Eliminating “Nonpoint” from Nonpoint Source Pollution

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(among many others)

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Soil and Water Lab

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Point Source Pollution

Clean Water Act - 1972

1969: Cuyahoga River, Ohio
Nonpoint Source Pollution

Landscape

Transport

Rivers
Traditionally the only control considered has been land use.

Can we find sources in the landscape?
Outline

• Locate Runoff Sources

• Source-Specific Phosphorus Mobility

• Phosphorus Mobility with Hydrology
  • Predicting Phosphorus Loads
  • Evaluating Management Practices

• New Ideas
Northeastern U.S. Hydrology

- Hillside
- Flood Plain (valley bottoms)
- Stream
- Baseflow (groundwater)
- Shallow bedrock, fragipan, or other restrictive layer
Common Perception of Runoff
Most 21st century water quality models, tools, & protection strategies assume this pre-1940’s theory proposed by R.E. Horton

Infiltration Excess
a.k.a. Hortonian Flow
Is Hortonian Flow Common?

Soil Permeability Distribution

Precipitation Frequency Analysis

Scientific Background
Is Hortonian Flow Common?

Scientific Background

Is Hortonian Flow Common?

Saturation Excess Runoff

Some areas saturate to the surface

Subsurface water rises

Rain
Saturation Excess Runoff

Rain on saturated areas becomes overland flow.

Upland interflow may exfiltrate.

Runoff Sources = Wet Areas

Variable in Space and Time!
New Hydrology Models
Soil Moisture Routing Model (SMR, a.k.a., SMDR, CSMR, SMorMod)

- Interflow
- ET
- Precipitation
- Runoff
- Percolation
- Interflow
- Bedrock Reservoir
- Baseflow

Watershed: Tremper Kill
Land Use
New York Crow Rd Watershed

Streamflow (mm)
Models and Tools: New hydrology models

Predicting Soil Moisture

Saturation Degree

\[ y = 1.4x - 0.23 \quad r^2 = 0.76 \]

95% Prediction Intervals
We Are Not Just Modeling

Town Br. Watershed

Being repeated Locally
...just Google It

Take-home Message

• Storm runoff is generated from small parts of the landscape
  • Areas prone to saturate – e.g., toe slopes, shallow soils, topographically converging areas
  • Variable Source Areas – they expand and contract
• We can predict where and when storm runoff will be generated
Outline

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• **Source-Specific Phosphorus Mobility**
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Each specific land use is assumed to have a characteristic pollutant concentration in its storm runoff.

This type of model cannot predict the impacts of targeted management practices, like incorporating riparian buffers.
Phosphorus Sources We Considered

- Land-applied manure (or chemical fertilizers)
- Soil
- Impervious areas
- “background P observed during baseflow (i.e., non-storm periods)”
Land-applied manure

Data from: Sharpley and Moyer. 2000. JEQ 29: 1462-1469

Upshot: We can predict P from land-applied manure if we know what kind of animal pooped it, how long it’s been in the field, and what its water extractable P is (which appears to be pretty constant)
Ag. Watershed (Town Br., NY)

Forested Watershed (Catskills, NY)
Phosphorus Load = \[ \mu_{T,S} \frac{Q}{10^S} \left( \frac{T - T_S}{10} \right) \]

Calculated

Soil Test Phosphorus

Modeled Runoff

Avg. summer temperature

Air Temperature

Photo by Susan Boyer, www.ars.usda.gov
Calculated Parameters

\[
\ln\left(\frac{C}{STP}\right) = \frac{(T-T_s)}{10} \ln(Q_{10S}) - \ln(\mu_{T,S})
\]
**P in baseflow**

- Curiously, there is some P during non-storm flows
- During these periods the water feeding the stream is largely groundwater
- Groundwater has very little P

- I assume that the source in these cases is near- or in-stream soils... thus we can use an equation similar to what we used for soils
We use several P concentrations measured during summer low flow conditions and determine parameters similarly to the soil parameters.
Take-home Message

- We can independently quantify the relative potential loads for different likely P sources.
- The near- and in-stream mechanisms controlling P constitute obvious knowledge gaps.
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The Watershed

Water
Impervious/Barnyard
Deciduous Forest
Shrub
Pasture
Hay
Crop
Stream Phosphorus

Observed: 0.49 kg/ha-yr
Predicted: 0.48 kg/ha-yr

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The BMPs

- New drainage, waterways, etc.
Change Flow Patterns

New drainage, waterway, etc.

Pre BMP

Post BMP
The BMPs

- Riparian fencing/buffers
The BMPs

• Precision feeding
The BMPs

- New manure spreading schedule
Back to Phosphorus

Pre BMP

Post BMP

Dissolved P (kg)

Cumulative Export (kg)

Oct 93 Nov 94 Apr 97 Jun 98 Jul 99 Jun 00 Jul 01 Aug 02 Jul 03

Pre BMP

Post BMP

Observed

Predicted

0.49 0.27 kg/ha-yr

0.48 0.27

Easton, Walter, Steenhuis. 2007. J. Environ. Qual. (accepted)
<table>
<thead>
<tr>
<th></th>
<th>Kg/d</th>
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<tbody>
<tr>
<td>Impervious Areas</td>
<td></td>
</tr>
<tr>
<td>Non-manured Soil</td>
<td></td>
</tr>
<tr>
<td>Manured Soil</td>
<td></td>
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<tr>
<td>Manure</td>
<td></td>
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<tr>
<td>&quot;baseflow&quot;</td>
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<tr>
<td><strong>Pre-BMP (1993-1995)</strong></td>
<td>0.004</td>
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<tr>
<td><strong>Post-BMP (1997-2004)</strong></td>
<td>0.004</td>
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<tr>
<td><strong>No-BMP (1997-2004)</strong></td>
<td>0.004</td>
</tr>
</tbody>
</table>
BMPs that Worked

- Manure spreading strategy that avoids runoff contributing areas
- Eliminating cows and cropping from riparian areas (a little speculative)

WHAT ABOUT PRECISION FEEDING

Water extractable P decreased by only 4%
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Recall the “Nonpoint” Problem
Pollutant Transport
Nonpoint Source Pollution

Hydrologic Flowpaths

Landscape  
Rivers
Microtracers

PLGA microspheres

Dan Luo

Jay Regan

Transport

sample

Real-Time PCR

Time PCR
Tip-of-the-Iceberg

Transport

Sample

Cytometer

Fluorescent Barcode

Blue Green Red

Lasers

3G2R
2G3R
1G4R
3G2R
2G3R
1G4R
3G2R
2G3R
1G4R
Thank You

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