Minnesota River Basin:
Near Stream Sediment Sources

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Background

• The Le Sueur contributes a disproportionate amount of sediment pollution to the Minnesota River and Lake Pepin
  – Only comprises 7% of the basin land surface area
  – A majority of the watershed has slope steepness less than 2%
  – 53% TSS

• Why?
Sources of Sediment

- Gully and ravine erosion
- Stream bank and bluff erosion
- Upland sheet and rill erosion

- Where are these sources located?
- What are the relative influences of changes in climate and land use/land management?
Ravines
Ravines
Minnesota River Basin Ravines
Slumping River Bluffs
Slumping River Bluffs
## Minnesota River Ravines and Bluffs

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Area (ac)</th>
<th>Ravines (ac)</th>
<th>Bluffs (ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Le Sueur</td>
<td>711,607</td>
<td>1354</td>
<td>245</td>
</tr>
<tr>
<td>Blue Earth</td>
<td>991,705</td>
<td>1,657</td>
<td>156</td>
</tr>
<tr>
<td>Cottonwood</td>
<td>839,800</td>
<td>2,727</td>
<td>52</td>
</tr>
<tr>
<td>Watonwan</td>
<td>561,431</td>
<td>598</td>
<td>27</td>
</tr>
<tr>
<td>Chippewa</td>
<td>1,326,637</td>
<td>2,401</td>
<td>2.5</td>
</tr>
<tr>
<td>Redwood</td>
<td>451,267</td>
<td>971</td>
<td>4.9</td>
</tr>
<tr>
<td>Hawk-Yellow</td>
<td>1,327,131</td>
<td>3,463</td>
<td>37</td>
</tr>
<tr>
<td>Lac Qui Parle</td>
<td>701,727</td>
<td>2,584</td>
<td>32</td>
</tr>
<tr>
<td>Lower</td>
<td>1,164,358</td>
<td>10,601</td>
<td>19.8</td>
</tr>
<tr>
<td>Middle</td>
<td>862,030</td>
<td>6,657</td>
<td>9.9</td>
</tr>
<tr>
<td>Upper</td>
<td>1,319,227</td>
<td>13,259 (small)</td>
<td>0</td>
</tr>
</tbody>
</table>
Total Suspended Solids
Seven Mile Creek Watershed

*Four Year Flow Weighted Average, 2000-2003
Estimated Sediment Sources
Seven Mile Creek Watershed

- Riparian: 49%
- Open Tile Intakes: 13%
- Upland: 31%
- Streambank Erosion: 7%
SWAT Modeling

• SWAT stands for SOIL and Water Assessment Tool

• SWAT model was developed by the USDA-ARS Laboratory in Temple, Texas.

• Why the SWAT Model?
  – User friendly and uses readily available input data
  – Computationally efficient: reasonable time
  – Accepted by the scientific and regulatory agencies
SWAT Modeling

- Developed to predict impacts of land management practices on watershed hydrology and water quality.
- Deterministic physically based and spatially distributed continuous watershed scale model:
  - Models known upland physical processes.
  - Channel sources can be estimated by difference.
Processes Modeled by SWAT

Upland Landscape Processes:
Weather, Hydrology, Plant growth, Erosion, Nutrients (N, P), Ag Management

Source: SWAT Model Theoretical Document, 2000
Beauford minor watershed SWAT model

Validation of Sediment Yield (Year 2001-2005)

- Beauford: NSE 0.61
- Measured 961 t/yr
- Predicted 994 t/yr

SWAT model accurately predicts upland sediment
Measured and SWAT Predicted Annual Water Yield: Le Sueur River Watershed (1990-2006)

NSE=97%

SWAT model accurately predicts Le Sueur watershed discharge
Measured and SWAT Predicted Annual Sediment Yields: Le Sueur River Watershed Mouth 2000-2005

Upland Sources Account for only 22% of Measured Load

SWAT model fails to predict channel sources of sediment
SWAT Upland Sediment Yields

Percent of sediment load from upland areas:
Upper Le Sueur  24%
Big Cobb       65%
Maple         38%

Legend
- Watershed Boundary
- Sub-watershed Boundary
SYLD, ton/ha
- < 0.25
- 0.25 - 0.65
- 0.66 - 1.00
- 1.01 - 2.00
- > 2.00
Ecological Ranking Project

• To more effectively target conservation programs to CRP lands and other critical upland regions such as
  – Marginally productive croplands
  – Surface water protection areas
  – Important habitat areas
Data layers for ecological ranking

- Potential Soil Erosion
- Terrain Analysis
- Surface Water Proximity
- Habitat Quality

Soil erosion risk + Water quality risk + Habitat quality rating

Environmental Benefits Index

Final Priority Ranking
Environmental Benefits Index (EBI)
http://www.bwsr.state.mn.us/ecological_ranking/

- High EBI means:
  - high risk (e.g. water erosion)
  - high quality (e.g. habitat)
  - high value for conservation
Seven Mile Creek study

Weather Inputs
- Precipitation
- Temperature
- Wind Speed
- Relative Humidity
- Solar Radiation

Land Cover (NLCD)
Soils - SSURGO
Digital Elevation Model
Management Practices
Flow-Sediment relationship at watershed outlet

\[ y = 548.02x^{1.925} \]

\[ R^2 = 0.9851 \]
Model performance – including non-field sources

Validation - including non-field sources
Observed Mean = 461.2 t
Predicted Mean = 452.1 t
NSE = 0.95
Seven Mile Creek: Sediment sources

Field sources

Non-field sources
Alternative Landscape Results – Sediment

- Sediment - Non-Field Sources
- Sediment - Field Sources

- Baseline
- Conservation Tillage
- Low P (50% of baseline)
- Nd P
- All Prairiegrass
- All Switchgrass
- Forest
- 25 m stream buffer
- 250 m stream buffer
- 250 m wildlands buffer
- SP 1
- SP 2

Average Annual Sediment (tons)
Effects of Climatic Variability on Seven Mile Creek Discharges

Seven Mile Creek Land Management Changes Simulated

- Area in agricultural production increases
- Cropping system changes (soybeans replaces alfalfa and small grains)
- Crop yield increases
- N fertilizer application rates, forms and timing
- Adoption of conservation tillage increases
- Tile drain spacing decreases (area tile drained increases)
Simulated Climate Scenarios

- 5 year continuous measured climate record centered around 1967, 1978 and 2001 with actual landuse and management information
Discharge Trends With and Without Climatic Variability

(Horizontal % changes due to effect of climate, Vertical % changes due to effects of management)

- 70% increase
- 51% decrease
- 6% decrease
- 21% decrease

- Actual climate
  - 1967: 11.0 Mm³
  - 1978: 11.6 Mm³
  - 2001: 13.8 Mm³

- 1999-2003 climate
  - 1967: 18.7 Mm³
  - 1978: 17.5 Mm³
  - 2001: 13.8 Mm³
Influence of Changing Climate on Flows in the Minnesota River at Mankato
Annual - Flows Minnesota River at Mankato (1932-2005)

- Peakflow trend 240 cfs/yr, p-value = .0016
- Mean Flow trend 66 cfs/yr, p-value = .000003
PDSI as a Metric for Climate

- Palmer Drought Severity Index (PDSI)
- Accounts for precipitation, temperature, AWC, and latitude
- Range of values from (+8 - -8) comparable across regions and time scales
- PDSI is calculated independent of actual stream discharge or runoff
Annual - Average PDSI vs. Mean Flow in Minnesota River at Mankato
1930-2005

Correlation Coefficient = 0.83
Yearly Change in Flow on the Minnesota River at Mankato with and without the Effects of Climate Change

Note that flow trends are smaller when climate effects are removed. Non-climatic effects are largest during May and June – periods of greatest tile drainage.
Comparing Area Normalized Discharge: 16 Small Minnesota River Basin Watersheds Forty Year Discharge Data Records

Note that steeper watersheds have larger discharge than flatter watersheds.
Changes in Normalized Discharge (16 small watersheds before and after 1979)

% Change in Peak Flow for STEEP & FLAT Watersheds

Flatter watersheds reduce impacts of climate change on peak flow more than steeper watersheds with less tile drainage.
Conclusions

- Slumping river bluffs are a major source of sediment, particularly in the Le Sueur and Blue Earth watersheds.
- Ravines are locally important sources of sediment, particularly along the Minnesota River Valley bluff and the Coteau bluff.
- Upland agricultural sources of sediment are generally smaller than river bluffs, but larger than ravines.
- Streambank erosion is locally important, but of variable magnitude.
Conclusions

• Minnesota River mainstem discharge at Mankato has increased 66 cfs/yr since 1932, while peak flow has increased 240 cfs/yr

• An increasingly wetter climate during this same period was strongly correlated with increased Minnesota River discharge

• After removing effects on discharge of an increasingly wetter climate, non-climatic factors were also found to increase discharge, particularly during May and June
Conclusions

• Increased discharge in Seven Mile Creek is strongly correlated with increased streambank erosion

• Discharge in Seven Mile Creek has increased significantly since 1967 due to an increasingly wetter climate

• If climate were constant, changes in land management and cropping systems during the same period would have reduced discharge by 29%, despite increases in tile drainage

• Increased biomass and ET of corn helps reduce river discharge and channel sediment loss
Conclusions

• Steeper watersheds with less tile drainage have greater mean discharge at all return periods than flatter watersheds with more tile drainage

• An increasingly wetter climate has increased peak discharge significantly in steeper watersheds, but not in flatter watersheds

• Climate change effects are a more important driver of increased river discharge than increased tile drainage
Thank You. Questions?