Examining Impaired Waters from Different Angles
Multi-Prong Monitoring to Support the Lower Minnesota River Model

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Sponsors

Metropolitan Council
Lower Minnesota River Watershed District
Metropolitan Airports Commission
Minnesota Pollution Control Agency
US Army Corps of Engineers
US Geological Survey
First, the truth about water-quality monitoring in Minnesota…
Lake Pepin Watershed

Lake Pepin Basins

<table>
<thead>
<tr>
<th>BASIN</th>
<th>Feature</th>
<th>Area (Kilometers$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannon River Basin</td>
<td>Lake Pepin Watershed</td>
<td>122,575</td>
</tr>
<tr>
<td>Minnesota River Basin</td>
<td></td>
<td>218,480</td>
</tr>
<tr>
<td>St. Croix River Basin</td>
<td></td>
<td>105,368</td>
</tr>
<tr>
<td>Upper Mississippi River Basin</td>
<td>Lake Pepin Watershed with in Minnesota</td>
<td>105,368</td>
</tr>
</tbody>
</table>

US Map: Minnesota River Basin Data Center
Sources Upstream of Lake Pepin

Mississippi River at Anoka
- NOx: 80%
- TSS: 82%
- TP: 63%

St. Croix River at Stillwater
- NOx: 17%
- TSS: 15%
- TP: 29%

Minnesota River at Jordan
- TKN: 48%
- TSS: 82%

Based on Median Pollutant Mass Load (tonnes/year) from 1992 - 2001

Regional Progress in Water Quality, Metropolitan Council, 2004
Bridge Over Troubled Waters

- **Waste Load Allocation Study (1985)**
  - Lower Minnesota River: BOD/DO, NH4
  - Effluent limits for point sources
  - 40% reduction goal for nonpoint sources

- **Impaired Waters & TMDL Studies**
  - Mississippi & Minnesota Rivers: Turbidity (2009)
  - Lake Pepin: Nutrients (2009)

- **Water-Quality Models**
  - Minnesota River Basin, miles 300-40 (HSPF)
  - Mississippi River Model, Pools 2-4 (ECOM-RCA)
  - Lower Minnesota River, miles 40-0 (?)
Lower Minnesota River

Problems

- Oxygen, turbidity, bacteria, PCBs, mercury
- Excessive algae, nutrients, sediment

Stressors

- Large agricultural watershed
- Rapid growth in SW Metro Area
- Point-source dischargers
- Navigation

Minnesota Valley National Wildlife Refuge
Scoping Workshop, February 2003

• What are the issues and our priorities?
  – Oxygen, ammonia, nutrients, sediment

• Which model should we apply?
  – CE-QUAL-W2 Model, USA-ERDC
  – Mississippi River Model, HydroQual & MCES

• What are the model data requirements?
  – Tom Cole & others, USA-ERDC
  – Pooled experience of partners
Monitoring Program, 2003-2006

• Base monitoring over three years
  – River, tributaries, and discharges

• Intensive low flow monitoring
  – River flow < 2000 cfs during June-Sept

• Special field studies
  – Hydrodynamics (e.g., mixing, ground water)
  – Oxygen (e.g., reaeration, oxygen demand)
  – Nutrients (e.g., P dynamics, sediment fluxes)
  – Algae (e.g., growth factors, oxygen balance)
  – Sediment (e.g., distribution, characteristics)
Long-Term Water-Quality Monitoring Program
Metropolitan Council Environmental Services

[Map showing water-quality monitoring sites in the Metropolitan Area.]
Ground-Water Inflows

- Conducted at low river flows in late summer
- Measured river flow at multiple sites with ADCP
- Measured tributary flows near base of bluff
- Estimated ground-water inflows or outflows by difference
- Concluded that ground-water inputs are minor
Sediment Bed Assessment

- Conducted at low river flows with seismic profiler
- Profiled sediment along shores and transects every 200 ft
- Collected some sediment cores and noted sediment type
- Metropolitan Council later mapped the sediment bed
River Sediment Types

- Gravel-Rock
- Gravel-Sand
- Hardclay
- Sand
- Silt
- Silt-sand

Sediment Bed Map

Minnesota River, Mile 1
# Mixing Characteristics

Vertical Difference in Dissolved Oxygen > 0.5 mg/L

<table>
<thead>
<tr>
<th>Date</th>
<th>Discharge</th>
<th>Average water temperature, degrees C</th>
<th>River Mile</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>39.4</td>
</tr>
<tr>
<td>July 29, '03</td>
<td>2880</td>
<td>27.0</td>
<td>YES</td>
</tr>
<tr>
<td>Aug 21, '03</td>
<td>1160</td>
<td>27.1</td>
<td>YES</td>
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<tr>
<td>Sep 24, '03</td>
<td>554</td>
<td>16.4</td>
<td>YES</td>
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<tr>
<td>Apr 22, '04</td>
<td>1640</td>
<td>13.9</td>
<td>YES</td>
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<tr>
<td>Jun 2, '04</td>
<td>16900</td>
<td>16.9</td>
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<tr>
<td>Aug 11, '04</td>
<td>4880</td>
<td>20.0</td>
<td></td>
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</table>
Surface Dissolved Oxygen (mg/L)
Lower Minnesota River, 8/21/03

Distance from mouth (miles)
Distance along transect (ft)

Surface Dissolved Oxygen (mg/L)
Lower Minnesota River, 8/21/03
Representative Sampling
Equal-Width-Increment Versus Discrete
Phosphorus Fractions: Soluble & Particulate
Percent of Load, Minnesota River at Jordan, 2006

- Soluble P
- Loosely-bound PP
- Iron-bound PP
- Labile organic PP
- Aluminum-bound PP
- Calcium-bound PP
- Refractory organic PP

Green = Biologically Labile PP
Blue = Biologically Refractory PP

Nutrient Dynamics and Budgetary Analysis of the Lower Minnesota River: 2003-2006, W.F. James, USA-ERDC, 2008
Phosphorus Sorption

- Measured equilibrium P concentration, the tipping point for P attachment to particles
- EPC roughly equals mean ambient SRP (.11 mg/L)
- Concluded that TSS buffers SRP at higher flows but algae & point sources regulate P dynamics at lower flows
Chlorophyll-a & Soluble Reactive P Concentrations
Minnesota River at Jordan & Ft Snelling, 2004-2006

Nutrient Dynamics and Budgetary Analysis of the Lower Minnesota River: 2003-2006, W.F. James, USA-ERDC, 2008
Sediment P Release Rates

- Related to iron-bound P
- Related to silt content
- Mean Oxic = 4 mg/m²/d
- Mean Anoxic = 21 mg/m²/d
- <10% of total P budget

Nutrient Dynamics and Budgetary Analysis of the Lower Minnesota River: 2003-2006, W.F. James, USA-ERDC, 2008
## Percent Load Contributions in 2006

Sample of Budgetary Analyses for 2004-2006

<table>
<thead>
<tr>
<th>Source</th>
<th>Flow</th>
<th>TSS</th>
<th>TKN</th>
<th>NOX</th>
<th>NH4</th>
<th>TP</th>
<th>SRP</th>
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</thead>
<tbody>
<tr>
<td>River at Jordan</td>
<td>95.0</td>
<td>91.6</td>
<td>92.9</td>
<td>97.3</td>
<td>89.1</td>
<td>88.4</td>
<td>82.9</td>
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<tr>
<td>Monitored Streams</td>
<td>3.6</td>
<td>8.4</td>
<td>5.5</td>
<td>1.2</td>
<td>6.7</td>
<td>7.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Point Sources</td>
<td>1.5</td>
<td>0.0</td>
<td>1.6</td>
<td>1.5</td>
<td>4.2</td>
<td>4.2</td>
<td>12.7</td>
</tr>
<tr>
<td>Retention (-) or Export (+)</td>
<td>+1.1</td>
<td>-22.0</td>
<td>-3.6</td>
<td>-3.9</td>
<td>+43.2</td>
<td>-10.9</td>
<td>-12.7</td>
</tr>
</tbody>
</table>

*Nutrient Dynamics and Budgetary Analysis of the Lower Minnesota River: 2003-2006, W.F. James, USA-ERDC, 2008*
Summer Low Flow Studies

- **Intensive river monitoring (MCES)**
  - Weekly sampling at 10 sites for 8-12 weeks

- **Synoptic sonde survey (MPCA)**
  - Sondes suspended from buoys deployed for several days at 6 sites plus grab samples

- **Oxygen dynamics assessment (HydrO₂)**
  - Measure oxygen sources and sinks from the atmosphere, sediment, and water
Compared to Low Flow Target of 2000 cfs
Dissolved Oxygen (mg/L), Minnesota River at Mile 3.5
MCES Continuous Monitoring, July-September 2003
Oxygen Dynamics Assessment
HydrO₂, Inc. with MCES & MPCA

- Reaeration
- Atmospheric diffusion
- Community oxygen metabolism
- Water-column production and respiration
- Sediment oxygen demand
- Community substrate oxygen demand
Figure 4, Minnesota River Reaeration

Lower Minnesota River: Oxygen Dynamics Assessments, HydrO₂, Inc., 2007
2006 Minnesota River GPP:R

River Mile

gmO2/m²/day

July

Aug/Sep

Lower Minnesota River: Oxygen Dynamics Assessments, HydrO₂, Inc., 2007
Lower Minnesota River: Oxygen Dynamics Assessments, HydrO₂, Inc., 2007
Challenges

- Equipment Deployment
- Navigation Effects
- Backwashing
- Black Dog Generating Plant
- High Quality Effluent
- CBOD Measurement
- TOC Measurement
Navigation Effects on Water Quality
Mean Annual CBOD5 Concentration
River and Effluent, 1985-2004

CBOD5 (mg/L)

85-89 90-94 95-99 00-04

MI 39.4 Blue Lake Seneca
Preliminary Model Results

- **TDS**: Graph showing the trend of Total Dissolved Solids (TDS) over days.
- **ISS**: Graph for Inorganic Suspended Solids (ISS) showing fluctuations.
- **PO4**: Graph for Phosphate (PO4) indicating variations.
- **NH4**: Graph for Ammonium (NH4) displaying its concentration over days.
- **NO3**: Graph for Nitrate (NO3) with changes over time.
- **DSI**: Graph for Dissolved Soluble Inorganic (DSI) showing peaks and troughs.
Paddle on down to our website:
www.metrocouncil.org/environment/Water/LMRM/