A Toolbox for Water Management

By Nick Schneider, Winnebago County Ag Agent and Doral Kemper
On-Farm Bioreactors
by Madeline Fisher, *Crops and Soils*, Nov-Dec 2010

- AKA: Denitrifying biofilter reactors
- Removes nitrate from drainage before reaching surface water.
- Think of C:N ratios in compost and manure. Too much dry bedding actually ties up the nitrogen.
- Nitrogen is needed to promote microbial activity which breaks down the carbon.
- Naturally occurring, this speeds it up.
The Nitrogen Cycle

- Rainfall
- N\textsubscript{2}/N\textsubscript{2}O
- Plant Residue
- Manure
- Atmospheric N\textsubscript{2}
- Fertilizer
- Volatilization NH\textsubscript{3}
- Symbiotic Fixation
- Industrial Fixation
- N\textsubscript{2} fixation
- Ammonification
- Ammonium N NH\textsubscript{4}⁺
- Nitrate N NO\textsubscript{3}⁻
Denitrification Bioreactors

- Biologically mediated reduction reaction
- $\text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$ gas
- Denitrifiers: anaerobic, need carbon and nitrate
Filling a wood chip trench. Photo courtesy of Dan Jaynes, USDA's National Laboratory for Agriculture and the Environment
Crew members from Reding's Gravel & Excavating Co. lower the upper control structure into place at the Hancock County, IA bioreactor installation. Photo courtesy of Keegan Kult, Iowa Soybean Association.
Designs

• 6 foot deep trenches dug parallel to the tile line.
• 4 feet of wood chips with 2 feet of soil on top
  Or
Broad bed 25 feet wide, 50 feet long, 4 ft deep

Control boxes with stop logs control flow.
Nitrate Concentrations at Claremont in 2008

From U of MN, Ranaivonson et al.
Claremont: Pollutant Loading - 2009

<table>
<thead>
<tr>
<th>Station</th>
<th>Nitrate</th>
<th>Total P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet, lbs/acre</td>
<td>16.1</td>
<td>0.119</td>
</tr>
<tr>
<td>Outlet, lbs/acre</td>
<td>8.5</td>
<td>0.057</td>
</tr>
<tr>
<td>Reduction, lbs/ac</td>
<td>7.6</td>
<td>0.063</td>
</tr>
<tr>
<td>Reduction, %</td>
<td>47%</td>
<td>52.4%</td>
</tr>
</tbody>
</table>
Summary
• Nitrate concentrations in patterned tile field ranged from 11 to 28 mg/l.

• During snowmelt, nitrate reduction ranged from 7% to 50%

• Total phosphorus from no reduction to 30%

• During spring and summer time, the percentage of nitrate reduction ranged from 10-100% with an average of 47% in 2009.

• A 50% reduction in nitrate concentration required a residence time of 1-2 days

• Most of the total phosphorus was in the soluble form, total phosphorus reduction (by bioreactor) reached 54%
Summary

- E. Coli count were reduced by 61%

For incoming concentrations of 2.0 ppb, 3.5 ppb, and 7.5 ppb of Acetochlor (1.6 ppb, 2.8 ppb, and 6.0 ppb for Atrazine):

- Acetochlor concentrations dissipation was 69%
- Atrazine was dissipated at a rate of 53%
Water Gains Through Precipitation

Infiltration and Percolation (Recharge): Storage of water for use by plants and people.

Versus

Run-Off: Loss of topsoil, nutrients, pesticides, leading to sedimentation.
Water Losses Through Evapotranspiration

Evaporation: Water moves back to the atmosphere directly from the soil.

versus

Transpiration: Water moves back to the atmosphere through plants.
Desirable Water Function

Water that infiltrates into the soil and is transpired through the plant as it grows.

Water that evaporates from the soil surface when it’s an obstacle to field operations or damages plants through excessive amounts.
Undesirable Water Function

Water that runs-off the surface carrying soil particles and contributing to floodwater damage.

Water that evaporates from the soil surface when fieldwork is complete and soil is already dry.
## How Much Water Do Crops Use?

Pounds of water transpired per pound of dry plant tissue

<table>
<thead>
<tr>
<th>Crop</th>
<th>Greatest Variation</th>
<th>3-Year Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>119</td>
<td>349</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>411</td>
<td>853</td>
</tr>
<tr>
<td>Wheat</td>
<td>102</td>
<td>453</td>
</tr>
</tbody>
</table>

“Relative Water Requirements of Plants,” Brigg and Shantz, 1914

YourCountyExtensionOffice.org
Agriculture & Natural Resources
# How Much Rain Do Crops Need?

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield</th>
<th>Gallons/Acre</th>
<th>Acre/Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>7 t/DM (20 T Wet)</td>
<td>586,000</td>
<td>21.5</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>5 t/DM</td>
<td>1,023,000</td>
<td>37.7</td>
</tr>
</tbody>
</table>

1 gallon water = 8.34 pounds, 1 acre-inch water = 27,154 gallons
## How Much Water Does the Soil Store?

### Available Water Capacity by Soil Texture

<table>
<thead>
<tr>
<th>Textural Class</th>
<th>Available Water Capacity (Inches/Foot of Depth)</th>
<th>Available Water to 3 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>0.25–0.75</td>
<td></td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.75–1.00</td>
<td></td>
</tr>
<tr>
<td>Loamy sand</td>
<td>1.10–1.20</td>
<td>3.6 inches</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>1.25–1.40</td>
<td></td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>1.50–2.00</td>
<td></td>
</tr>
<tr>
<td>Silt loam</td>
<td>2.00–2.50</td>
<td></td>
</tr>
<tr>
<td>Silty clay loam</td>
<td>1.80–2.00</td>
<td>6 inches</td>
</tr>
<tr>
<td>Silty clay</td>
<td>1.50–1.70</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>1.20–1.50</td>
<td>4.5 inches</td>
</tr>
</tbody>
</table>
Average Annual Precipitation in NE Wisconsin
31.01 Inches

Alfalfa growing from April through October:
22.36” = 72% of annual rainfall

Corn growing from May through September:
17.12” = 55% of annual rainfall
So What?

• In general, more water available to transpire through the plant increases plant dry matter.
• In Wisconsin on average, precipitation and evapotranspiration are roughly equal.
• However, timing doesn’t quite match.
• At a given time, the soil only can store a modest portion of the crop’s water need.
• Encouraging infiltration and percolation helps balance precipitation and transpiration.
Infiltration Obstacles

Surface Sealing and Crusting

Infiltration normally declines rapidly during the early part of a rainstorm event and reaches a constant value after several hours of rainfall including:

(1) The filling of small pores on the soil surface with water reduces the ability of capillary forces to actively move water into the soil.

(2) As the soil moistens, the micelle structure of the clay particles absorb water causing them to expand. This expansion reduces the size of soil pores.

(3) Raindrop impact breaks large soil clumps into smaller particles. These particles then clog soil surface pores reducing the movement of water into the soil.

http://www.physicalgeography.net/fundamentals/8l.html
### Water Infiltration Rate and Class Guide

<table>
<thead>
<tr>
<th>Infiltration Rate (minutes per inch)</th>
<th>Infiltration Rate (inches per hour)</th>
<th>Infiltration Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3</td>
<td>&gt;20</td>
<td>Very Rapid</td>
</tr>
<tr>
<td>3 to 10</td>
<td>6 to 20</td>
<td>Rapid</td>
</tr>
<tr>
<td>10 to 30</td>
<td>2 to 6</td>
<td>Moderately Rapid</td>
</tr>
<tr>
<td>30 to 100</td>
<td>0.6 to 2</td>
<td>Moderate (or slower)</td>
</tr>
</tbody>
</table>
Tools for Increasing Infiltration While Decreasing Run-Off

• Forages, Pasture
• Crop Diversity and Cover Crops
• Increasing Residue and Organic Matter
• Buffer Ditches
• Ditch Design
• Tile Drainage and Controlled Drainage
• Tillage Systems to Increase Macro Pores and Earthworms
# Erosion from Crop and Tillage

40 Acres of Kewaunee Soil, 2-4% rolling slopes, T= 3

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Corn Grain</th>
<th>Corn Silage</th>
<th>Winter Wheat</th>
<th>Soybean</th>
<th>Alfalfa</th>
</tr>
</thead>
<tbody>
<tr>
<td>MB Plow</td>
<td>2.8</td>
<td>5.6</td>
<td>0.8</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Fall Chisel</td>
<td>1.2</td>
<td>4.1</td>
<td>0.3</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Spring Chisel</td>
<td>1.1</td>
<td>4.2</td>
<td></td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Strip Till</td>
<td>0.3</td>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No-Till</td>
<td>0.1</td>
<td>2.0</td>
<td>0.1</td>
<td>1.4</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Buffers slow water velocity causing solids to drop out of suspension.
Infiltration and captured sediment, atrazine, metolachlor, and cyanazine in buffer strips from six natural rainfall events.


<table>
<thead>
<tr>
<th>Rain Event</th>
<th>Infiltration</th>
<th>Sediment</th>
<th>Atrazine</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E)</td>
<td>(%)</td>
<td>(% Retained)</td>
<td>(% Retained)</td>
</tr>
<tr>
<td>E1</td>
<td>9</td>
<td>44</td>
<td>13</td>
</tr>
<tr>
<td>E2</td>
<td>34</td>
<td>57</td>
<td>44</td>
</tr>
<tr>
<td>E3</td>
<td>97</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>E4</td>
<td>44</td>
<td>65</td>
<td>54</td>
</tr>
<tr>
<td>E5</td>
<td>98</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>E6</td>
<td>69</td>
<td>86</td>
<td>58</td>
</tr>
</tbody>
</table>
Harvesting Buffers Uses Nutrients
Cover Crops
Two Stage Ditch Design

http://www.nature.org/wherewework/northamerica/states/indiana/howwework/art30290.html
Two Stage Ditch Design

http://www.nature.org/wherewework/northamerica/states/indiana/howwework/art30290.html
Controlled Drainage

R. Cooke, University of Illinois
Water control structures enable shallower water tables to be achieved, conserving water and nutrients in the soil profile.

- Structures can be used to manage water level in a variety of applications including ponds, wetlands, manure management, drainage water management, and saturated buffers.
- Rugged 1/2" PVC structure with lockable top.
- Stainless steel screws and custom anodized aluminum corner extrusions are used for strength and durability.
- 5" & 7" stoplogs for adjustability.
- Flexible couplers allow PVC, Corr. HDPE plastic pipe, or other materials to be easily attached. (Please specify type of pipe when ordering)
- Annual maintenance of stoplogs is recommended. Remove stoplogs and grease the o-ring on each board with a vegetable based lubricant. Ensure that there is no debris in the tracks or along the bottom of the structure. Replace your stoplogs after greasing.
- 5-Year Warranty on all standard structures.
- Customized or special orders will carry a 1-Year warranty on workmanship and material and have no return policy.
- Please allow up to 2 weeks for shipment.

Typical Installation and Recommended Component Items--

Installing a **bar guard** on our inlet pipe helps prevent debris, rodents, fish and turtles from entering your inlet.

An **anti seep collar** should be installed on both the inlet and outlet side of your structure to prevent water from cutting a path along your pipeline causing erosion.

A **slide gate valve** (not pictured above) installed in front of your structure on the inlet side allows you to completely shut off your water flow allowing you to remove all of your stoplog boards for maintenance and/or cleaning (annual maintenance of stoplogs is recommended).

A **rat guard** needs to be installed on your outlet pipe to avoid rodent entry.

**PVC Fish Screens** Also Available. See web page or call for details.
Controlled Drainage Fits...

- Field must need drainage
- Patterned drainage design installed
- Generally flat fields <0.5% slope
- Design so one structure controls as many acres as possible
- Reduces nitrate loss by 40-50%, phosphorous loss by 25-35%, potential small yield increase.

Skaggs et. All 2005
Managing Controlled Drainage

- Raise water depth after harvest to reduce delivery of nitrate during off-season
- Lower in early spring and fall so water freely drains before field operations
- Raise after planting and spring field operations to store water for midsummer use
“Because good subsurface drainage increases available profile storage and reduces surface runoff, it is more effective in reducing soil loss from gently sloping land than most conventional erosion control methods….
Subsurface drainage, therefore, should be considered as a possible best management practice for controlling sediment and other pollutants carried by surface water”

Figure 2.

Corn Grain Yield (tons/hectare @ 15.5% water)

Distance (meters) from N.5 S. side of field (down slope)

Corn Grain Yield (bushels/acre @ 15.5% water)
Estimated Relative Magnitude and Sequence of Surface Runoff From Watersheds With and Without Tile Drainage.

Based on data from Mississippi delta, published in the Journal of Irrigation and Drainage Engineering, 121:292-295 by Bengtson et al.

Surface runoff from fields with no tile drainage (≈100 units)

Surface runoff from fields with tile drainage (≈65 units)

Drainage from tiles (≈35 units)

Time (days)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>768</td>
<td>768</td>
</tr>
<tr>
<td>Surface Run Off</td>
<td>38.1</td>
<td>117.4</td>
</tr>
<tr>
<td>Lateral Flow</td>
<td>7.1</td>
<td>0.40</td>
</tr>
<tr>
<td>Tile Flow</td>
<td>136.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Groundwater Flow</td>
<td>10.8</td>
<td>11.7</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>569.2</td>
<td>638.6</td>
</tr>
<tr>
<td>Potential Evapotranspiration</td>
<td>1190.6</td>
<td>1191.6</td>
</tr>
</tbody>
</table>
Questions?
Thank You