Regression Analysis of Total Suspended Solids Concentrations to Estimate Streambank, Upland Field, and Classic Gully Sediment Contributions to Minnesota River Tributaries

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Acknowledgements

- Scott Matteson – High Island CWP, MNSU Water Resource Center
- Paul Wymar – Chippewa River CWP
- Watonwan River CWP
- Maple River CWP
- Scott MacLean – Little Cottonwood River, Seven Mile Creek CWP’s
- USGS
- Bill VanRyswyk - MDA
Sediment source contributions: what are the percentages?

Chetomba Creek

Photos courtesy of Stephanie Klamm – Hawk Creek CWP
Sediment Sources:

- Construction Sites
- Urban Stormwater
- Classic Gullies
- Agricultural Fields (includes sediment from open tile intakes)
- Streambanks and Bluffs
The Link Between Runoff Source and Sediment Source Contributions to Rivers
The Link Between Runoff Type and Sediment Source Contributions to Rivers

Bottom of ravine 10/18/07

Top of ravine 10/18/07
The Link Between Runoff Type and Sediment Source Contributions to Rivers

Maple River
Lower Monitoring Site
TSS Streambank Erosion Regression Method Example: Maple River

Map courtesy of Eileen Campbell - MPCA
Sampling Frequency
TSS Streambank Erosion Regression Method – Hypothesis

Lower Maple River Stream Bank Erosion Regression Samples

\[ y = 0.081x + 8.7161 \]

\[ R^2 = 0.8837 \]

- Non-SBE TSS Samples
- SBE TSS samples
- Linear (SBE TSS samples)
Step 1: Select Samples For SBE Regression

Example: Samples used in the 600 to 900 cfs sample category:
21 samples in entire sample set, 4 used in the SBE regression (19%)

Discharge Range of Sample Categories
Lower Maple River

<table>
<thead>
<tr>
<th>Sample Date</th>
<th>Flow</th>
<th>TSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4/22/2005</td>
<td>626.115</td>
<td>88</td>
</tr>
<tr>
<td>4/6/2007</td>
<td>881.282</td>
<td>88</td>
</tr>
<tr>
<td>5/23/2005</td>
<td>766.125</td>
<td>94</td>
</tr>
<tr>
<td>09/27/04</td>
<td>685.443</td>
<td>104</td>
</tr>
</tbody>
</table>

From each sample category approximately 20-25% of the samples with the lowest TSS concentrations are used in the stream bank erosion regression.

Example category 100-200 cfs

Example: Samples used in the 600 to 900 cfs sample category:
21 samples in entire sample set, 4 used in the SBE regression (19%)

Note - sub-samples selected represent the full range of flows in this category.
Step 2: Create SBE Regression

Stream Bank Erosion Regression
Lower Maple River 2003-2007

\[ y = 0.081x + 8.7161 \]
\[ R^2 = 0.8837 \]
Stream Bank Erosion Regression Samples and Daily Average Discharge
Lower Maple River

Date


Daily Average Discharge (cfs)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000

Flow
SBE Samples
Step 2: Compute Daily Streambank Erosion (SBE) Loads

With a Daily Average Discharge of 100 cfs, the estimated SBE TSS concentration using this regression would be 16.8 mg/L. The Daily TSS load from stream bank erosion is estimated to be 4114 kg (load = concentration x flow).
Step 3: Compute Seasonal Streambank Erosion Load
(generally 4/1 through 9/30)

Sum of Daily SBE loads = Seasonal SBE load
Step 4: Compute the Streambank Erosion Proportion of Seasonal TSS Loads

### Lower Maple River Streambank Erosion Contribution

<table>
<thead>
<tr>
<th>Year</th>
<th>Seasonal TSS Load (tons)</th>
<th>Seasonal Stream Bank Erosion TSS Load (tons)</th>
<th>% of Seasonal TSS Load from Stream Bank Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>20511</td>
<td>4190</td>
<td>20%</td>
</tr>
<tr>
<td>2004</td>
<td>111604</td>
<td>25572</td>
<td>23%</td>
</tr>
<tr>
<td>2005</td>
<td>93808</td>
<td>33129</td>
<td>35%</td>
</tr>
<tr>
<td>2006</td>
<td>24610</td>
<td>18217</td>
<td>74%</td>
</tr>
<tr>
<td>2007</td>
<td>36902</td>
<td>16953</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>Numeric 5 year average SBE contribution</td>
<td></td>
<td>40%</td>
</tr>
</tbody>
</table>
### Lower Maple River Streambank Erosion Contributions

<table>
<thead>
<tr>
<th>Year</th>
<th>Monitoring season dates</th>
<th>Lower Maple Seasonal TSS FWMC</th>
<th>Lower Maple Stream Bank Erosion TSS FWMC</th>
<th>% of TSS load from Streambank Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>4/24-10/1</td>
<td>264</td>
<td>54</td>
<td>20.4%</td>
</tr>
<tr>
<td>2004</td>
<td>3/21-10/18</td>
<td>561</td>
<td>129</td>
<td>23.0%</td>
</tr>
<tr>
<td>2005</td>
<td>4/1-10/26</td>
<td>353</td>
<td>126</td>
<td>35.7%</td>
</tr>
<tr>
<td>2006</td>
<td>3/31-10/4</td>
<td>140</td>
<td>103</td>
<td>73.2%</td>
</tr>
<tr>
<td>2007</td>
<td>3/20-10/26</td>
<td>171</td>
<td>79</td>
<td>45.9%</td>
</tr>
</tbody>
</table>

**Numeric 5 year average SBE contribution** 40%
## Summary Table – Average Streambank Erosion Proportion of Seasonal TSS Loads by Watershed

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Data Years</th>
<th>Average streambank erosion proportion of seasonal TSS load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watonwan R.</td>
<td>7</td>
<td>41%</td>
</tr>
<tr>
<td>High Island Cr.</td>
<td>5</td>
<td>31%</td>
</tr>
<tr>
<td>Little Cottonwood R.</td>
<td>7</td>
<td>20%</td>
</tr>
<tr>
<td>Chippewa R.</td>
<td>8</td>
<td>38%</td>
</tr>
<tr>
<td>7 Mile Cr.</td>
<td>8</td>
<td>20%</td>
</tr>
<tr>
<td>Maple River</td>
<td>5</td>
<td>40%</td>
</tr>
</tbody>
</table>
Computing Field and Classic gully
TSS Load Proportions
Upper Maple River Site
Upper Maple River SBE Regression

Regression equation:

\[ y = 0.0004x + 25.984 \]

\[ R^2 = 0.0018 \]

Discharge (cfs) vs. Total Suspended Solids Concentration (mg/L)

Graph showing the relationship between discharge and TSS concentration with the linear regression line and equation provided.
Streambank Erosion Proportion of Seasonal TSS Load by Year – Upper Maple River

<table>
<thead>
<tr>
<th>Year</th>
<th>Seasonal TSS FWMC</th>
<th>Streambank Erosion TSS FWMC</th>
<th>Field Erosion TSS FWMC</th>
<th>% of Seasonal TSS Load from SBE</th>
<th>% of TSS Load from Field Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>50.86</td>
<td>26.4</td>
<td>24.5</td>
<td>51.9%</td>
<td>48.1%</td>
</tr>
<tr>
<td>2007</td>
<td>61.57</td>
<td>26.3</td>
<td>35.2</td>
<td>43%</td>
<td>57.2%</td>
</tr>
</tbody>
</table>

Two Year numeric Average SBE contribution: 47%
## Upper Maple River - TSS Source Contributions

<table>
<thead>
<tr>
<th>Year</th>
<th>Seasonal TSS FWMC</th>
<th>Streambank Erosion TSS FWMC</th>
<th>Field Erosion TSS FWMC</th>
<th>% of Seasonal TSS Load from SBE</th>
<th>% of TSS Load from Field Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>50.86</td>
<td>26.4</td>
<td>24.5</td>
<td>51.9%</td>
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<td>2007</td>
<td>61.57</td>
<td>26.3</td>
<td>35.2</td>
<td>43%</td>
<td>57.2%</td>
</tr>
</tbody>
</table>

Two Year numeric Average SBE contribution: 47%
## Lower Maple River Source Contributions

<table>
<thead>
<tr>
<th>Year</th>
<th>Lower Maple Seasonal TSS FWMC</th>
<th>Lower Maple SBE TSS FWMC</th>
<th>Field Erosion TSS FWMC (computed from Upper Maple site)</th>
<th>% of TSS load from SBE</th>
<th>% of TSS load from Field Erosion</th>
<th>% of TSS load from Classic Gulleys</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>264.3</td>
<td>54.0</td>
<td></td>
<td>20.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>561.1</td>
<td>128.8</td>
<td></td>
<td>23.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>353</td>
<td>126.0</td>
<td></td>
<td>35.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>140</td>
<td>102.5</td>
<td>24.5</td>
<td>73.2%</td>
<td>17.5%</td>
<td>9.3%</td>
</tr>
<tr>
<td>2007</td>
<td>171.25</td>
<td>78.7</td>
<td>35.2</td>
<td>45.9%</td>
<td>20.6%</td>
<td>33.5%</td>
</tr>
</tbody>
</table>
Caveats and Criticisms

- Streambank Erosion from ice
- Rainfall on streambanks is not included
- Ephemeral gully erosion from tile outlets is included in the SBE calculation
- Too many samples: over-predicting SBE contributions
- More SBE occurs when flows are rising
Conclusions

- For the analyzed watersheds, on average no more than 40% of TSS load can be from SBE
- SBE proportions are variable from year to year: climate, timing of events affect TSS source contributions
- When field and gully erosion are the dominant sediment sources, streams are the dirtiest
- In some watersheds all major sediment source contributions can be determined with this method.
Daily Rainfall 2006 Lower and Upper Maple River Monitoring sites – Red bars are the Lower Maple 1.5”
2006 15 minute rainfall intensities and discharge at the Lower Maple site. During the early April rains (the two big events at the beginning of this hydrograph), the maximum one hour rainfall intensity was about 0.25”/hr. The maximum value on the scale is 0.5.” Note how little influence large intense rains have on these systems after crop canopies close.
Streambank/Bluff Erosion Estimates for High Island Creek Watershed

High Island Creek Watershed

Rush River Watershed
Percentage of Land with Slopes Greater than 12% by Watershed

Watonwan River Watershed and High Island Creek Watershed
Steeply Sloped Lands (>12%)

Watonwan River Watershed Outlet Area
- Watershed Acreage: 544,545
- Percentage of Watershed >12% Slope: 0.4%

High Island Creek Watershed Outlet Area
- Watershed Acreage: 152,149
- Percentage of Watershed >12% Slope: 1.2%

Map Prepared by: Scott Matteson
Water Resources Center, Minnesota State University, Mankato
5/2006
EXPLANATION

Slope classes are based upon percent slope values calculated from the USGS Digital Elevation Model (DEM) data. DEM elevation data are based upon USGS 24,000 scale topographic maps. Elevation data are collected at 50-meter (198.4-ft) intervals.

<table>
<thead>
<tr>
<th>ACRES</th>
<th>PERCENT</th>
<th>SLOPE CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>146,483</td>
<td>90%</td>
<td>&lt;= 3%</td>
</tr>
<tr>
<td>3,593</td>
<td>2%</td>
<td>&gt; 3% and &lt;= 6%</td>
</tr>
<tr>
<td>1,586</td>
<td>1%</td>
<td>&gt; 6% and &lt;= 12%</td>
</tr>
<tr>
<td>1,558</td>
<td>1%</td>
<td>&gt; 12%</td>
</tr>
</tbody>
</table>

INDEX MAP

PRIMARY SAMPLE AREAS

LOCATION MAP
2002 High Island Creek
Daily Average Discharge and Total Suspended Solids Concentrations

Discharge (cfs)
0 200 400 600 800 1000 1200 1400

Date

Flow
Smpl collected

25% of the TSS at a higher flow
30 fold difference
4 fold difference
30 fold difference
4.5 times less sediment at a higher flow
30 fold difference

12-61 1380 1660 1730
53 6575 232 327
606 354 191 327
25 236 673 990

191 990 236 673
140 327
2001 High Island Creek Total Suspended Solids Load