Experience from the Cedar River TMDL

“Hypoxia in the Gulf of Mexico: Implications and Strategies for Iowa”

Jim Baker
Professor emeritus, ISU/IDALS
October 16, 2008
Project personnel:

- Jim Baker, ISU/IDALS
- Dean Lemke, IDALS
- Jack Riessen, IDNR
- Dan Jaynes, USDA-ARS
- Marty Atkins, USDA-NRCS
- Rick Robinson, AFBF
- Sunday Tim, ISU
- Matt Helmers, ISU
- John Sawyer, ISU
- Mike Duffy, ISU
- Antonio Mallarino, ISU
- Steve Padgitt, ISU
- Bill Crumpton, ISU
“Case study of the cost and efficiency of practices needed to reduce nutrient loads locally and to the Gulf of Mexico”

- Cedar River Watershed
- **Preliminary** results
- Funded
  - 90% State of Iowa (IDALS)
  - 10% UMRSHNC (EPA Grant)
UPPER MISSISSIPPI RIVER SUB-BASIN HYPOXIA NUTRIENT COMMITTEE
UMRSHNC

Mississippi River Basin
Agriculture drainage concerns:

- Quality issues of:
  - “fishable”
  - “swimable”
  - “drinkable”

- But also quantity issues:
  - not too “little”
  - not too “much”
  - timed “right”
An aerial image of downtown Cedar Rapids, Iowa shows flood-affected areas June 13, 2008. (Photo by David Greedy/Getty Images)
Need to educate the public to avoid having “unrealistic expectations”

- Natural variations (in weather) can dominate outcomes.
  - a 10+ inch rain will overwhelm everything
  - any time excess water moves over or through the soil, nutrient losses will occur

- Extreme measures come with extreme costs
  - e.g., converting Corn Belt back to prairies and wetlands
  - yield reductions with severe reductions in nutrient inputs to reduce off-site losses

- Concern for unintended side-effects
  - “mining of the soil” when nutrient removal exceeds inputs
  - displacing needed production to more environmentally sensitive areas
Background

• Nitrate issues
  – TMDL for drinking water impairment
  – Gulf of Mexico hypoxia area reduction

• Phosphorus issues
  – Pending criteria for local flowing and standing waters
  – Gulf of Mexico hypoxia area reduction
Loss reduction goals

• TMDL nitrate
  – Maximum concentration 9.5 mg/L
  – Reduce losses 35%
  – Reduce losses 10,000 tons/year (equals 5.5 lb N/acre/year)
  – Load allocation: 92% nonpoint source; 8% point source

• Hypoxia area
  – Reduce N losses 45%
  – Reduce P losses 45%
Cedar River Watershed

- 3,650,000 acres within Iowa above city of Cedar Rapids
- Nitrate losses (2001 – 2004 period)
  - 28,561 tons/year
  - 15.6 lb/acre/year
- 73% row-crop (2,400,000 acres corn/beans; 150,000 acres continuous corn)
- About 2/3 of the row-crop land has tile drainage
- Annual precipitation: about 34 inches
- Stream flow (2001 - 2004 period)
  - Total 8 inches
  - “Base flow” about 65% of total
Potential N Management Practices

• In-field
  – N rate/timing
  – Cropping
  – Tillage
  – Cover crops
  – Water management

• Off-site
  – Buffer strips
  – Constructed wetlands
Practices (nitrate)

- **N rate**
  - Starting point critical
  - NASS fertilizer data for 2005 for four northeast Iowa sub-regions is 124 lb N/acre/year on corn
  - IDALS state-wide fertilizer sales data for 2001 – 2005 averaged 137 lb N/acre/year on corn
  - Manure applications (?)

- **ISU recommendations**
  - For corn following soybeans: 100 – 150 lb N/acre
  - For continuous corn: 150 – 200 lb N/acre
Based on Iowa yield and water quality data; corn at $5.00/bu and N at $0.50/lb

<table>
<thead>
<tr>
<th></th>
<th>Corn soybeans</th>
<th>Continuous corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>assumed initial rate (lb N/ac)</td>
<td>140</td>
<td>190</td>
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<tr>
<td>nitrate loss</td>
<td>19.5 lb/ac</td>
<td>23.2 lb/ac</td>
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<tr>
<td>loss reduction with 40 lb/ac N rate reduction</td>
<td>20.1%</td>
<td>16.2%</td>
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<tr>
<td>nitrate-N loss reduction</td>
<td>3.9 lb/ac</td>
<td>3.8 lb/ac</td>
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<tr>
<td>corn yield reduction</td>
<td>4.8 bu/ac</td>
<td>5.0 bu/ac</td>
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<tr>
<td>cost of N loss reduction</td>
<td>$1.03/lb</td>
<td>$1.32/lb</td>
</tr>
<tr>
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<td>Continuous corn</td>
</tr>
<tr>
<td>--------------------------------</td>
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<td>-----------------</td>
</tr>
<tr>
<td>assumed initial rate (lb N/ac)</td>
<td>120</td>
<td>170</td>
</tr>
<tr>
<td>nitrate loss</td>
<td>17.3 lb/ac</td>
<td>21.2 lb/ac</td>
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<tr>
<td>loss reduction with 20 lb/ac N</td>
<td>10.0%</td>
<td>8.6%</td>
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<tr>
<td>rate reduction</td>
<td></td>
<td></td>
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<tr>
<td>nitrate-N loss reduction</td>
<td>1.7 lb/ac</td>
<td>1.8 lb/ac</td>
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<tr>
<td>corn yield reduction</td>
<td>3.0 bu/ac</td>
<td>2.9 bu/ac</td>
</tr>
<tr>
<td>cost of N loss reduction</td>
<td>$2.94/lb</td>
<td>$2.50/lb</td>
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Based on Iowa yield and water quality data; corn at $5.00/bu and N at $0.50/lb

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<tr>
<td>nitrate loss</td>
<td>19.5 lb/ac</td>
<td>23.2 lb/ac</td>
</tr>
<tr>
<td>loss reduction with 80 lb/ac N rate reduction</td>
<td>32.7%</td>
<td>30.3%</td>
</tr>
<tr>
<td>nitrate-N loss reduction</td>
<td>6.4 lb/ac</td>
<td>7.0 lb/ac</td>
</tr>
<tr>
<td>corn yield reduction</td>
<td>16.1 bu/ac</td>
<td>15.2 bu/ac</td>
</tr>
<tr>
<td>cost of N loss reduction</td>
<td>$6.33/lb</td>
<td>$5.12/lb</td>
</tr>
</tbody>
</table>
Practices (nitrate)

N timing
• 25 to 33% of N for corn is applied in fall
• Leaching losses with spring-applied N are 0 – 15% less
• Half of total N applied is ammonia-N and half of that is applied in the fall
• Costs of ammonia could go up 5 cents/lb for additional infrastructure needed to apply all of it in the spring (yield effects could be + or -)
• However, this increase would apply to all N sold, not just that currently fall-applied.
Practices (nitrate)

- Fall cover crops
  - Fall-planted rye or ryegrass can reduce nitrate leaching loss by 50%
  - Fall-planted oats by 25%
- Costs
  - Incentive costs for rye: $30/acre (seed, planting, dealing with the living plants in the spring, possible corn yield reduction)
  - For oats: $20/acre (plants not alive in spring)
- For continuous corn
  - Rye loss reduction: $2.59/lb N
  - Oats loss reduction: $3.44/lb N
- For corn-soybeans
  - Rye loss reduction: $3.07/lb N
  - Oats loss reduction: $4.10/lb N
Practices (nitrate)

• Drainage water management
  – Modeling predicts a ~50% nitrate loss reduction with installation of drainage water management

• Costs
  – Installation: $1000/acre (20 year life; 4% interest)
  – Operation: $10/acre/year

• Applicable to about 6.7% of the row crops

• Nitrate reduction costs of $1.56/lb
Practices (nitrate)

• Constructed wetlands
  – At a fraction of 0.5 to 2% of watershed as wetland, removal could average 50%
  – This would equate to about 8 lb/ac/yr for drainage from row-crop land

• Costs
  – Assuming a cost of $250/ac of “treated field” for wetland establishment, this would be about $1.45/lb over 50 years (4% interest).
Practices (nitrate)

• Tillage
  – There are some indications that reduced tillage, and particularly no-till, could reduce nitrate concentrations in tile drainage, possibly because of reduced mineralization with reduced soil disturbance.
  – Also water flow through more macropores with reduced tillage could allow water to “by-pass” nitrate within soil aggregates.
  – However, usually any reductions in concentrations are off-set by increased flow volumes with reduced tillage.
  – Thus, without more conclusive results, tillage is not currently being considered as a practice to reduce nitrate leaching losses.
Practices (nitrate)

• Buffer strips
  – Tile drainage “short-circuits” subsurface flow through buffer strips, eliminating any chance they would have in reducing concentrations and/or flow volumes and thus nitrate losses.
One example scenario to reduce nitrate losses 35% (9,200 tons/non-point source allocation) while retaining row-crop production

<table>
<thead>
<tr>
<th>Practice</th>
<th>% reduction</th>
<th>Acres* treated</th>
<th>Tons reduced</th>
<th>Cost per lb</th>
<th>Total cost/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>140 to 100 N rate - CB</td>
<td>20.1% or 3.9 lb/ac</td>
<td>all or 1.70 M ac</td>
<td>3,315</td>
<td>$1.03</td>
<td>$6.83 M</td>
</tr>
<tr>
<td>190 to 150 N rate - CC</td>
<td>16.2% or 3.8 lb/ac</td>
<td>all or 0.10 M ac</td>
<td>190</td>
<td>$1.32</td>
<td>$0.50 M</td>
</tr>
<tr>
<td>Avoid fall application</td>
<td>15% or 2.5 lb/ac</td>
<td>all or 300,000 ac</td>
<td>375</td>
<td>$6.00</td>
<td>$4.50 M</td>
</tr>
<tr>
<td>Rye cover crops</td>
<td>50% or 8 lb/ac</td>
<td>10% or 170,000 ac</td>
<td>680</td>
<td>$3.00</td>
<td>$4.08 M</td>
</tr>
<tr>
<td>Water mgt.</td>
<td>50% or 8 lb/ac</td>
<td>10% or 167,000 ac</td>
<td>670</td>
<td>$1.56</td>
<td>$2.09 M</td>
</tr>
<tr>
<td>Construct. wetlands</td>
<td>50% or 8 lb/ac</td>
<td>59% or 1.00 M ac</td>
<td>4,000</td>
<td>$1.45</td>
<td>$11.60 M</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>[*2/3 of 2.55 M or 1.70 M ac]</td>
<td></td>
<td><strong>9,230</strong></td>
<td><strong>$1.60</strong></td>
<td><strong>$29.60 M/yr</strong></td>
</tr>
</tbody>
</table>
Scaling to Iowa Statewide

• About ¼ of Iowa is tile drained: equals 9 million acres
• Cost to Cedar River watershed (1.7 million acres drained) estimated at $29.6 million/year
• Cost to Iowa would be $157 million/yr for 35% nitrate removal
• For the next 10%, to reach a 45% reduction, wetlands, cover crops, and further reductions in N applications are only options left (unless cropping changes) – all with increased lb N/ac costs.
P loss reduction

- Based on report #3 of the “Integrated Assessment” and also the Iowa state nutrient budget, the average P loss with river flow is about 0.75 lb/ac/yr.
- A 45% reduction of the 1,560 tons of P loss per year would be 702 tons.
- Or the average, total P concentration (that in water plus sediment) would have to be reduced from 0.415 to 0.228 mg/L.

[Note that the draft P criterion for standing waters (i.e. lakes) in Iowa is being proposed at 0.035 mg/L].
Using the Iowa P Index

• It has three components:
  – erosion/soil loss
  – surface runoff
  – subsurface drainage (if any)

• It considers location and soil and weather characteristics
  – distance to water course
  – soil slope/type
  – annual precipitation

• It considers management
  – current P soil test level
  – amount of P additions
  – method of P additions
  – crop rotation

• It considers sediment transport control practices
  – vegetated buffer stripes

• It considers erosion control practices (using RUSLE2)
  – contouring
  – conservation tillage
P index calculations in two Cedar River subwatersheds
(Chad Ingels and John Rodecap; ISU extension)
Results of P index calculations

- **Coldwater-Palmer**
  - 207 fields
  - 99 with P index ≥ 1.00 (lb/ac/yr)
  - 9 with P index ≥ 2.00
  - max = 6.12; average = 1.06
  - average soil test P = 34 ppm (max = 401; 54% above the optimum range)

- **Lime Creek**
  - 209 fields
  - 67 with P index ≥ 1.00 (lb/ac/yr)
  - 3 with P index ≥ 2.00
  - max = 3.01; average = 1.07
  - average soil test P = 36 ppm (max = 120; 57% above the optimum range)
Practice: reducing soil test levels to the optimum level

- The break between “optimum” and “high” soil test P levels (Bray-1) for row-crops is 20 ppm.
- At 20 ppm soil test P level, soluble P in surface runoff is estimated at 0.150 mg/L.
- At 35 ppm, it is 0.225 mg/L.
- With 35% of river flow estimated to be surface runoff, that would be 2.8.”
- Over time, reduced or no P inputs to fields testing “high” would save money and reduce P levels and losses.
- The reduction in P loss associated with reducing the average soil test level from 35 to 20 ppm would meet about 1/7 of that needed for a 45% reduction.
Achieving the remaining 6/7 P reduction

- Further conversion to conservation and no tillage (currently 4% no-till).
- Additional contouring (currently 6%).
- Use of vegetated buffer strips.
- Use of water and sediment control basins.
- Use of terraces.
Summary: Potential and limitations (1)

• For the Cedar River TMDL for nitrate, there is the potential to reach the 35% reduction goal.
• The limitations will be the large direct costs, as well as program costs to achieve producer cooperation to make the major changes needed.
Summary: Potential and limitations (2)

- For the Gulf Hypoxia reduction goal of 45% for total nitrogen, the potential is much lower.
- One limitation will be that in the tile-drained areas, the unit costs for nitrate reduction over 35% will increase.
- Furthermore, if the reduction in total nitrogen, of which nitrate is about 2/3, has to come through additional nitrate reduction, the costs will be even higher.
• For the Gulf Hypoxia reduction goal of 45% for total phosphorus, the potential is also much lower.
• In addition to large costs and major production changes needed, there is the concern that reducing field P losses, and more importantly reducing P which is actually transported to streams, will not reduce in-stream P concentrations or the amount exported to the Gulf.
• At issue is how much P can be provided by recycling from the soils and sediment already present in the stream, lake, and marine systems.
Summary: Concerns

• Despite what some believe, there are few “win-win” situations, and those associated with rate of nutrient inputs will not get us to currently targeted water quality goals.

• Reaching those goals will come at considerable effort and costs, and therefore, it is imperative to be sure that the practices promoted will secure those goals; and furthermore, that reaching those goals will result in the anticipated environmental benefits.

• Producers and the public, once deceived and/or disappointed, will not readily cooperate or be supportive in the future.
Science of Soil Sustainability and Water Quality Issues

- 170 lb N/ac/yr for continuous corn is about the “tipping point” at which soil organic matter should not decrease
- However, for the corn-soybean rotation, at 120 lb N/ac in the corn year, the N mass balance is at least 80 lb N/ac negative over the two-year period of rotation
- Thus, any reduction in N rates would increase the “mining” of soil organic matter
- Reduced soil organic matter not only reduces soil productivity but also increases water quality problems
Question:

Will we make decisions based on:

• Emotion, perception, and opinion, or

• Logic, information, and knowledge?

And will they include probability of success and cost/benefit analyses?