Phosphorus

A Summary of Pertinent Research

Rick Wilson-DSW OEPA

September 10, 2007

Managing Variable Source Pollution in Agricultural Watersheds

Z. Qui, M.T. Walter, and C.Hall

JSWC-June 2007

- Summary and Conclusions:

  For more than 2 decades, BMPs have been installed across the country and yet non-point pollution remains an acute national problem, and agriculture has been strongly implicated.

  In some cases, researchers point directly to in in effectiveness of BMPs particularly the application of sediment control practices to reduce soluble chemical transport of runoff.

Managing Variable Source Pollution in Agricultural Watersheds
Z. Qui, M.T. Walter, and C.Hall

- Effective control of polluted runoff is greatly hampered by:

(1)incomplete understanding of fundamental processes affecting the movement of water in the landscape as well as the origin, fate, and transport of dissolved and suspended solids in rangeland, forestland, and agricultural watersheds

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2) incomplete understanding of social, economic, and institutional processes for developing management strategies

3) inadequate technology for assessing environmental and water quality risks; and

4) Insufficient resources for implementing BMPs and management plans in affected land and water bodies.

Whose Research?! Et al…

- **Andrew Sharpley**
- Peter Kleinman
- Douglas Beegle
- P.A. Vadas
- W.J. Gburek
- Carrie Volf
- Gerald Onkean
- A.R. Guidry, et al
- F.V. Schindler, et al
- L.E. Gentry, et al
- P.K. Kalita, et al
- B.R. Ball Coelho, et al
- Charles Wortmann
- Robert Kinley, et al
- B.L. Allen and P. Mallarino, et al
- A.S. Berg and Brad Joern
- Koopmans, et al
- T.H Dao
- Et al

A Template for this Afternoon's Discussion

Lesson 34

Agricultural Phosphorus Management: Protecting Production and Water Quality

By Andrew Sharpley, USDA-Agricultural Research Service

P in Agricultural Runoff

- P-Source to P-Sink
- Processes and Pathways
- Risk Assessment and Management
  - Agronomic soil test P
  - Environmental soil threshold
- Remedial Measures
  - Source and transport management

Applied P Tends to Accumulate at the Soil Surface

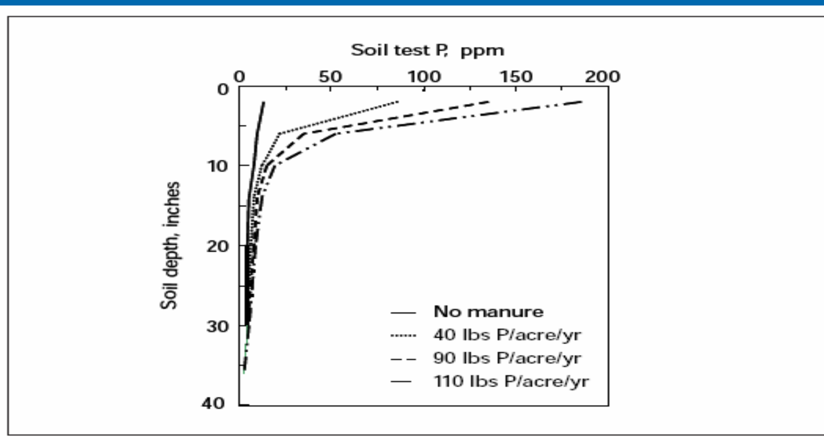
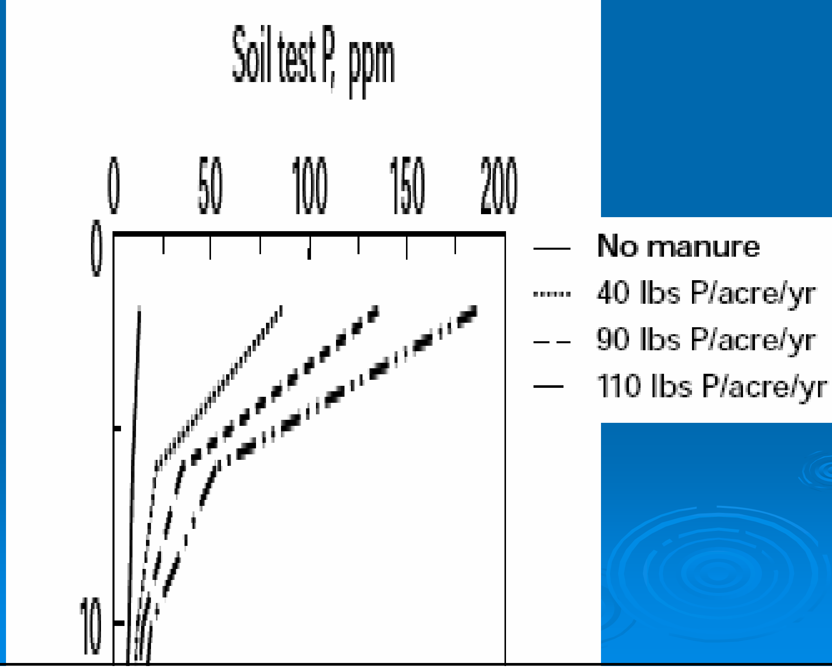


Figure 34-3. Soil test P (as Mehlich-3 P) accumulates at the surface with repeated application of P for 10 years. Note that typical fertilizer P applications for a corn crop in Oklahoma with a medium soil test P (20-40 ppm Mehlich-3 P) is about 20 lbs P/acre.
Adapted from Sharpley et al. 1984.



Wortmann and Walters, 2006
Phosphorus Runoff during Four Years following Composted Manure Application

- Land applied poultry manure - Spring 2000
- Soil Test spring 2004 (Bray P-1)

	0-5 cm	5-10 cm	10-15 cm	15-30 cm
High-P Compost	779	307	53	38
Low-P Compost	380	154	37	26
No Compost	16	9	10	10

P-Source to P-Sink

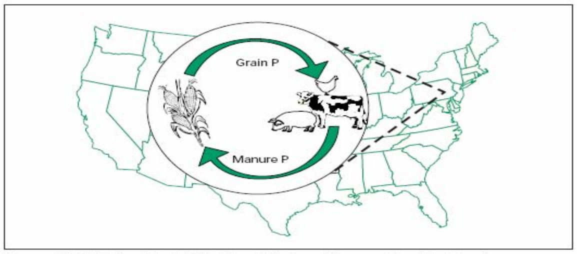


Figure 34-6. Before World War II, nutrient cycling was localized and sustainable within watersheds.

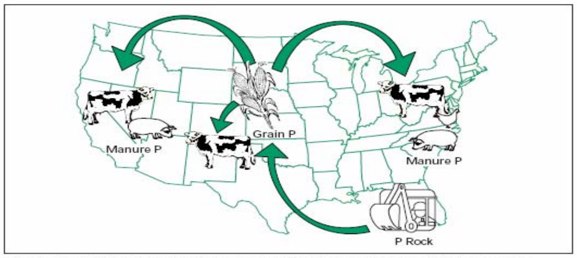


Figure 34-7. Since World War II, the nutrient cycle has been broken on a national level, with P tending to move from areas of grain production to areas of livestock production.

Nutrient Budget Studies

Table 34-3. Farming system and nutrient budget.

Farming System	Nutrient Input In			
	Feed	Fertilizer	Output	Balance
	lbs/acre/yr			
Phosphorus budget				
Cash crop [1]	—	20	18	+2
Dairy [2]	28	10	13	+25
Hog [3]	95	—	60	+35
Poultry [4]	1,390	—	470	+920
Nitrogen budget				
Cash crop [1]	—	85	82	3
Dairy [2]	138	9	68	79
Hog [3]	350	9	230	129
Poultry [4]	5,200	—	2,940	2,260

[1] 75-hectare cash crop farm growing corn and alfalfa.
[2] 100-hectare farm with 65 dairy Holsteins averaging 14,550 lbs milk/cow/yr, 5 dry cows, and 35 heifers. Crops were corn for silage and grain, and alfalfa and rye for forage.
[3] 75-hectare farm with 1,280 hogs; output includes 40 lbs P and 132 lbs N/acre/yr manure exported from the farm.
[4] 30-hectare farm with 74,000 poultry layers; output includes 7 kg P and 80 lbs N/acre/yr manure exported from the farm.
Adapted from Lanyon and Thompson 1996 and Bacon et al. 1990.

The Sink

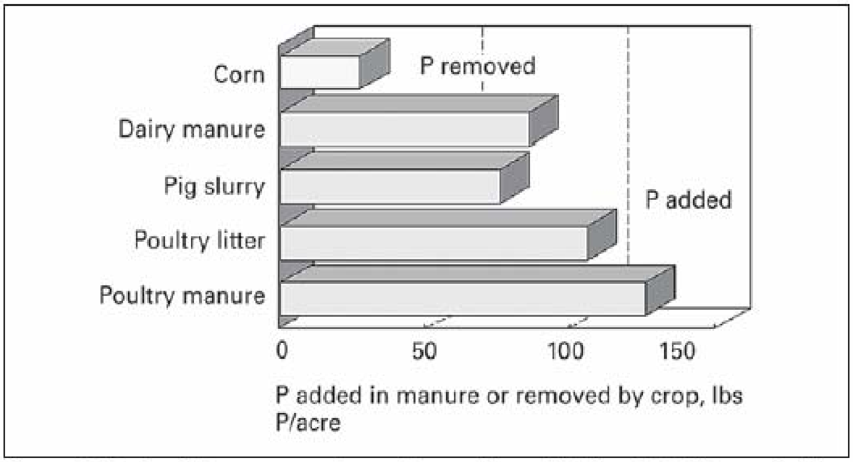


Figure 34-8. Applying manure to meet crop N needs (about 200 lbs available N/acre) will add much more P than corn uses annually.

Processes and Pathways

Table 34-4. Factors influencing P loss.

Factors	Description
Erosion	Total P loss is strongly related to erosion.
Surface runoff	Water serves as the transport mechanism for P either off or through the soil.
Subsurface flow	In sandy, organic, and P-saturated soils or soils with preferential pathways, P can leach through the soil.
Soil texture	Influences relative volumes of surface and subsurface flow
Irrigation runoff	Improper irrigation management can increase P loss by increasing surface runoff and erosion.
Connectivity to stream	The closer the field is to the stream, the greater the chance of P reaching it.
Proximity of P-sensitive water	Some watersheds are closer to P-sensitive waters than others (that is, point of impact).

Processes and Pathways

Sensitivity to P inputs	Shallow lakes with large surface areas tend to be more vulnerable to eutrophication.
Soil P	As soil P increases, P loss in sediment, surface runoff, and subsurface flow increases.
Application rate	The more P (fertilizer or manure) applied, the greater th e risk of P loss
Application method	P loss increases in the following order: subsurface injection, plowed under, and surface broadcast with no incorporation.
Application source	The P in some fertilizers and manure is more soluble than in others, and thus , more susceptible to runoff.
Application timing	The sooner it rains after P is applied, the greater the risk for P loss.

Forms and Processes

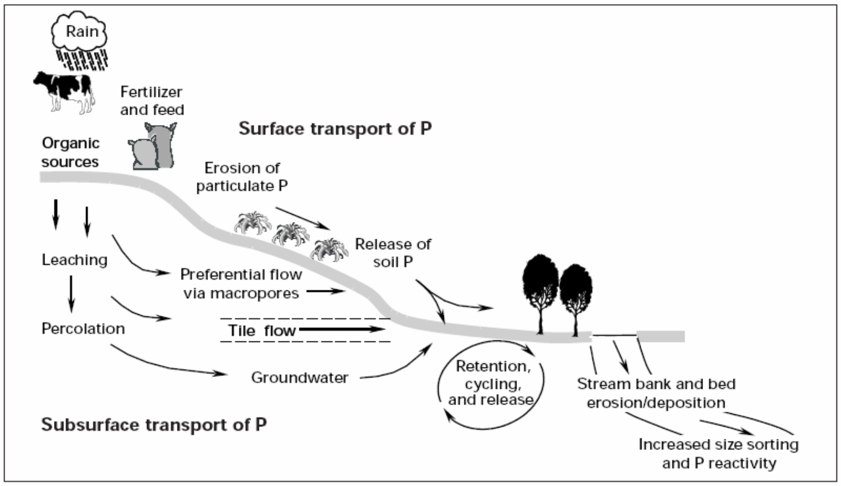


Figure 34-11. Factors affecting P transport to surface waters in agricultural ecosystems.

Surface Runoff and Dissolved P

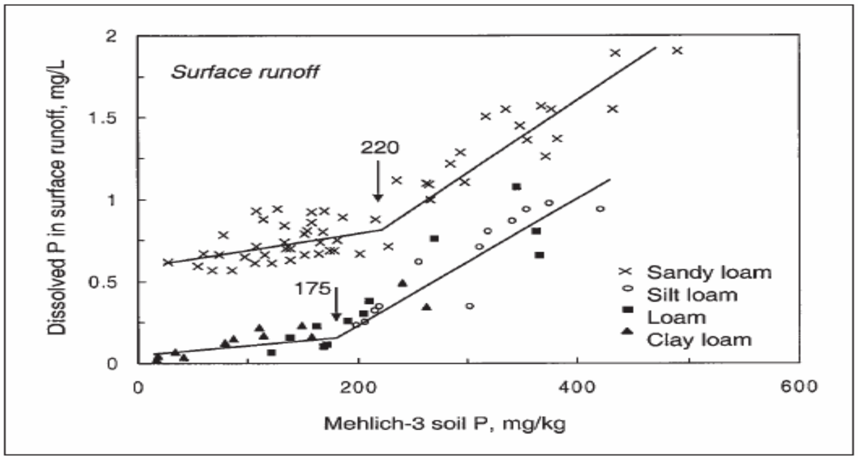


Figure 34-12. Relationship between the concentration of dissolved P in surface runoff and Mehlich-3 extractable soil P concentration of surface soil (0-2 inch depth) from a central PA watershed.

Subsurface Drainage and Dissolved P

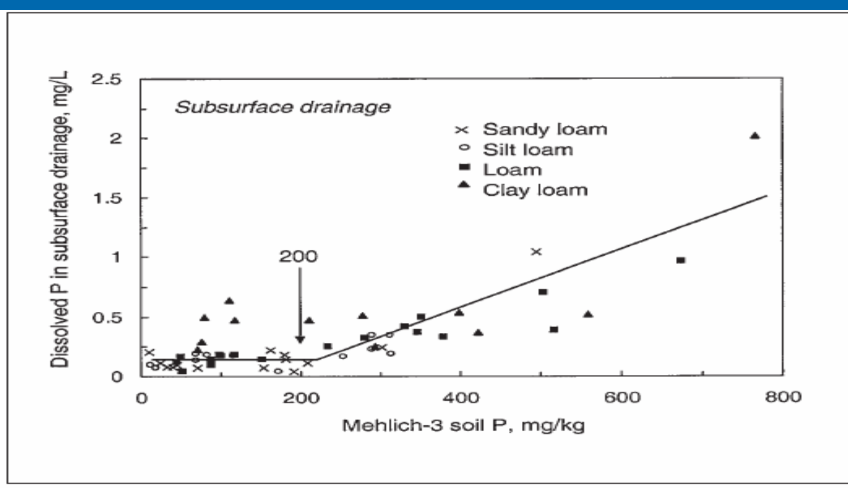


Figure 34-13. Relationship between the concentration of dissolved P in subsurface drainage from 30 cm deep lysimeters and the Mehlich-3 extractable soil P concentration of surface soil (0-2 inch depth) from a central PA watershed.

Unified Strategy for AFOs

- Joint USDA and U.S. EPA strategy for nutrient management to address water quality concerns
- Outlines 3 options:
  - Agronomic Soil Test P
  - Environmental Soil Test P Thresholds
  - P-Indexing of Site Vulnerability

Agronomic P

- Problem with approach
  - Sampling method, P-Extraction, and Interpretations developed strictly for crop response considerations.
  - No scientific basis for correlation with environmental impact
  - Only measures plant available P

Sampling Depth

- For fertility recommendations it is generally recommended that soil samples be collected at 6-8" depth (i.e., to plow depth or zone of greatest root concentration)
- When sampling to estimate P-loss from soil, it is the surface inch or two which will interact with rain and runoff that is most import to accurately reflect environmental considerations

Environmental P Threshold

Table 34-5. Threshold soil test P values and P management recommendations.

State	Threshold Values, ppm		Soil test P Method	Management Recommendations for Water Quality Protection
	Agronomic[1]	Environmental		
Maryland	25	75	Mehlich-1	**Above 75 ppm soil P:** Use P index. Soils with high index must reduce or eliminate P additions.
Michigan	40	75 and 100	Bray-1	**75 - 150 ppm soil P:** Added P not to exceed crop removal. **Above 150 ppm soil P:** Apply no P until soil test P is < 150 ppm.
Mississippi	40	70	Lancaster	**Above 70 ppm soil P:** No P added
Ohio	40	150	Bray-1	**Above 150 ppm soil P:** Apply no P until soil test P is < 150 ppm.

Agronomic v. Environmental

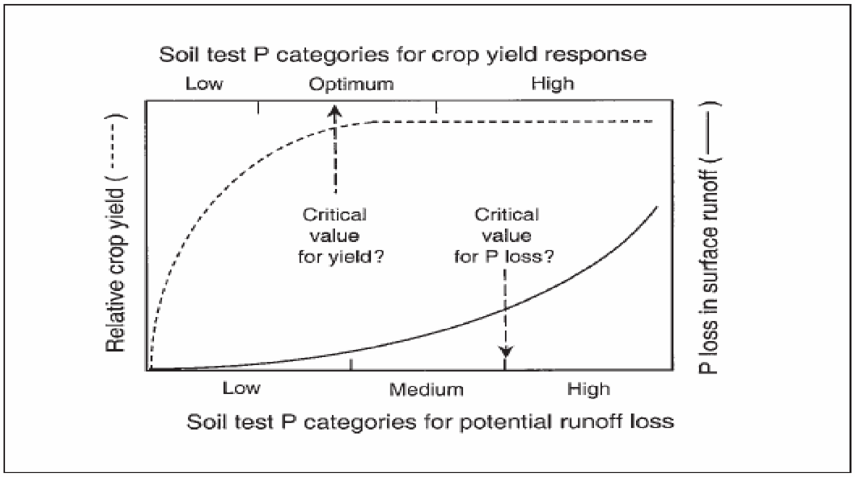
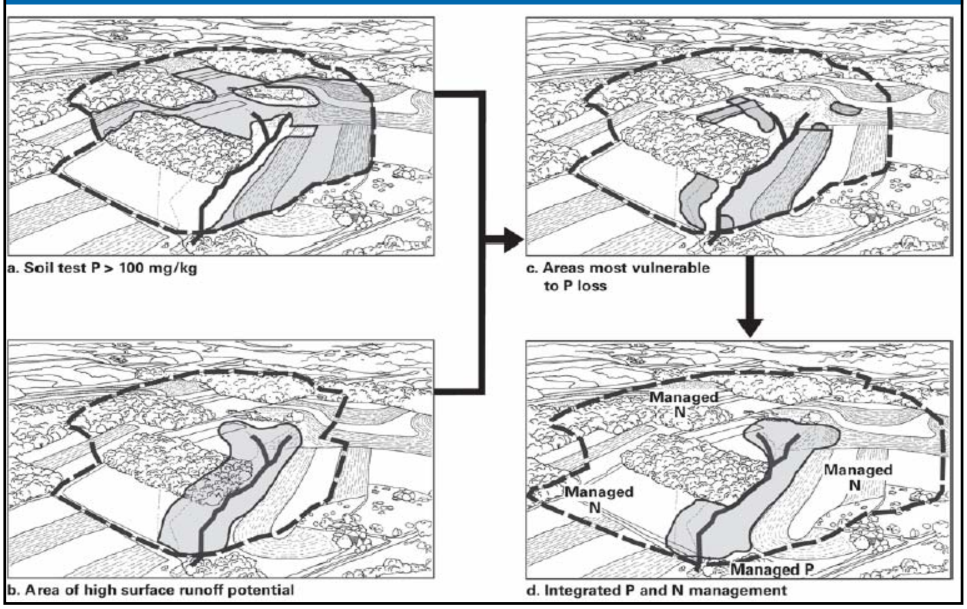


Figure 34-14. As soil P increases, so does crop yield and the potential for P loss in surface runoff. The interval between the critical soil P value for yield and runoff P is important for P management.

Source Area Management



P-Index Helps Identify and Rank …

- Agricultural areas or practices at greatest risk of P loss and provides management options that give land users flexibility in developing remedial strategies.
- Reviews of Manure Management Plans at Ohio EPA for permitting purposes rarely include P-Index strategies.

Source BMPs-Minimizing P Loss at Origin

- Balance P inputs with outputs at farm or watershed scale
- Add enzyme to feed to increase nutrient utilization by ani mals
- Minimize P in livestock feed by not overfeeding P
- Feed low phytic acid corn to reduce P in manure
- Test soil and manure to optimize P management
- Physically treat manure to separate solids from liquid
- Chemically treat manure to reduce P solubility, for example, alum, flyash, water treatment residuals
- Biologically treat manure, for example, microbial enhancement
- Calibrate fertilizer and manure application equipment

Source BMPs-Minimizing P Loss at Origin

- Apply proper application rates of P
- Use proper P application method, that is, broadcast, pl owed in, injected, subsurface placement, banding
- Carefully time P application to avoid imminent heavy rainfalls
- Use remedial management of excess P areas (spray fields, disposal sites)
- Compost and/or pelletize manures and waste products to provide alternat e use
- Mine P from high P soils with certain crops and grasses
- Manage urban P use (lawns and gardens)

Transport BMPs
Minimizing P Transport

- Minimize erosion, runoff, and leaching
- Plant cover crops to protect soil surface from erosion
- Implement terracing, strip cropping, and contour farming to minimize runoff and erosion
- Practice irrigation management and furrow management to minimize runoff and erosion
- Install filter strips, grass waterways, and other conservation buffers to trap eroded P a nd disperse runoff
- Manage riparian zones and wetlands to trap eroded P and disperse runoff
- Practice drainage ditch management and streambank stabilization to minimize erosion
- Build streambank fencing to exclude livestock from water
- Use wellhead protection to minimize by-pass flow to groundwater
- Install and maintain impoundments to trap sediment and P

Source and Transport BMPs "Systems Approach"

- Retain crop residues to minimize erosion and runoff
- Consider reduced tillage systems to mini mize erosion and runoff
- Practice grazing (pasture and range) management to minimize erosion and runoff
- Exclude animals from certain sites
- Install and maintain manure-handling systems (houses/lagoons)
- Practice barnyard storm water management
- Install and maintain milkhouse waste filtering systems
- Implement a comprehensive nutrient management plan (CNMP)
- Construct tailwater return flow ponds

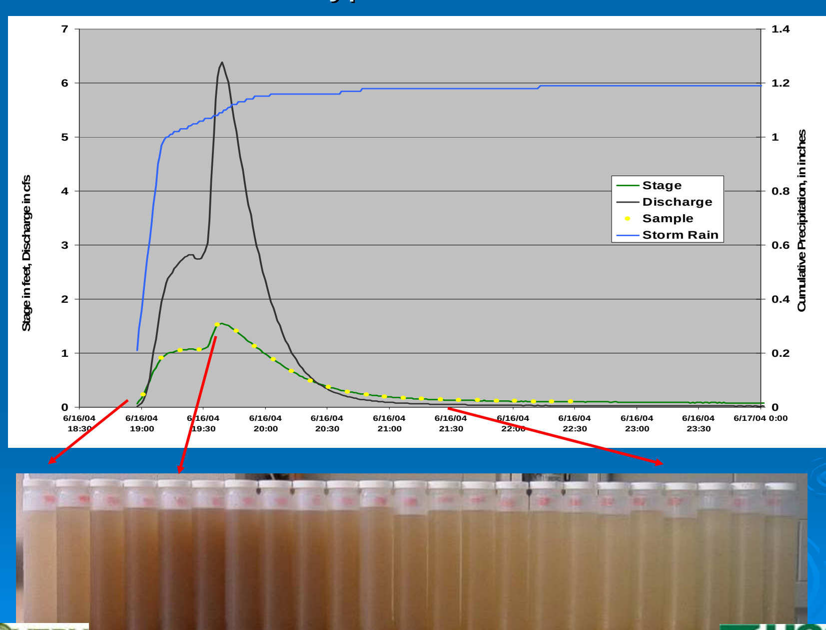
Water Body Treatment BMP "Once it's in the water…"

- Remove sediment from water bodies
- Inactivate sedimentary P with alum or straw
- Stimulate aerobic conditions
- Enhance vegetative growth in littoral zones to decrease water column mixing
- Mine sedimentary P with vegetation
- Harvest aquatic vegetation

Key issues

- Critical importance of the Soil Test (esp. depth)
- Manure and Nutrient Budget Surplus
- Environmental v. Agronomic Thresholds
- P-Index (Utility and extent of use)

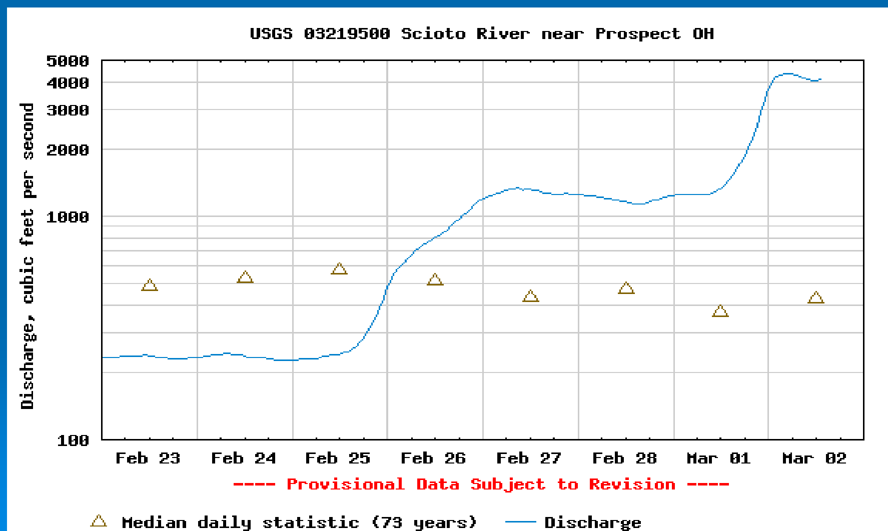
“Typical” Storm



DISCOVERY FARMS

USGS science for a changing world

Thaw Hydrograph Feb 22-March 3, 2007



Poultry Manure Runoff-Union Co.

Poultry-Layer Manure Land Application - Union County
Samples Collected Feb 26, 2007

Parameters (mg/L) → Location	BOD5	Susp. Solids	NH3-N	NO3 + NO2	Total P
Patrick Harmon Rd South Tile	360	15	**47.3**	0.51	5.38
Bokes Creek Upstream on SR 31	5.7	18	0.750	1.62	0.421
Bokes Creek Dowstream on Ford Reed Rd.	5.1	19	0.706	1.71	0.370

UT Tributary to Cessna Cr. @ Rd 90

March 1, 2007, 15:38 hrs.

February 26, 2007, 12:25 hrs
3 days earlier

Runoff Sampling from March 1, 2007 Downstream Land Where Separated Sand Solids from Dairy Manure were Land Applied onto Frozen/Snow Covered Land

Parameters **(mg/L)** → Location	BOD5 (mg/L)	Susp.solids (mg/L)	NH3-N (mg/L)	NO3+NO2 (mg/L)	Total P (mg/L)
Blanchard River at CR 100	7.9	296	0.477	0.91	0.586
UT Cessna Creek on Rd. 90 (Downstream from manure app location) (03-01-07)	30	334	2.96	1.70	1.48
UT Cessna Creek on Rd. 90 (Downstream from manure app location) (02-26-07)	**16**	**20**	**1.19**	**2.97**	**1.11**