Sources of Suspended Sediment in the Le Sueur River

St. Croix Watershed Research Station / SMM
Dept. of Soil, Water & Climate / UMN
National Center for Earth Surface Dynamics
What’s the problem?
1. Turbidity impairment of water quality
2. Accelerated infilling of Lake Pepin

What do we want to know?
1. What is the source of the sediment?
2. How has that changed over time?
Lake Pepin Sedimentation

1,500,000 m³ per year

Natural (background)
Why the Le Sueur?

- Between 80-90% of the TSS entering Lake Pepin arises in the Minnesota River Basin.
- On average 65% of the TSS leaving the Minnesota River Basin arises from the Le Sueur and Blue Earth River watersheds.

![Graph showing TSS Loads (tons/yr) for Blue Earth and Le Sueur, with MN River Average of 809,000 t/yr.]
Geologic Context

Source of Relief in Lower Le Sueur River

- The draining of Glacial Lake Agassiz 11,500 $^{14}C$ yr BP carved the Minnesota River valley
- Incision of the MN River spawned knickpoints, ~60 m high at the mouth of the Blue Earth/Le Sueur Rivers.
- Knickpoints are still migrating upstream.
- The migration of knickpoints upstream leads to high relief seen in lower Le Sueur.

Source of Fine-grained sediment

- Le Sueur River drains the area covered by Glacial Lake Minnesota
- Fine-grained lacustrine silts and clays cap ~3/4 of the watershed.
- These sediments are easily erodible.
Three Cooperative Studies (w/different approaches)

Sediment Budget & Routing Model
  National Center for Earth Surface Dynamics / Univ. of MN (and others)

Ravines and Bluffs Inventory
  Soil, Water & Climate and Biosystems Engineering / Univ. of MN

Sediment Fingerprinting
  St. Croix Watershed Research Station / Science Museum of MN
Sediment budget and routing model, Le Sueur River Watershed

Patrick Belmont, Stephanie Day, Karen Gran, Carrie Jennings, Andrea Johnson, J. Wesley Lauer, Gary Parker, Lesley Perg, Peter Wilcock
Goals and Approaches for study

Primary Goal:
Develop a sediment budget and routing model for the Le Sueur River watershed that incorporates
-- Contributions from bluffs, ravines, uplands, and stream banks
-- Sediment exchange in and out of storage in floodplains

Approach:
– Geomorphological assessment, surficial mapping, granulometry
– Measurement of contemporary sediment fluxes at gaging stations
– Annual surveys of bluffs
– Meander migration and bluff retreat from air photos (65 year record)
– Sediment provenance study with cosmogenic radionuclides
– Sediment routing model
Slope-Area Analysis shows presence of two major knickpoints

The biggest knickpoint is located 35-40 km upstream of the mouth on all three major branches of the Le Sueur River.

This knickpoint has migrated an average of 3 m/yr upstream for the past 11,500 yr.

The major knickpoint at 35-40 river km on all 3 branches essentially separates the rivers into two sections. Major bluffs and ravines are primarily confined to the river below the knickpoint.

A smaller knickpoint is located far upstream on all three branches. This knick moved an avg. of 10 m/yr upstream, and may have been eroding glacial lake sediments and loose tills only. This knick triggered smaller ravines and bluffs.
Blue Earth County LiDAR was used to measure the total volume eroded from major ravines and river valleys.

Minimum volume eroded: $1.9 \times 10^9$ Mg
If divide by 11,500 years: $1.6 \times 10^5$ Mg/yr

This is similar to current rates of TSS.

However, rates were likely NOT the same for the past 11,500 yrs. We need to understand changes in sediment flux over this time to determine what presettlement sediment flux rates were.

Much of this history is recorded in river terraces in the lower valleys.
Terraces have been mapped on all 3 major channels. They record incision history.
3 sets of paired gages record changes in sediment flux as the river passes through the lower knick zone.

The paired gaging stations show large increases in sediment load with minor increases in discharge.

These paired gages will be used to help constrain inputs to the routing model.
Ground-based side-scanning LiDAR:
Used to directly measure annual bluff retreat rates.

- **2007**
  - 25 scans
  - 12 sites

Grain size analyses of floodplain deposits along the 3 major channels.

Air photo analyses from 1938 to 2003 to measure bluff retreat and channel migration rates over 65 years.

- Average channel migration rate on mainstem LS River:
  - 20 cm/yr

Mouth of Le Sueur R.

- **1938**
- **2003**

0 0.5 1 Kilometers
Other constraints on sediment inputs from different sources

Cosmogenic nuclides to get the bluff contributions as a relative proportion of total sediment budget.

Al$^{26}$ and Be$^{10}$ are produced near the surface at a ratio of 6.1.

If they are buried, these nuclides decay, and the ratio declines.

Work by Balco et al. (2005) indicates buried tills in the Minnesota River Valley have ratios of 3.5.

We can use this as a tracer of bluff contributions.
Ravines and River Bluffs in the Le Sueur Watershed

David Mulla, Joel Nelson, John Nieber, Bruce Wilson, Brad Hansen
University of Minnesota
Background

• A few studies have been conducted to estimate TSS loads in the Blue Earth River watershed arising from stream bluffs, none have been conducted in the Le Sueur River watershed.

• No studies have been conducted to quantify the TSS loads arising from ravines in the Minnesota River Basin.

• HSPF modeling for the Minnesota River Basin sediment TMDL requires estimates of sediment contributions from ravines, bluffs and streambanks.
Ravine Identification - Methodology

- ESRI ArcGIS 9.2 Software Suite
- USGS 30 m digital elevation model (DEM)
- Terrain attributes
  - Specific catchment area
  - Slope
  - Stream power index
  - Profile curvature
Blue Earth County Ravines

Watonwan River Watershed

Le Sueur River Watershed

Blue Earth River Watershed
Preliminary Ravine Results – Le Sueur River Watershed

- **Area**
  - Watershed area 288,072 ha
  - Preliminary ravine area 2,083 – 2,734 ha (0.7-0.9% of watershed)

- **Sediment Loss**
  - Watershed TSS load 283,000 t/yr
  - Ravine TSS load TBD
Le Sueur and Blue Earth River Bluff Locations

Blue Earth Bluffs
- 258 sites
- 19 sites
- 139 sites
- 198 sites

Le Sueur Bluffs
- 614 sites

Blue Earth Bluffs
- 216 sites
Maple River
Conclusions

• Ravines can be accurately located using GIS and terrain analysis with 30 m DEMs

• Ravines have an impact on TSS loads in the Le Sueur River watershed that is out of proportion with their areal coverage (0.7-0.9%)

• The number of stream bluffs ranges from 216 in the Blue Earth River watershed to 614 in the Le Sueur River watershed

• Stream bluff slumping contributes large quantities of TSS to the Blue Earth and Le Sueur River watersheds
A new method for Fingerprinting Riverine Suspended Sediments

Shawn Schottler, Dylan Blumentritt, Daniel Engstrom
St. Croix Watershed Research Station / Science Museum of Minnesota

\[ y = 0.65 + 4.8x \quad R^2 = 0.58 \]
The Question:
How much from upland field erosion? vs. How much from non-field sources?

The Challenge:
How to quantify... ..and believe the answer?
...Fingerprinting Fundamentals

- **Cultivated Field**
- **Bank (etc.) Sediment**
- **Suspended Sediment**

**Constant Exposure to Atmosphere and Rain**

**Minimal Exposure to Atmosp. and Rain**

![Graph showing Pb-210 activity (bq/g)](image)
Seepage lakes as integrated reference systems

- No incoming rivers
- Time integrated
- Upland source integrated...
  ... sheet + rill + gully

Archive of Field Erosion Fingerprint

George Lake, Blue Earth Co.
... other integrator sites

Riverine Depositional (Integrator) Sites

Sites like Kasota Pond:
- collect and store suspended sediment
- integrate upstream erosion processes

Excess $^{210}\text{Pb} = 1.4 \text{ pCi/g}$
Relative Field Contribution to Riverine Sediment
Average of Cs and Pb methods

S. Fork Crow = 42%
Lake Pepin = 22%
Source of Sediment to Pepin---*Why change over time??*

<table>
<thead>
<tr>
<th>Year</th>
<th>Field (%)</th>
<th>Non-field (%)</th>
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</thead>
<tbody>
<tr>
<td>1996</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>1964</td>
<td>33%</td>
<td>67%</td>
</tr>
<tr>
<td>1940</td>
<td>83%</td>
<td>17%</td>
</tr>
<tr>
<td>Pre~1860</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>
... if you express as loading, some sources not really changing

- Field constant (or decreasing)
- Non-field constant until c. 1940
- Non-field accelerating since 1940
Project Timelines

Sediment Budget & Routing Model

Ravines and Bluffs Inventory

Sediment Fingerprinting