The University of Minnesota Water Resources Center: My Vision, My Experience

Mark B. David
University of Illinois at Urbana-Champaign
November 20, 2014
What I will cover

- vision for a water resources center in Minnesota
  - land with a diversity of water resources
  - current activities
  - possible directions
  - this would be developed as I knew more
- how am I prepared for this
  - academic training
  - research, teaching, and outreach experience
  - leadership
  - I like snow
- recent water quality work examples
Disclaimer

• difficult to state vision without talking to stakeholders, understanding resources

• my first task as director would be a visiting and listening tour

  – tens of thousands of lakes, streams and rivers, Lake Superior, and the Mississippi River
  – I want to see and hear about the water resource issues of the state
  – university, state, farm groups, NGOs, and public
  – former director (who left a strong center)
Current/recent programs

- onsite sewage treatment program
- wetland delineator certification program
- conservation drainage field days
- Minnogram
- reports and guides
- research symposiums
- Minnesota Water Conference
- Climate change impacts on water resources
Center vision

• the land-grant resource in the state, providing research, education, and outreach

• known for strong science in water issues in both the state and nationally
  – one of 54 water resource institutes across country

• education of students (Water Resources Science Graduate Program)

• public engagement on all aspects of water resources
  – homeowners to farmers to communities
  – work with, be a part of extension
Center vision

• integration of biophysical and social sciences
  – too often focus on technological solutions without the human side

• center where the sciences come together to solve problems (all involve people)

• graduate education must include both aspects for water resource issues

• strong linkages to other centers, departments, agencies, groups on and off campus
My preparation

• broad academic training
• a wide range of aquatic systems
• a variety of watersheds
• integrated projects
  – research (biophysical and social)
  – education
  – outreach
Teaching experience

• introductory courses to graduate
  – intro to NRES in various formats
  – a range of field courses on water resources
  – ecosystem biogeochemistry for graduate students
  – seminar/discussion courses for graduate students

• courses have a wide diversity of students

• should all students take a environmental science course?
Leadership

- graduate and teaching coordinator positions in department
- associate head, acting head
- research teams
- various positions in agronomy society
- led Illinois Science Assessment team that is basis for the Nutrient Loss Reduction Strategy
Outreach experience

• dozens of talks to a wide range of groups within and outside of Illinois
• extensive interaction with farm and point source communities
• present best information possible
Illinois Nutrient Loss Reduction Strategy

- led science assessment
  - riverine loads, nutrient sources
  - methods to reduce losses
  - costs and application across the state
  - point and non point
  - peer reviewed

- public process
  - still underway
Point and agricultural sources (1997-2011)

Riverine Load (million lb N or P yr\(^{-1}\))

- Vermilion
- Green
- Rock
- Illinois
- Embarras
- Kaskaskia
- Little Wabash
- Big Muddy
- Illinois-All

**Nitrate-N**

- Goal

**Total P**

- Goal
Nitrate-N and Total P Targets

Red line is target, purple is average 1997 to 2011
Illinois Nutrient Sources

**Total N**
- 82% Agricultural
- 16% Point sources
- 2% Urban runoff

**Nitrate-N**
- 80% Agricultural
- 18% Point sources
- 2% Urban runoff

**Total P**
- 48% Agricultural
- 48% Point sources
- 4% Urban runoff
What agricultural practices are available?

- three types of conservation practices could help
  - nutrient-use efficiency (4Rs)
  - in-field management (cover crops, drainage water management, complex rotations, perennials)
  - off-site measures (wetlands, bioreactors, two stage ditches, riparian buffer strips, saturated buffers)
Cover crops - annual ryegrass and radish - aerial seeding 09-08-12
Woodchip bioreactors
Constructed wetlands
Point source P and N removal

$13.71/lb for total P at 1.0 mg/L

$3.30/lb for total N at 10 mg/L
## Example Statewide Results for N

<table>
<thead>
<tr>
<th>Practice/Scenario</th>
<th>Nitrate-N reduction per acre (%)</th>
<th>Nitrate-N reduced (million lb N)</th>
<th>Nitrate-N Reduction % (from baseline)</th>
<th>Cost ($/lb N removed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td>410</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing N rate from background to the MRTN (10% of acres)</td>
<td>10</td>
<td>2.3</td>
<td>0.6</td>
<td>-4.25</td>
</tr>
<tr>
<td>Nitrification inhibitor with all fall applied fertilizer on tile-drained corn acres</td>
<td>10</td>
<td>4.3</td>
<td>1.0</td>
<td>2.33</td>
</tr>
<tr>
<td>Split (50%) fall and spring (50%) on tile-drained corn acres</td>
<td>7.5 to 10</td>
<td>13</td>
<td>3.1</td>
<td>6.22</td>
</tr>
<tr>
<td>Fall to spring on tile-drained corn acres</td>
<td>15 to 20</td>
<td>26</td>
<td>6.4</td>
<td>3.17</td>
</tr>
<tr>
<td>Cover crops on all corn/soybean tile-drained acres</td>
<td>30</td>
<td>84</td>
<td>20.5</td>
<td>3.21</td>
</tr>
<tr>
<td>Cover crops on all corn/soybean non-tiled acres</td>
<td>30</td>
<td>33</td>
<td>7.9</td>
<td>11.02</td>
</tr>
<tr>
<td>Practice/Scenario</td>
<td>Nitrate-N reduction per acre (%)</td>
<td>Nitrate-N reduced (million lb N)</td>
<td>Nitrate-N Reduction % (from baseline)</td>
<td>Cost ($/lb N removed)</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------</td>
<td>---------------------------------</td>
<td>---------------------------------</td>
<td>-------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing N rate from background to the MRTN (10% of acres)</td>
<td>10</td>
<td>2.3</td>
<td>0.6</td>
<td>-4.25</td>
</tr>
<tr>
<td>Nitrification inhibitor with all fall applied fertilizer on tile-drained corn acres</td>
<td>10</td>
<td>4.3</td>
<td>1.0</td>
<td>2.33</td>
</tr>
<tr>
<td>Split (50%) fall and spring (50%) on tile-drained corn acres</td>
<td>7.5 to 10</td>
<td>13</td>
<td>3.1</td>
<td>6.22</td>
</tr>
<tr>
<td>Fall to spring on tile-drained corn acres</td>
<td>15 to 20</td>
<td>26</td>
<td>6.4</td>
<td>3.17</td>
</tr>
<tr>
<td><strong>In-field</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cover crops on all corn/soybean tile-drained acres</td>
<td>30</td>
<td>84</td>
<td>20.5</td>
<td>3.21</td>
</tr>
<tr>
<td>Cover crops on all corn/soybean non-tiled acres</td>
<td>30</td>
<td>33</td>
<td>7.9</td>
<td>11.02</td>
</tr>
<tr>
<td><strong>Edge-of-field</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioreactors on 50% of tile-drained land</td>
<td>40</td>
<td>56</td>
<td>13.6</td>
<td>1.38</td>
</tr>
<tr>
<td>Wetlands on 25% of tile-drained land</td>
<td>40</td>
<td>28</td>
<td>6.8</td>
<td>5.06</td>
</tr>
<tr>
<td>Buffers on all applicable crop land (reduction only for water that interacts with active area)</td>
<td>90</td>
<td>36</td>
<td>8.7</td>
<td>1.63</td>
</tr>
</tbody>
</table>
## Example Statewide Results for N

<table>
<thead>
<tr>
<th>Practice/Scenario</th>
<th>Nitrate-N reduction per acre (%)</th>
<th>Nitrate-N reduced (million lb N)</th>
<th>Nitrate-N Reduction % (from baseline)</th>
<th>Cost ($/lb N removed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing N rate from background to the MRTN (10% of acres)</td>
<td>10</td>
<td>2.3</td>
<td>0.6</td>
<td>-4.25</td>
</tr>
<tr>
<td>Nitrification inhibitor with all fall applied fertilizer on tile-drained corn acres</td>
<td>10</td>
<td>4.3</td>
<td>1.0</td>
<td>2.33</td>
</tr>
<tr>
<td>Split (50%) fall and spring (50%) on tile-drained corn acres</td>
<td>7.5 to 10</td>
<td>13</td>
<td>3.1</td>
<td>6.22</td>
</tr>
<tr>
<td>Fall to spring on tile-drained corn acres</td>
<td>15 to 20</td>
<td>26</td>
<td>6.4</td>
<td>3.17</td>
</tr>
<tr>
<td>Cover crops on all corn/soybean tile-drained acres</td>
<td>30</td>
<td>84</td>
<td>20.5</td>
<td>3.21</td>
</tr>
<tr>
<td>Cover crops on all corn/soybean non-tiled acres</td>
<td>30</td>
<td>33</td>
<td>7.9</td>
<td>11.02</td>
</tr>
<tr>
<td><strong>In-field</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioreactors on 50% of tile-drained land</td>
<td>40</td>
<td>56</td>
<td>13.6</td>
<td>1.38</td>
</tr>
<tr>
<td>Wetlands on 25% of tile-drained land</td>
<td>40</td>
<td>28</td>
<td>6.8</td>
<td>5.06</td>
</tr>
<tr>
<td>Buffers on all applicable crop land (reduction only for water that interacts with active area)</td>
<td>90</td>
<td>36</td>
<td>8.7</td>
<td>1.63</td>
</tr>
<tr>
<td><strong>Edge-of-field</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perennial/energy crops equal to pasture/hay acreage from 1987</td>
<td>90</td>
<td>10</td>
<td>2.6</td>
<td>9.34</td>
</tr>
<tr>
<td>Perennial/energy crops on 10% of tile-drained land</td>
<td>90</td>
<td>25</td>
<td>6.1</td>
<td>3.18</td>
</tr>
</tbody>
</table>
## Example Statewide Results for N

<table>
<thead>
<tr>
<th>Practice/Scenario</th>
<th>Nitrate-N reduction per acre (%)</th>
<th>Nitrate-N reduced (million lb N)</th>
<th>Nitrate-N Reduction % (from baseline)</th>
<th>Cost ($/lb N removed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td>410</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reducing N rate from background to the MRTN (10% of acres)</td>
<td>10</td>
<td>2.3</td>
<td>0.6</td>
<td>-4.25</td>
</tr>
<tr>
<td>Nitrification inhibitor with all fall applied fertilizer on tile-drained corn acres</td>
<td>10</td>
<td>4.3</td>
<td>1.0</td>
<td>2.33</td>
</tr>
<tr>
<td>Split (50%) fall and spring (50%) on tile-drained corn acres</td>
<td>7.5 to 10</td>
<td>13</td>
<td>3.1</td>
<td>6.22</td>
</tr>
<tr>
<td>Fall to spring on tile-drained corn acres</td>
<td>15 to 20</td>
<td>26</td>
<td>6.4</td>
<td>3.17</td>
</tr>
<tr>
<td>Cover crops on all corn/soybean tile-drained acres</td>
<td>30</td>
<td>84</td>
<td>20.5</td>
<td>3.21</td>
</tr>
<tr>
<td>Cover crops on all corn/soybean non-tiled acres</td>
<td>30</td>
<td>33</td>
<td>7.9</td>
<td>11.02</td>
</tr>
<tr>
<td><strong>In-field</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioreactors on 50% of tile-drained land</td>
<td>40</td>
<td>56</td>
<td>13.6</td>
<td>1.38</td>
</tr>
<tr>
<td>Wetlands on 25% of tile-drained land</td>
<td>40</td>
<td>28</td>
<td>6.8</td>
<td>5.06</td>
</tr>
<tr>
<td>Buffers on all applicable crop land (reduction only for water that interacts with active area)</td>
<td>90</td>
<td>36</td>
<td>8.7</td>
<td>1.63</td>
</tr>
<tr>
<td><strong>Edge-of-field</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perennial/energy crops equal to pasture/hay acreage from 1987</td>
<td>90</td>
<td>10</td>
<td>2.6</td>
<td>9.34</td>
</tr>
<tr>
<td>Perennial/energy crops on 10% of tile-drained land</td>
<td>90</td>
<td>25</td>
<td>6.1</td>
<td>3.18</td>
</tr>
<tr>
<td><strong>Land use change</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point source reduction to 10 mg nitrate-N/L</td>
<td>14</td>
<td>3.4</td>
<td></td>
<td>3.30</td>
</tr>
<tr>
<td>Point source reduction in N due to biological nutrient removal for P</td>
<td>8</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Example Statewide Results for P

<table>
<thead>
<tr>
<th>Practice/Scenario</th>
<th>Total P reduction per acre (%)</th>
<th>Total P reduced (million lb P)</th>
<th>Total P Reduction % (from baseline)</th>
<th>Cost ($/lb P removed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td>37.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-field</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convert 1.8 million acres of conventional till eroding &gt;T to reduced, mulch or no-till</td>
<td>50</td>
<td>1.8</td>
<td>5.0</td>
<td>-16.60</td>
</tr>
<tr>
<td>P rate reduction on fields with soil test P above the recommended maintenance level</td>
<td>7</td>
<td>1.9</td>
<td>5.0</td>
<td>-48.75</td>
</tr>
<tr>
<td>Cover crops on all corn/soybean acres</td>
<td>30</td>
<td>4.8</td>
<td>12.8</td>
<td>130.40</td>
</tr>
<tr>
<td>Cover crops on 1.6 million acres eroding&gt;T currently in reduced, mulch or no-till</td>
<td>50</td>
<td>1.9</td>
<td>5.0</td>
<td>24.50</td>
</tr>
<tr>
<td>Edge-of-field</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetlands on 25% of tile-drained land</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Buffers on all applicable crop land</td>
<td>25-50</td>
<td>4.8</td>
<td>12.9</td>
<td>11.97</td>
</tr>
<tr>
<td>Land use change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perennial/energy crops equal to pasture/hay acreage from 1987</td>
<td>90</td>
<td>0.9</td>
<td>2.5</td>
<td>102.30</td>
</tr>
<tr>
<td>Perennial/energy crops on 1.6 million acres&gt;T currently in reduced, mulch or no-till</td>
<td>90</td>
<td>3.5</td>
<td>9.0</td>
<td>40.40</td>
</tr>
<tr>
<td>Perennial/energy crops on 10% of tile-drained land</td>
<td>50</td>
<td>0.3</td>
<td>0.8</td>
<td>250.07</td>
</tr>
<tr>
<td>Point source</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Point source reduction to 1.0 mg total P/L (majors only)</td>
<td>8.3</td>
<td>22.1</td>
<td></td>
<td>13.71</td>
</tr>
</tbody>
</table>

USLE method
## Example Statewide N & P Scenarios

<table>
<thead>
<tr>
<th>Name</th>
<th>Combined Practices and/or Scenarios</th>
<th>Nitrate-N (% reduction)</th>
<th>Total P (% reduction)</th>
<th>Cost of Reduction ($/lb)</th>
<th>Annualized Costs (million $/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP1</td>
<td>MRTN, fall to spring, bioreactors 50%, wetlands 25%, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding &gt; T, buffers on all applicable lands, point source to 1.0 mg TP/L and 10 mg nitrate-N/L</td>
<td>35</td>
<td>45</td>
<td>**</td>
<td>383</td>
</tr>
<tr>
<td>NP2</td>
<td>MRTN, fall to spring, bioreactors 50%, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding &gt; T, cover crops on all CS, point source to 1.0 mg TP/L and 10 mg nitrate-N/L</td>
<td>45</td>
<td>45</td>
<td>**</td>
<td>810</td>
</tr>
<tr>
<td>NP3</td>
<td>MRTN, fall to spring, bioreactors 15%, no P fert. on 12.5 million ac above STP maintenance, reduced till on 1.8 million ac conv. till eroding &gt; T, cover crops on 87.5% of CS, buffers on all applicable lands, perennial crops on 1.6 million ac &gt;T, and 0.9 million additional ac.</td>
<td>45</td>
<td>45</td>
<td>**</td>
<td>791</td>
</tr>
</tbody>
</table>
County Level Analysis of Mississippi River Basin

- counties in MRB (all 1768)
- 1997 to 2006 annual data on fertilizer, crops, animals, people, deposition
- predictive model from watersheds applied to all MRB counties
- both N and P

From David et al. (2010)
Annual N Fertilizer Applications

From David et al. (2010)
Tile drainage is concentrated in the corn belt from David et al. (2010).
Some counties negative, N from soil mineralization
Linking N balances to N Export

• hydrology overwhelming factor
  – channelization, tile drainage
• can look at watershed N export as a fraction of net N inputs
  – most studies, about 25%
  – however in MRB we know it is larger in critical areas
  – can be > 100% in heavily tile drained watersheds
Drainage by tiles and ditches
Illinois Drainage Tile Installed

Year
1870 1880 1890 1900 1910 1920
Cumulative Drain Tile Produced (million feet)
0
100
200
300
400
500
600
700
800
Tiles, Farms and the Dead Zone

Published: October 20, 2010

Every year, usually beginning in late spring, an oxygen-depleted dead zone forms in the Gulf of Mexico at the Mississippi River’s mouth, killing off fish, shrimp and other marine life. By the time cooler weather restores life to the zone, the fishing industry has sustained substantial losses.

Scientists have long known that the dead zone — this year it covered 7,000 square miles — is created largely by nitrate washed downstream from fertilized fields as far north as Minnesota. A study in the Journal of Environmental Quality by scientists from Cornell University and the University of Illinois has now conclusively identified the largest source of that nitrate: tiled farm fields.

For as long as farmers have been farming in the Midwest, they have been laying drainage tile — often perforated plastic tubes installed 2 feet to 4 feet below the surface — to drain wetlands and create arable fields in places that would normally hold standing water. The problem is that the system also sluices away nitrogen fertilizer, which eventually flows through tributaries into the Mississippi and ends in the Gulf of Mexico.

Mark David, a University of Illinois researcher, observed that “farmers are not to blame.” We agree. Tiling is as old as Midwestern farming. What’s needed now is more research and direct incentives from the Agriculture Department to find ways to mitigate this problem.

These include: restoring wetlands, where possible; growing cover crops to absorb water in the spring, when runoff is heaviest; different methods of applying fertilizer; and even methods of treating the runoff before it reaches creeks and rivers. Sacrificing life in the gulf for corn in the fields is a trade-off that has to stop.
Modeled January to June Nitrate Export

Best model includes fertilizer, sewage effluent, and tile drainage
Illinois N budget through 2014

Graph showing Net Nitrogen Inputs from various sources:
- Fertilizer
- Legume N
- NOy deposition
- Grain harvest
- Manure
- Human consumption
Embarras River

Nitrate N (mg N L$^{-1}$)

Water year

Importance of a Few Storm Events

From Royer et al. (2006)
Fate of N

- limited in-stream losses of nitrate during high flow periods
  - Lake Shelbyville
  - Saylorville Reservoir
- retention times too short
- spring nitrate, headed to Gulf

![Graph showing nitrate removal over depth/time of travel](image)
Biofuels reduce tile nitrate

![Graph showing nitrate levels over time for different biofuels]

- C-C-S
- Miscanthus
- Switchgrass
- Prairie

Nitrate (mg N L⁻¹)

Date
Jan-08  Jul-08  Jan-09  Jul-09  Jan-10  Jul-10  Jan-11  Jul-11  Jan-12  Jul-12  Jan-13  Jul-13  Jan-14  Jul-14  Jan-15
Concluding remarks

- Minnesota WRC has great record
- continue/expand role as source of science and outreach for water resource issues in state
  - central role in new nutrient reduction strategy?
- my background and experience have prepared me for the range of water resources in Minnesota
- exciting opportunity
Thank you