Changes in suspended sediment transport in the Town Creek Watershed: interpretation of sediment rating curves

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Town Creek Watershed

- Located in the northeastern part of Mississippi within the Southeastern Plains Ecoregion or Ecoregion 65
- Area: 1769 km²
- 50% upper Tombigbee River basin – Aberdeen Pool on TTW
- Estimated TCW $Q_s$: 320000 Mg yr$^{-1}$
- Estimated deposition on AP: 570000 Mg yr$^{-1}$
- Annual dredging AP: 280000 Mg yr$^{-1}$
Town Creek Watershed

- **MDEQ** - MS 2010 Section 303 (d) list of impaired waterbodies from headwater to mouth at the Tombigbee River
- **2006 TMDL** - streams located near cultivated lands, road crossings and construction activities - priority for streambank and riparian buffer zone restoration and $Q_s$ reduction
Justification

• To develop remedial measures and future BMPs within the Town Creek watershed for reducing water quality impairment and dredging costs (expressed in terms of a percent reduction of sediment loads), it is necessary to identify the sediment sources and loads currently transported within the watershed.
Hypothesis

• Streambank erosion is an important mechanism driving sediment supply in the Town Creek watershed, a representative area within the Southeastern Plains Ecoregion in Mississippi (also identified as Ecoregion 65)
Suspended Sediment Transport Analysis

- To identify trends and possible mechanisms driving sediment supply and exportation by evaluating spatial and temporal variation of suspended sediment yields and loads
- To determine the relations among the sediment rating parameters, suspended sediment load trends, channel evolution and watershed characteristics, in order to identify trends and possible mechanisms driving sediment supply and exportation
Analysis Procedure

- Variation of suspended sediment loads and yields on 7 stations along the principal channel
- Determined time trends and possible relationships between parameters in the different suspended sediment transport rating relations
Methods

• Spatially distributed grab sampling
  – Biweekly (May 2008 – May 2009)
  – 7 stations along principal channel
  – Stream velocity (Son Tek Flow)
Methods

• Automatic stream water sampling at 1 automatic monitoring station
  - Daily (February 2009 – May 2009)
  - ISCO model 2700 Station #8 (USGS station 02436500)

• Collection USGS database information for Q, SSC (1980 - 1995)
Grab sampling stations

1. Yonaba Ck at Rd 9
2. Town Ck at Natchez Trace
3. Town Ck at Main St. Tupelo, MS
4. Mud Ck at Main St. Tupelo, MS
5. Town Ck at Eason Blvd Tupelo, MS
6. Town Ck at Brewer Rd
7. Town Ck at Hwy 278 near Nettleton, MS
8. Town Ck at USGS Station near Nettleton, MS
Methods

• Laboratory Analysis
  – 500 ml (2 bottles)
  – Filtration TSS (SSC)
Results

- Variation of SS Loads
- Relative flow discharge, SS loads and yields for each station (May 2008 – May 2009)
Results

[Graph showing relative suspended sediment yield and relative flow discharge vs. area (km²)]

- Relative Suspended Sediment Yield
- Relative Suspended Sediment Discharge
- Relative Flow Discharge
Results

![Graph showing relative suspended sediment yield, sediment discharge, and flow discharge against area (km²)].

- **Relative Suspended Sediment Yield**
- **Relative Suspended Sediment Discharge**
- **Relative Flow Discharge**
Results

- Relative Suspended Sediment Yield
- Relative Suspended Sediment Discharge
- Relative Flow Discharge

Graph showing the relationship between area and relative fractions. Points are marked 0 to 8 on the map.

Inset images: Town Creek and road signs.
Results

[Graph showing relative suspended sediment yield, relative suspended sediment discharge, and relative flow discharge as a function of area (km²)].

- Red diamonds for relative suspended sediment yield.
- Brown diamonds for relative suspended sediment discharge.
- Blue triangles for relative flow discharge.

[Map with marked areas (1 to 8)].
Results

Relative fraction

Area (km²)

- Relative Suspended Sediment Yield
- Relative Suspended Sediment Discharge
- Relative Flow Discharge
Results
Results

• Analysis of suspended sediment transport rating relations ($Q_s = aQ^b$)
  – Annual Rating Curve
Results

Analysis of suspended sediment transport rating relations \( Q_s = aQ^b \)


\[ Q_s = 2.968Q^{1.6536} \quad R^2 = 0.93 \]
Results

Suspended Sediment Load (T yr$^{-1}$)

- Annual suspended sediment load estimated from entire dataset relation (Q) (T/yr)
- Average Annual suspended sediment load estimated from entire dataset relation (Q) (T/yr)
- Annual suspended sediment load estimated from individual annual relations (Q) (T/yr)
- Average Annual suspended sediment load estimated from individual annual relations (Q) (T/yr)

$Q_s = 1,073,433$ T yr$^{-1}$

$Q_s = 1,102,687$ T yr$^{-1}$
Results

\[ Q_s = aQ^b \]

\[ a = 148.39b^{7.498} \]

\[ R^2 = 0.77 \]
Results

Rate of increase in load ($b$) vs. Annual average instantaneous flow ($Q$) for different periods:

- **Early 90's (1991-1995) and 2008-2009**
  - $b = 1.8544Q^{-0.0554}$
  - $R^2 = 0.54$

- **Late 80's (1986-1990)**
  - $b = 2.7278Q^{-0.1277}$
  - $R^2 = 0.85$

- **Early 80's (1981-1985)**
  - $b = 2.5514Q^{-0.1304}$
  - $R^2 = 0.61$

**Outlier (1988)**
Results

\[ Q_s = 6.375Q^{1.5319} \]
\[ R^2 = 0.97 \]

\[ Q_s = 3.543Q^{1.5967} \]
\[ R^2 = 0.93 \]

\[ Q_s = 2.563Q^{1.7089} \]
\[ R^2 = 0.94 \]

\[ Q_s = 0.408Q^{1.864} \]
\[ R^2 = 0.94 \]
## Results

<table>
<thead>
<tr>
<th>Model</th>
<th>Rating curve coefficient a</th>
<th>Rating curve exponent b</th>
<th>R²</th>
<th>Effective Flow (Q₁.₅)</th>
<th>Daily Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Load (Td⁻¹)</td>
<td>Yield (Td⁻¹km²)</td>
</tr>
<tr>
<td>Early 80's (1981-1985)</td>
<td>6.375</td>
<td>1.545</td>
<td>0.97</td>
<td>106,433</td>
<td>66</td>
</tr>
<tr>
<td>Late 80's (1986-1980)</td>
<td>3.543</td>
<td>1.597</td>
<td>0.93</td>
<td>136,274</td>
<td>85</td>
</tr>
<tr>
<td>Early 90's (1991-1995)</td>
<td>2.563</td>
<td>1.709</td>
<td>0.94</td>
<td>158,336</td>
<td>99</td>
</tr>
<tr>
<td>May 2008-April 2009</td>
<td>0.408</td>
<td>1.864</td>
<td>0.94</td>
<td>68,597</td>
<td>40</td>
</tr>
<tr>
<td>Entire dataset (1401 records)</td>
<td>2.968</td>
<td>1.654</td>
<td>0.93</td>
<td>127,728</td>
<td>80</td>
</tr>
</tbody>
</table>

*Average annual value for the years in the cluster.

**Average annual value for continuous estimation from January 1 1981 to March 30 2008 and May 1 2008 to April 30 2009
Results

Stage of Channel Evolution

Rate of increase in load (b)

Early 80's
Late 80's
Early 90's
2008 - 2009

(Adapted from Simon, 1989)

(Simon, 1989)
Results

• In Stage I, yields are relatively low and are a function of contributions from sheet erosion and gully erosion in the fields.

• Following construction (Stage II), migrations of knickpoints up tributary streams cause a significant increase in yields during Stage III.

• Streambank failures by mass wasting during Stage IV serve to further increase yields.

• During Stage V, mass wasting slows, main channel exhibits much lower energy conditions, and yields decrease.

• Suspended sediment emanating from tributary streams and gullies continues to be delivered to main channel, thereby maintaining yields during net aggradational phases (Stage VI).
Conclusions

• High spatial and temporal variability of flow and suspended sediment concentrations, discharges and yields in the watershed

• Incised channels in the northern and western area are the major producers of sediment within the Town Creek watershed

• Sediment yield reduced at the watershed outlet when compared with sediment production from headwaters.
  – presence of natural and established sediment control structures
  – wide vegetated channels
  – significant increase in flow along the middle and lower area of the watershed
Conclusions

• Av. Qs at station #8 over 29-yr period 1,000,000 (260,000) Mg yr⁻¹

• SSY at effective flow (Q₁.₅) was 80 (40) Mg d⁻¹ km⁻²

• Both, temporal reduction of Qₙ at a specific instantaneous flow and rising of sediment rating exponent shows high erosion potential of important geomorphic processes in a specific area of the watershed

• Streambank erosion processes at the headwaters appear to be acting as the most significant sediment supplier and need to be reduced under a stream restoration process.
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It’s sedimentary, Watson!
Any question?
THANKS