes to the estimated 320,000 T yr^{-1} of deposition in Aberdeen pool, where annual dredging averages 310,000 T yr^{-1}. To develop remedial measures and plan future BMPs for reducing water quality impairment and dredging costs (expressed in terms of a percent reduction of sediment loads) in Town Creek watershed, it is necessary to know the sediment sources and loads currently transported within the watershed. A sediment budget for a partial sub-basin (1,606 km^2) within the watershed is being developed by means of flow, streambank, streambed and suspended sediment monitoring, GIS applications, and modeling methods.

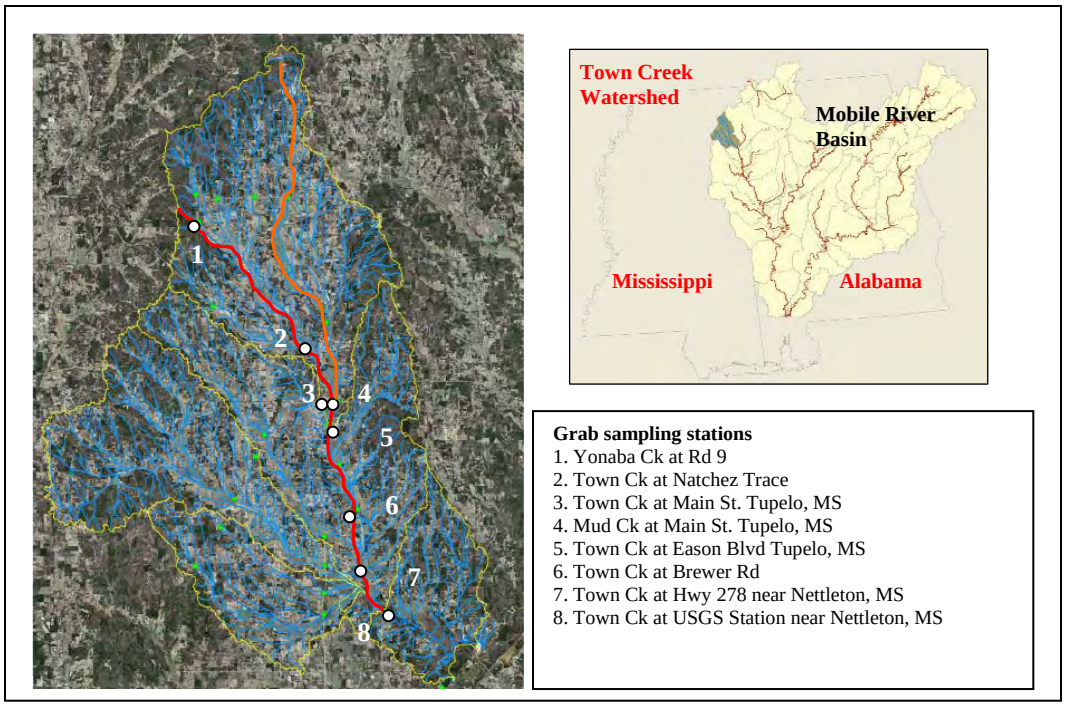


Figure 1. Location of the Town Creek watershed and the USGS gauging station 02436500 (Town Creek near Nettleton, MS).

Previous reports from this study documented the identification of geomorphic processes and a baseline of the water quality conditions within the area (Ramírez-Avila et al., 2009a; 2009c). This paper presents preliminary results of the streambank erosion monitoring and jet testing along the principal channel of the Town Creek watershed, in order to better understand how streambank erosion is affected by the position and characteristics of the eroding streambank in the watershed.

METHODS

Watershed Characterization: Field reconnaisance along the entire watershed was performed during summer 2008 to identify potential areas for establishing monitoring places for water quality and streambank erosion processes. The physiographic characterization of Town Creek Watershed has been performed by using GIS tools. Parameters such as watershed area and perimeter, watershed shape factors, watershed and channel slopes, watershed hypsometric characterization, channel length and profile, and land use were determined.

Watershed Monitoring: The data collection plan for the test watershed relied on four monitoring strategies: (a) spatially distributed grab sampling at 24 stations; (b) stream gauging and water sampling at 3 automatic monitoring stations; (c) streambank erosion monitoring using erosion pin arrays, cross section surveys, and jet testing; and (d) streambed sediment sampling. This document presents preliminary results of the erosion pin monitoring and jet testing from the third strategy.

Streambank Erosion Assessment: Eight field sites were established at two locations along the principal channel of Town Creek. The first field site was located at the edge of the northern headwaters near the bridge at the Natchez Trace with a drainage area of 350 km^2 (near grab sampling station #2, see Fig. 1). The transition from incised stream channels with unstable active bank profiles adjacent to agricultural lands to wide stable vegetated channels is the most representative condition at this site. The second field site was located near the Brewer Road bridge crossing (near grab sampling station #6, see Fig. 1), and can be characterized as a wide vegetated stable channel.

Streambank erosion rates at each site were monitored using 760 mm (30”) long and 6 mm (1/4”) diameter steel-rod erosion pins inserted perpendicularly into the streambank face. Pins were inserted into the streambank without disturbing the surrounding soil and 125 mm (≈5”) was left exposed. Each erosion plot array had at least 31 columns (1 m apart) in streamwise direction at both channel sides and four rows along the streambank height. During the monitoring period from September 2008 to August 2009, the exposed length of each pin was measured after each storm flow event.

Jet Testing: The erosion resistance of fine-grained materials can be measured in situ using a jet-test apparatus (Hanson and Cook, 2004). Jet testing was completed at all study sites to estimate a detachment rate coefficient (k_d) and a critical shear stress (τ_c) of the streambank materials present. Volumetric and disturbed streambank soil samples were collected at each study site and physical and chemical properties were determined at the

Environmental Laboratory of the Civil and Environmental Engineering Department of Mississippi State University.

PRELIMINARY STUDY RESULTS

Watershed Characterization: Ramirez-Avila et al. (2009b) found higher rates of increase in suspended sediment load and yield along the upper 20% of study area (350 km^2), representing the Northern headwaters of Town Creek watershed and the transitional zone upstream of the City of Tupelo, MS. At this drainage area flow discharge is about 25% and suspended sediment discharge is about 65% of that measured at the USGS station near Nettleton, MS, respectively (See Figure 1). Northern headwaters in Town Creek, located within the Black Prairie Subecoregion, exhibit incised streams with unstable active streambank profiles near agricultural lands. The most common gravitational failure mechanisms are slab failure, soil fall, and cantilever failure, accompanied by a basal clean out process when stormflow events occur. Streambank failure events at these channels tend to be periodic, most frequently occurring during stormflow events. Unstable conditions and resulting failures are frequently caused by saturation of the streambank, which decreases the strength of bank soils and increases soil unit weight. Field observations also evidenced seepage from intermediate soil layers along the incised streambanks causing piping and sapping failures. Agricultural practices near streambanks with limited or no riparian vegetation destabilize streambanks and favor gully erosion (Figure 2). Channel morphology changes from incised V-shaped channels to wide U-shaped channels with an increase in riparian vegetation density upstream of the Natchez Trace station (Figures 2 and 3).

Figure 2. (a) Gully erosion and (b) streambank erosion processes near agricultural areas at northern headwaters, and (c) transitional areas upstream of the Natchez Trace in the Town Creek watershed.

The middle 20 km of the principal channel system is located within the transitional zone between the Tombigbee Hills and the Black Prairie subecoregions. Wide stable channels showing evidence of streambank erosion induced by fluvial erosion, shallow slides, and rotational failures are mixed with natural, vegetated zones and regions with sediment deposition on streambed and streambanks (Figure 3). Especially along this section of the principal channel, sediment bed deposition and erosion are significantly modified seasonally by flow conditions. Low flow velocities and sediment deposition occur on the inside of incipient meander bends in the sinuous reach, along the downstream most 10 km before the outlet at the Tombigbee River.

Figure 3. Channel morphology and streambank sediment deposition along the middle 20 km of Town Creek.

The physiographic characterization of Town Creek yields a watershed shape factor (K_f) of 0.37 and a compactness coefficient (K_c) of 1.5 representative of an oblong oval area, and an asymmetric index (I_a) of 1.42, which is representative of a watershed with a principal channel located towards the eastern part of the watershed. This asymmetry could cause a possible reduction in contributing runoff for this part of the watershed. The watershed mean elevation is around 31.8 m (104 ft) amsl, and the maximum and minimum elevations are 72.2 m (237 ft) amsl and 17.4m (57 ft amsl), respectively. The length of the principal channel is 70.9 km (44.33 mi). The estimated average channel slope is 0.57 m km^{-1} (0.69 ft mi^{-1}) and the mean downstream slope is 0.25 m km^{-1} (1.3 ft mi^{-1}) (Figure 4).

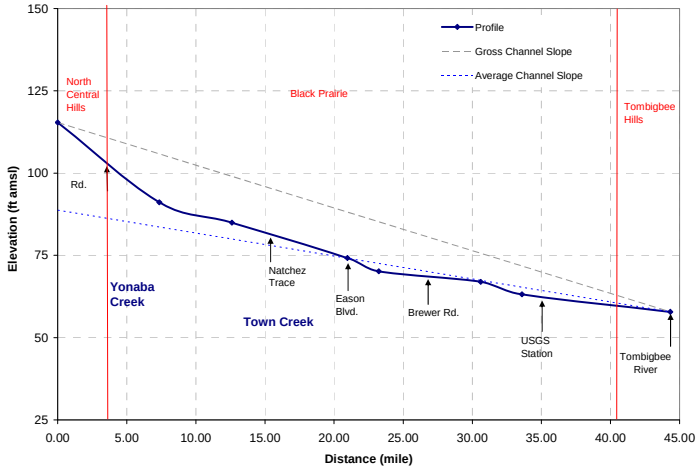


Figure 4. Profile and slope of the principal channel in Town Creek watershed (from Yonaba Creek at Road MS-9 to Town Creek outlet).

Land use of Town Creek watershed is presented in Figure 5 and Table 1. About 22% of the watershed total area is cultivated, the remaining lands are mainly pasture/hay lands (19%) and forest lands (29%). Agricultural practices significantly affect bank gully and streambank erosion processes where riparian vegetation is limited.

Table 1. Land use distribution at Town Creek watershed.

Land Use	% Area
Forest	29.1
Crops	21.5
Pastures	19.0
Shrublands	11.8
Wetlands	6.2
Urban	10.2
Water	1.5
Grassland	0.6
Bare rock	0.05

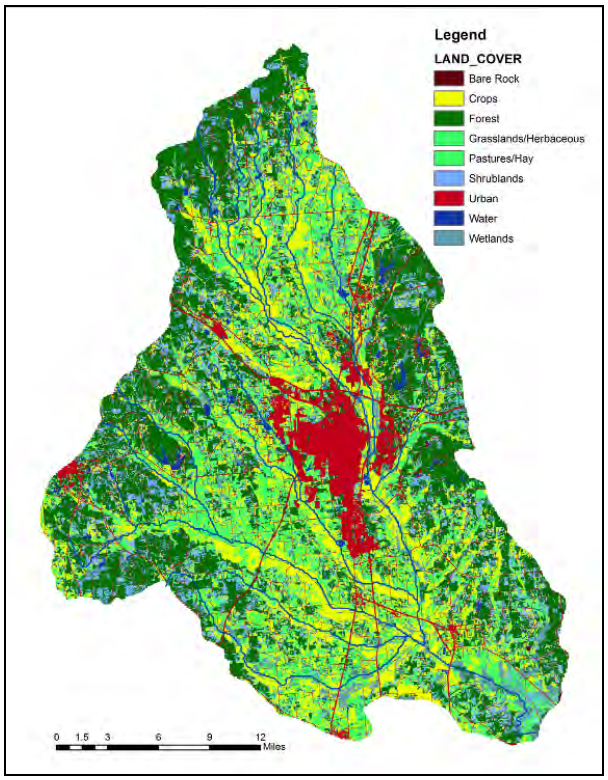
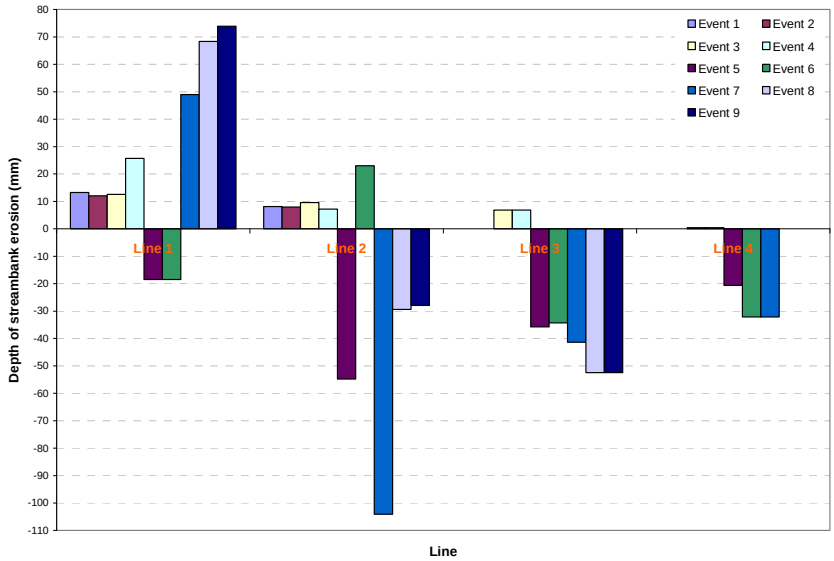
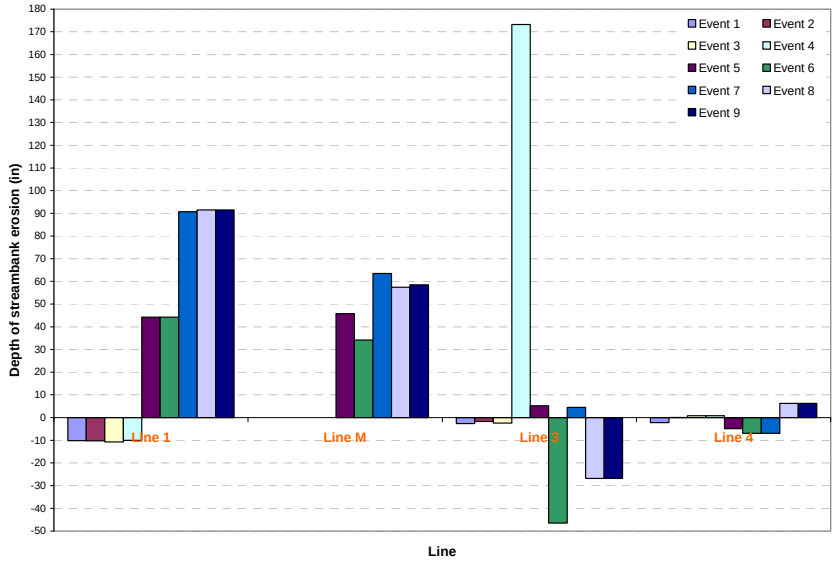


Figure 5. Town Creek Watershed - Land Use

Streambank Erosion Assessment: Nine storm flow events causing streambank erosion or deposition in at least the first row of pins occurred during the evaluated period from October 10, 2008 to April 16, 2009. Measured erosion depths ranged from 0.25 mm to 173 mm. On December 10, 2008 (Event 5) a bankfull flow event occurred (water level exceeded 8.5 m (28 ft) at the outlet), which produced both erosion and deposition on the erosion pin plots along each streambank at the Natchez Trace site (Figure 6) and significant amount of sediment deposition on the right streambank at the Brewer Rd site (Figure 3). Deposition rates ranged from 2.5 mm to 135 mm (negative values in Fig. 6) with maximum depths caused by the Event 5.



(A)



(B)

Figure 6. Mean erosion depths along (A) left streambank and (B) right streambank erosion pin plots on Town Creek at Natchez Trace, MS. (Sequential pin lines are: Line 1 at the toe streambank and Line 4 at 1 m below the top streambank)

Streambank erosion monitoring performed along the middle 20 km of the principal channel (at the Brewer Rd site) showed low streambank erosion rates dominated by fluvial erosion and high streambank deposition rates especially during the winter and the spring seasons (Ramirez-Avila et al., 2009a). Sediment deposition on streambanks was principally due to peak discharge attenuation during high stages on the Tombigbee River. Rising water levels on the Tombigbee River were affected by weather conditions, as well as by the presence of the Aberdeen lock, dam and pool on the Tenn-Tom Waterway, which is located only a few kilometers downstream of the Town Creek watershed mouth. Figure 7 shows the observed temporal changes in streambank morphology during the study period at the Brewer Rd site (A) and the Natchez Trace Site (B).

(A)

(B)

Figure 7. Temporal changes in erosion and deposition on erosion pin plots at (A) Brewer Rd and (B) Natchez Trace to determine streambank erosion rates along Town Creek, MS

Table 2 lists the observed erosion rates for the eight erosion pin plots between October 10, 2008 and April 16, 2009. Average erosion rate is greatest for Plot 4 at the Brewer Rd site. Deposition depths along Plots 5 and 6 at the Brewer Rd site and Plot 7 at the Natchez Trace site are very similar.

Table 2. Streambank erosion depth and volume per height of bank on pin erosion plots in Town Creek watershed, MS.

Site	Streambank	Plot	Mean Bank Erosion depth* (mm)	Soil Erosion Volume per bank height (m^3/m bank height)
Brewer Rd	Left	Plot 1	0.00	0.00
	Right	Plot 2	-12.7**	-4.43
	Left	Plot 3	-9.3	-57.53
	Right	Plot 4	25.6	10.26
	Left	Plot 5	-32.5	-249.94
	Right	Plot 6	-31.2	-59.82
Natchez Trace	Left	Plot 7	-32.2	-112.11
	Right	Plot 8	10.4	38.84

*Mean from all the pins on each erosion plot. **Negative values represent deposition.

Jet Testing: Results of the jet testing at the study sites are presented in Table 3. The values of τ_c and k_d indicate a wide range of erosion resistance among the test locations. Most streambank materials are fairly erodible that could generate high rates of streambank erosion along the principal channel. Although the streambank erosion rates have not been quantified yet, continuous visual inspection of the surveyed streambanks at the northern headwaters indeed show significant streambank erosion (Figures 8 and 9). Channel morphology and increasing riparian vegetation density appear to be the most important factors controlling streambank erosion rates along the middle 20 km of the

principal channel. Relationships between τ_c, k_d, and soil properties will be determined from the streambank soil laboratory analysis. These relations combined with flow characteristics obtained from computer modeling will allow predictions of watershed-scale streambank erosion rates.

Table 3. Summary of collected resistance-to-erosion data in Town Creek watershed, MS.

Test Location*	**Critical Shear Stress (τ_c) (Pa)**	**Detachment rate coefficient (k_d) ($cm^3\ N^{-1}\ s^{-1}$)**	**Erodibility Clasifications (Hanson and Simon, 2001)**
Yon 1	7.44	1.69	Erodible
Yon 2	4.22	4.08	Erodible to Very Erodible
Yon 3	2.02	95.55	Very Erodible
Yon 4	1.87	14.66	Very Erodible
Yon 5	2.01	15.09	Very Erodible
Yon 6	1.22	35.80	Very Erodible
Yon 7	0.80	22.15	Very Erodible
Yon 8	1.35	98.57	Very Erodible
Yon 9	4.38	2.94	Erodible
Yon 10	1.80	4.63	Erodible to Very Erodible
Yon 11	0.55	23.60	Very Erodible
Yon 12	0.39	5.93	Erodible to Very Erodible
Yon 13	0.14	24.09	Very Erodible
Yon 14	0.01	104.10	Very erodible
Br 15	1.57	16.13	Very erodible
Br 16	11.89	0.76	Erodible
Br 17	1.36	15.03	Very erodible
Br 18	0.92	6.73	Erodible to Very Erodible
Br 19	0.93	7.40	Erodible to Very Erodible
Br 20	0.72	46.44	Very erodible
Br 21	2.22	20.83	Very erodible
Br 22	0.34	33.00	Very erodible
Nat 23	0.52	7.69	Erodible to Very Erodible
Nat 24	0.34	12.55	Very erodible
Nat 25	0.44	105.30	Very erodible
Nat 26	0.10	20.60	Very erodible
Nat 27	0.05	62.71	Very erodible
Nat 28	2.73	9.51	Very erodible

* Yon: Yonaba Creek reach at the Northern headwaters; Br: Brewer Rd site; Nat: Natchez trace site

Figure 8. Streambank erosion process at a surveyed streambank in the Northern headwaters of Town Creek, MS.

Figure 9. Streambank erosion processes along a surveyed streambank reach at the northern headwaters of Town Creek, MS.

CONCLUSIONS

Preliminary results from watershed characterization, streambank erosion monitoring, jet testing, and field observations indicate that seasonal runoff (affecting streambank saturation and vegetation) and channel morphology (channel shape) are the more important factors affecting streambank erosion and deposition rates on streambanks and streambeds.

Implementation of management practices that protect streambanks and restore riparian vegetation are necessary within Town Creek watershed to obtain measurable improvements in water quality. Particularly in the northern headwaters, strategies to reduce suspended sediment load should focus on the attenuation of geomorphic processes and stabilization of reaches and adjacent agricultural lands.

Analysis of streambank soil properties in combination with computer modeling could offer more insight into the relative contributions of land and streambank erosion on the sediment budget of the watershed, stream water quality, and performance of conservation measures.

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