Lower Great Miami River Nutrient Management Project

**Agenda:**

- **Project Goal**
- **Overview of Work Completed**
  - Original Model Development and Application
  - Supplemental Modeling
- **Nutrient Reduction Scenarios**
  - Overview
  - Summary of Results
- **Findings**
Project Goal:

- “...develop a water quality model that builds on...sampling by the WRRFs, MCD, OEPA and others...”
  - Include “...nutrient sources...and the necessary water quality and nutrient transport dynamics...”
  - Scientifically sound

- Use model to estimate the effect of nutrient reduction on dissolved oxygen and algal growth in the river
Overview of Work Completed
Lower Great Miami River Nutrient Management Project

Original Work Completed:
• Data compilation and review
• Model selection
• Model development & calibration
  – Watershed model
  – River hydrodynamic model
  – River water quality model
• Apply model to nutrient reduction scenarios

Report available on MCD web site:  https://www.mcdwater.org/water-studies/
Supplemental Scenarios:

• Apply model to additional nutrient reduction scenarios
  – What nutrient load reduction is needed to move the water quality needle?
  – Evaluate the potential benefits of reducing non-point source and point source phosphorus loads
  – Evaluate the effect of nitrogen load reductions
Nutrient Reduction Scenarios

Overview
Nutrient Reduction Scenarios:

- Simulate potential real-world management actions to comparatively evaluate the water quality benefits.
# Lower Great Miami River Nutrient Management Project

## Nutrient Reduction Scenarios

<table>
<thead>
<tr>
<th>Point Sources</th>
<th>Agricultural Non-Point Source Load Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No change</td>
</tr>
<tr>
<td>No change</td>
<td>Baseline</td>
</tr>
<tr>
<td>Dayton &amp; Montgomery Co. effluent 0.75 mg-P/l</td>
<td>✓</td>
</tr>
<tr>
<td>Dayton &amp; Montgomery Co. effluent 0 mg-P/l</td>
<td>✓</td>
</tr>
<tr>
<td>All major WRRFs in WQ domain effluent 0.75 mg-P/l</td>
<td>✓</td>
</tr>
<tr>
<td>All major WRRFs in WQ domain effluent 0 mg-P/l</td>
<td>✓</td>
</tr>
<tr>
<td>All major and minor WRRFs effluent 0.75 mg-P/l</td>
<td>✓</td>
</tr>
<tr>
<td>All major and minor WRRFs 60% TN reduction</td>
<td>✓</td>
</tr>
<tr>
<td>All major and minor WRRFs 60% TN reduction and All major and minor WRRFs effluent 0.75 mg-P/l</td>
<td>✓</td>
</tr>
<tr>
<td>All major and minor WRRFs effluent 0 mg-P/l</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Details:
- TP limit of 1 mg/l was simulated assuming 0.75 mg/l (53% ortho-P)
- Applied July-October only; historical conditions for November-June
- Point source TN reductions were applied the entire year
### Average Annual TP Load Reduction into the LGMR

<table>
<thead>
<tr>
<th>Point Sources</th>
<th>Agricultural Non-Point Source Load Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No change</td>
</tr>
<tr>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Dayton &amp; Montgomery Co. effluent 0.75 mg-P/l</td>
<td>1.5%</td>
</tr>
<tr>
<td>Dayton &amp; Montgomery Co. effluent 0 mg-P/l</td>
<td>2.5%</td>
</tr>
<tr>
<td>All major WRRFs <em>in WQ domain</em> effluent 0.75 mg-P/l</td>
<td>2.8%</td>
</tr>
<tr>
<td>All major WRRFs <em>in WQ domain</em> effluent 0 mg-P/l</td>
<td>4.8%</td>
</tr>
<tr>
<td>All major and minor WRRFs effluent 0.75 mg-P/l</td>
<td>5.0%</td>
</tr>
<tr>
<td>All major and minor WRRFs 60% TN reduction</td>
<td></td>
</tr>
<tr>
<td>All major and minor WRRFs 60% TN reduction and All major and minor WRRFs effluent 0.75 mg-P/l</td>
<td>5.0%</td>
</tr>
<tr>
<td>All major and minor WRRFs effluent 0 mg-P/l</td>
<td>7.9%</td>
</tr>
</tbody>
</table>

*Original Scenarios*

*Supplemental Scenarios*
## Average Jul-Oct TP Load Reduction into the LGMR

<table>
<thead>
<tr>
<th>Point Sources</th>
<th>Agricultural Non-Point Source Load Reductions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No change</td>
</tr>
<tr>
<td>No change</td>
<td>-</td>
</tr>
<tr>
<td>Dayton &amp; Montgomery Co. effluent 0.75 mg-P/l</td>
<td>11%</td>
</tr>
<tr>
<td>Dayton &amp; Montgomery Co. effluent 0 mg-P/l</td>
<td>17%</td>
</tr>
<tr>
<td>All major WRRFs <em>in WQ domain</em> effluent 0.75 mg-P/l</td>
<td>20%</td>
</tr>
<tr>
<td>All major WRRFs <em>in WQ domain</em> effluent 0 mg-P/l</td>
<td>33%</td>
</tr>
<tr>
<td>All major and minor WRRFs effluent 0.75 mg-P/l</td>
<td>34%</td>
</tr>
<tr>
<td>All major and minor WRRFs 60% TN reduction</td>
<td>-</td>
</tr>
<tr>
<td>All major and minor WRRFs 60% TN reduction and All major and minor WRRFs effluent 0.75 mg-P/l</td>
<td>34%</td>
</tr>
<tr>
<td>All major and minor WRRFs effluent 0 mg-P/l</td>
<td>55%</td>
</tr>
</tbody>
</table>

*Original Scenarios*  
*Supplemental Scenarios*
Nutrient Reduction Scenarios

Results
Nutrient Reduction Scenario Results

- Model results are shown in two ways:
  - Time series plots for Fairfield, 2011 – 2013
  - Results shown are monthly average values.
- Results are for August 31, 2012, which was the lowest flow date during the simulation period (460 cfs).
- The plots are oriented with upstream on the left, downstream on the right.
TP = 0.13 mg/l suggested as a potential management target for over enriched waters
R.J. Miltner, 2018, Eutrophication endpoints for larger rivers in Ohio, USA. *Environ Monit Assess.*
TN Time Series Plot

Great Miami River at Fairfield, OH

- **Baseline**
- **WRRF ↓N 60%**
- **WRRF ↓P 1 mg/l**
- **WRRF ↓N,P**
- **WRRF ↓N,P & agri NPS ↓N,P 75%**

**Total Nitrogen (mg/l)**

Month

Jan-11, Feb-11, Mar-11, Apr-11, May-11, Jun-11, Jul-11, Aug-11, Sep-11, Oct-11, Nov-11, Dec-11, Jan-12, Feb-12, Mar-12, Apr-12, May-12, Jun-12, Jul-12, Aug-12, Sep-12, Oct-12, Nov-12, Dec-12, Jan-13, Feb-13, Mar-13, Apr-13, May-13, Jun-13, Jul-13, Aug-13, Sep-13, Oct-13, Nov-13, Dec-13
Sestonic Algae Time Series Plot

Great Miami River at Fairfield, OH

- Baseline
- WRRF ↓N 60%
- WRRF ↓P 1 mg/l
- WRRF ↓N,P
- WRRF ↓N,P & agri NPS ↓N,P 75%

Sestonic Chlorophyll (µg/l)

Month

Jan-11 to Dec-13
Diurnal DO Time Series Plot

Great Miami River at Fairfield, OH

- **Baseline**
- **WRRF ↓N 60%**
- **WRRF P 1 mg/l**
- **WRRF ↓N,P**
- **WRRF ↓N,P & agri NPS ↓N,P 75%**

The graph shows the diurnal dissolved oxygen (DO) concentration over a year from January 2011 to December 2013 for the Great Miami River at Fairfield, OH. The data is color-coded to represent different pollution reduction scenarios. The x-axis represents the months from January 2011 to December 2013, and the y-axis represents the diurnal DO range (mg/l).
Nutrient Reduction Scenario Results

• Model results are shown in two ways:
  – Time series plots for Fairfield, 2011 – 2013
    • Results shown are monthly average values.
  – Longitudinal plots for the entire LGMR model domain
    • Results are for August 31, 2012, which was the lowest flow date during the simulation period (460 cfs).
    • The plots are oriented with upstream on the left, downstream on the right.
Nutrient Reduction Scenario Results

- Longitudinal plots for the 8/31/12 low flow date
- Key locations shown as vertical lines
TP Longitudinal Plot

Great Miami River, 8/31/2012

- Baseline
- WRRF ↓N 60%
- WRRF P 1 mg/l
- WRRF ↓N,P
- WRRF ↓N,P & agri NPS ↓N,P 75%

Total Phosphorus (mg/l)

River Mile
DIP Longitudinal Plot

Great Miami River, 8/31/2012

- Baseline
- WRRF ↓ N 60%
- WRRF P 1 mg/l
- WRRF ↓ N, P
- WRRF ↓ N, P & agri NPS ↓ N, P 75%

Dissolved Inorganic Phosphorus (mg/l)

River Mile

NO2+NO3 Longitudinal Plot

Great Miami River, 8/31/2012

- Baseline
- WRFF ↓N 60%
- WRFF P 1 mg/l
- WRFF ↓N, P
- WRFF ↓N, P & agri NPS ↓N, P 75%

Nitrate+Nitrite (mg/l)

River Mile

110 100 90 80 70 60 50 40 30 20
Sestonic Algae Longitudinal Plot

Great Miami River, 8/31/2012

- Baseline
- WRRF ↓N 60%
- WRRF P 1 mg/l
- WRRF ↓N,P
- WRRF ↓N,P & agri NPS ↓N,P 75%

Sestonic Chlorophyll a (μg/l)

River Mile
Diurnal DO Longitudinal Plot

Great Miami River, 8/31/2012

- Baseline
- WRRF ↓ N 60%
- WRRF P 1 mg/l
- WRRF ↓ N, P
- WRRF ↓ N, P & agri NPS ↓ N, P 75%

River Mile

Diurnal DO Range (mg/l)
Findings:

- Drastic, systematic reductions in phosphorus loading are needed before noticeable improvements in dissolved oxygen and algal growth are predicted.
Findings:

- Water quality (i.e., algae, dissolved oxygen) in the LGMR responds to reductions in both phosphorus and nitrogen, but the response to phosphorus reductions is relatively greater than the response to nitrogen reductions.
Findings:

• Phosphorus concentrations in the LGMR are sensitive to reductions in agricultural non-point source phosphorus loads on an average annual basis, but are relatively insensitive during critical low flow periods.
Questions?

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Discussion
Limitation on the Effects of TP Load Reductions

- Phosphorus is still too high to limit algal growth
Limiting Nutrients: Liebig’s Law of the Minimum

• Growth is dictated not by total resources available, but by the scarcest resource
  – Based on observations that increasing the amount of plentiful nutrients did not increase plant growth

• Water quality management ramifications
  – Often* most efficient to control algal growth by reducing one nutrient to limiting levels
  – Site-specific determination of whether N or P is the most cost-effective to limit**

*Not meant to imply that co-limitation doesn’t exist, just that it is typically more economical to control a single nutrient

**As a general rule, P has been the most economical to limit in the Midwest. N is more economical to limit in the western US and estuarine waters, due to the relative abundance of naturally-occurring P in those areas.
## General Water Quality Parameters

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Initial value(s)</th>
<th>Calibrated value(s)</th>
<th>Recommended Range (or Value)</th>
<th>Units</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_{89C}$</td>
<td>Mineralization rate of LDOP</td>
<td>0.10</td>
<td>0.10</td>
<td>0.1</td>
<td>/day</td>
<td>QEA, 2009</td>
</tr>
<tr>
<td>$K_{1415C}$</td>
<td>Nitrification rate at 20°C</td>
<td>0.075</td>
<td>0.30</td>
<td>0.1 – 1.0</td>
<td>/day</td>
<td>Brown and Barnwell, 1987</td>
</tr>
<tr>
<td>$K_{150C}$</td>
<td>Denitrification rate at 20°C</td>
<td>0.10</td>
<td>0.05</td>
<td>0.03</td>
<td>/day</td>
<td>QEA, 2009</td>
</tr>
<tr>
<td>$K_{1921C}$</td>
<td>Hydrolysis rate of LPOC</td>
<td>0.10</td>
<td>0.10</td>
<td>0.08</td>
<td>/day</td>
<td>QEA, 2009</td>
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<tr>
<td>$K_{210C}$</td>
<td>Oxidation rate of LDOC</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>/day</td>
<td>QEA, 2009</td>
</tr>
</tbody>
</table>

## Sestonic Algae

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Initial value(s)</th>
<th>Calibrated value(s)</th>
<th>Recommended Range (or Value)</th>
<th>Units</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_C$</td>
<td>Saturated growth rate</td>
<td>2.0-2.3</td>
<td>2.2-2.6</td>
<td>1.5-2.5</td>
<td>/day</td>
<td>Thomann &amp; Mueller 1987</td>
</tr>
<tr>
<td>$I_S$</td>
<td>Saturating algal light intensity</td>
<td>150-200</td>
<td>50</td>
<td>100-400</td>
<td>ly/day</td>
<td>Chapra 1997</td>
</tr>
<tr>
<td>$K_{mN}$</td>
<td>Half saturation constant for N</td>
<td>0.005-0.020</td>
<td>0.010-0.020</td>
<td>0.010-0.020</td>
<td>mg-N/L</td>
<td>Chapra 1997</td>
</tr>
<tr>
<td>$K_{mP}$</td>
<td>Half saturation constant for P</td>
<td>0.005</td>
<td>0.005</td>
<td>0.001-0.005</td>
<td>mg-P/L</td>
<td>Chapra 1997</td>
</tr>
</tbody>
</table>

## Benthic Algae

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Initial value(s)</th>
<th>Calibrated value(s)</th>
<th>Recommended Range (or Value)</th>
<th>Units</th>
<th>Reference(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRMAXBA</td>
<td>Zero-order maximum growth rate</td>
<td>250</td>
<td>400-1000</td>
<td>15-500</td>
<td>mg-Chla/m²/day</td>
<td>Flynn et al. 2013</td>
</tr>
<tr>
<td>KMPBA</td>
<td>External P half-saturation constant</td>
<td>0.125</td>
<td>0.125</td>
<td>0.005-0.175</td>
<td>mgP/L</td>
<td>Flynn et al. 2013</td>
</tr>
<tr>
<td>KQPBA</td>
<td>Intercellular P half-saturation constant</td>
<td>0.00325</td>
<td>0.00325</td>
<td>0.000625-0.0125</td>
<td>mgP/mgC</td>
<td>Flynn et al. 2013</td>
</tr>
<tr>
<td>RMAXBA</td>
<td>Maximum respiration rate</td>
<td>0.2</td>
<td>0.4</td>
<td>0.02-0.8</td>
<td>/day</td>
<td>Flynn et al. 2013</td>
</tr>
<tr>
<td>EXCBA</td>
<td>Excretion rate</td>
<td>0</td>
<td>0.2</td>
<td>0-0.8</td>
<td>/day</td>
<td>Flynn et al. 2013</td>
</tr>
<tr>
<td>DTHBA</td>
<td>Death rate</td>
<td>0.3</td>
<td>0.2</td>
<td>0-0.5</td>
<td>/day</td>
<td>Flynn et al. 2013</td>
</tr>
<tr>
<td>KMLBA</td>
<td>Light half-saturation constant</td>
<td>100</td>
<td>50</td>
<td>30-90</td>
<td>ly/day</td>
<td>Flynn et al. 2013</td>
</tr>
</tbody>
</table>
This report documents work related to the development, calibration and initial application of a water quality model of the lower Great Miami River (LGMR), Ohio. This work was conducted by LimnoTech under contract to the Miami Conservancy District (MCD), on behalf of a partnership of Water Resource Recovery Facilities (WRRFs). The partnership includes: the cities of Dayton, Englewood, Fairfield, Franklin, Hamilton, Miamisburg, Middletown, Springboro, Troy, Union, and West Carrollton; Tri-Cities Wastewater Authority on behalf of the cities of Huber Heights, Vandalia, and Tipp City; and Montgomery County. The purpose of this work was to conduct a scientifically sound evaluation of the potential effects of nutrient load reduction on water quality in the LGMR.

As a result of a water quality investigation of the LGMR conducted by the Ohio Environmental Protection Agency (OEPA) and policy set forth in the 2013 Ohio Nutrient Reduction Strategy, the OEPA notified NPDES permittees in the LGMR that the OEPA was planning to write numeric phosphorus limits into permits starting with the next permit renewal cycle. Although extensive data collection up to this point had defined conditions in the LGMR that were potentially attributed to excessive nutrient loading, specifically large diurnal DO variation and high sestonic chlorophyll, a model had not been developed to evaluate that relationship and estimate the effect of reducing phosphorus loading on these conditions. Several of the WRRFs that would be subject to phosphorus limits in their NPDES permits decided to fund the development of such a model.

The primary purpose of the LGMR water quality model is to comparatively evaluate the water quality benefits of different potential levels of nutrient load reduction, reduction of nutrients from different sources and/or other potential actions, such as dam removal. As part of this project, seven scenarios were run, each of which involved some aspect of potential nutrient load reduction. Those scenarios and their results are described in this section.
Watershed model

- Used existing HSPF models from MCD
  - Orig. dev. for flood eval.
- Repurposed models by recalibrating hydrology
- Calibrated for nutrients