Michigan Chapter SWCS Seminar

A Matter or Balance: Feeding our Crops and Protecting our Waters in a Changing Climate

Kellogg Center, Michigan State University

March 16, 2015

Long-term Trends in Agricultural Runoff to Lake Erie: Consequences, Causes, and Remedies

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Heidelberg University
Tiffin, Ohio 44883

Southernmost

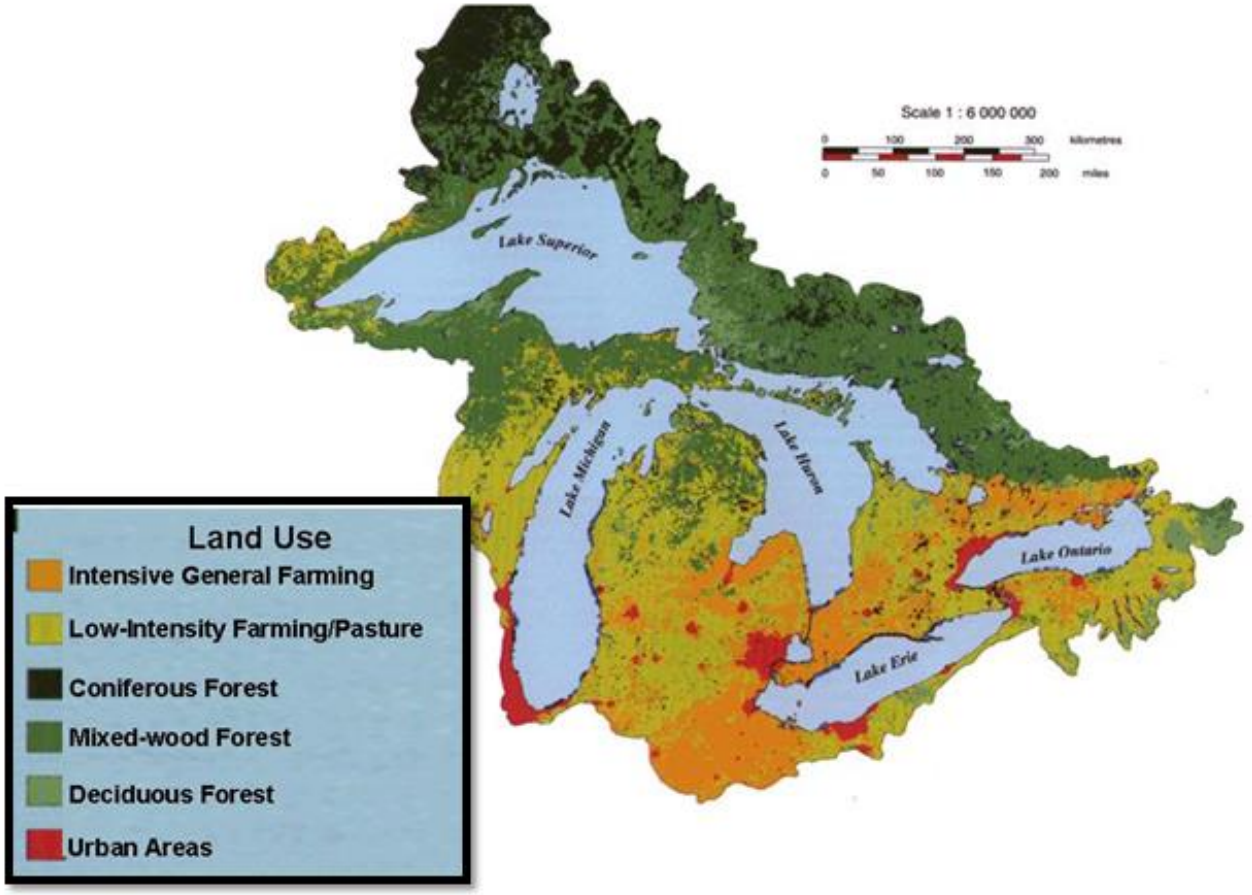
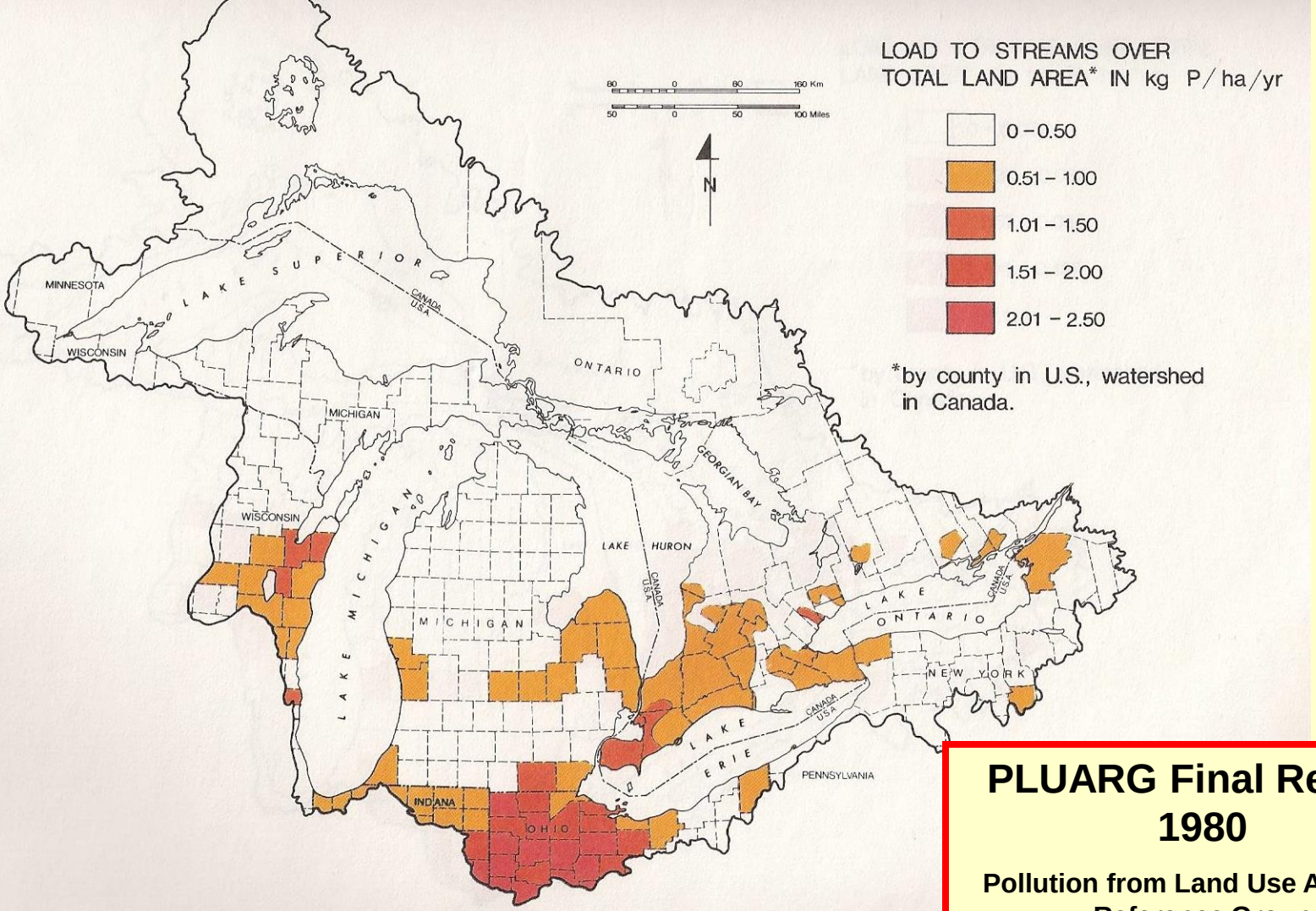


Image: Ohio Sea Grant



PLUARG Final Report, 1980

Pollution from Land Use Activities Reference Group

FIGURE 1. LOCATIONS OF ESTIMATED AGRICULTURAL CONTRIBUTIONS OF TOTAL PHOSPHORUS TO STREAM LOADINGS (by extrapolation, 1976 data).

The Lake Erie Watershed: Sources of Phosphorus Loading

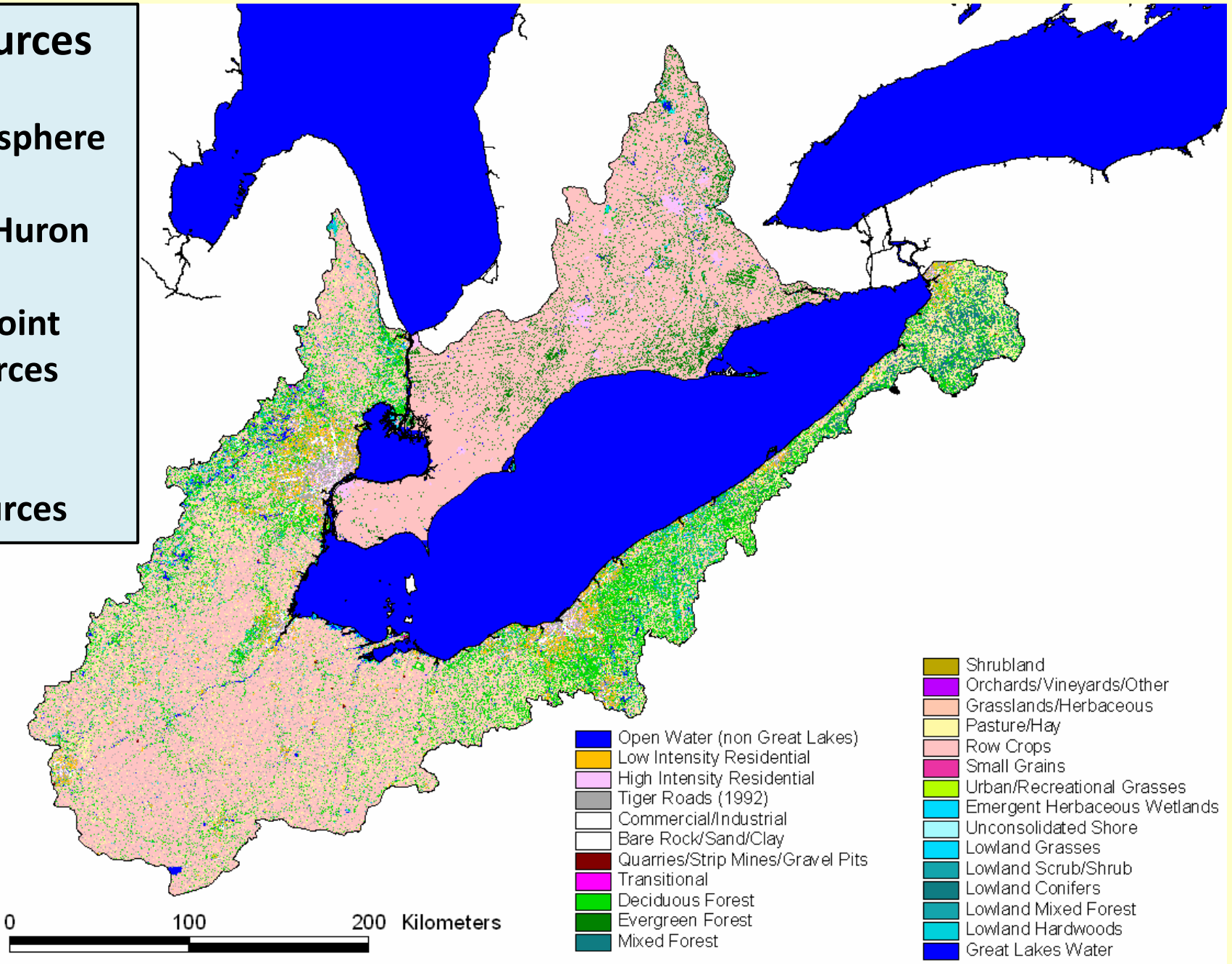
P Sources

Atmosphere

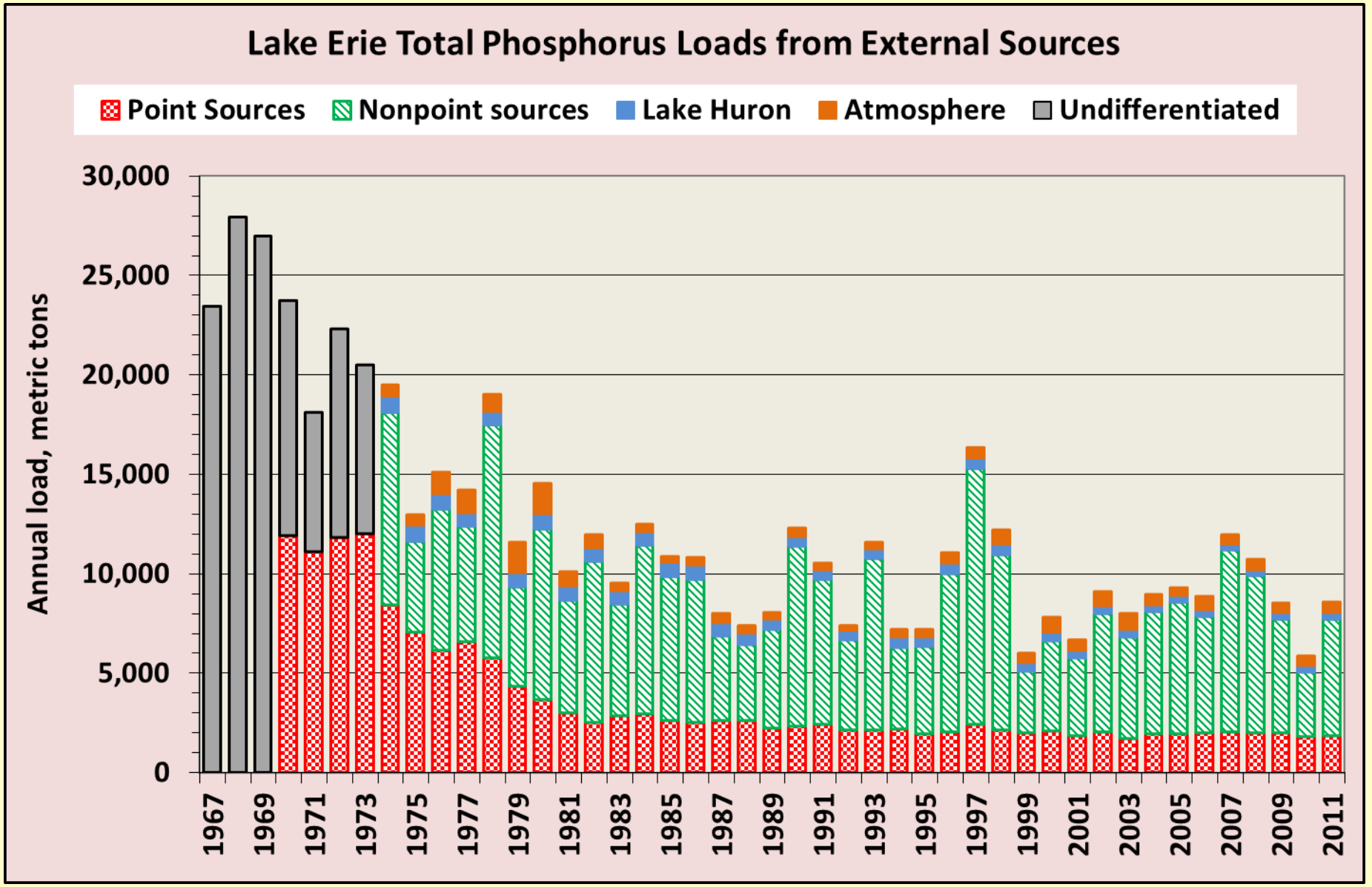
Lake Huron

Nonpoint Sources

Point Sources

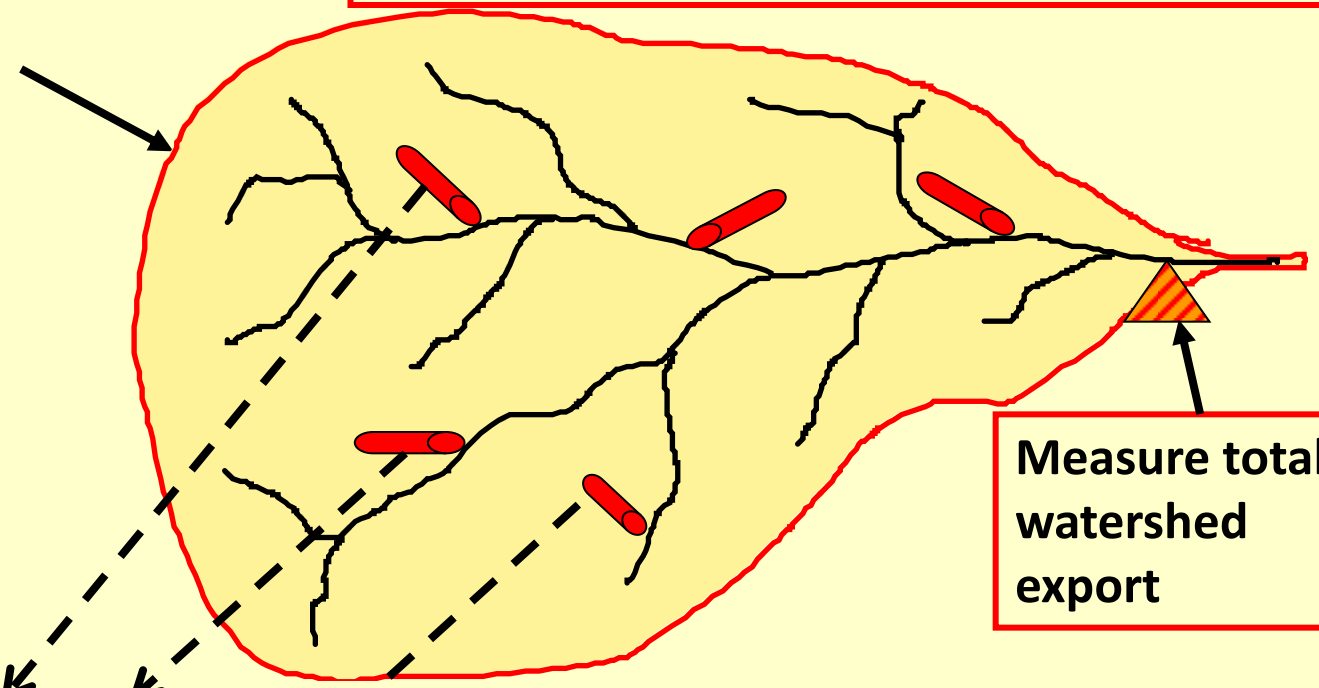


There is a long-term record of total phosphorus loading to Lake Erie



How do we measure nonpoint phosphorus loads?

The Watershed Approach



Data on point source inputs from EPA-required monitoring by dischargers.

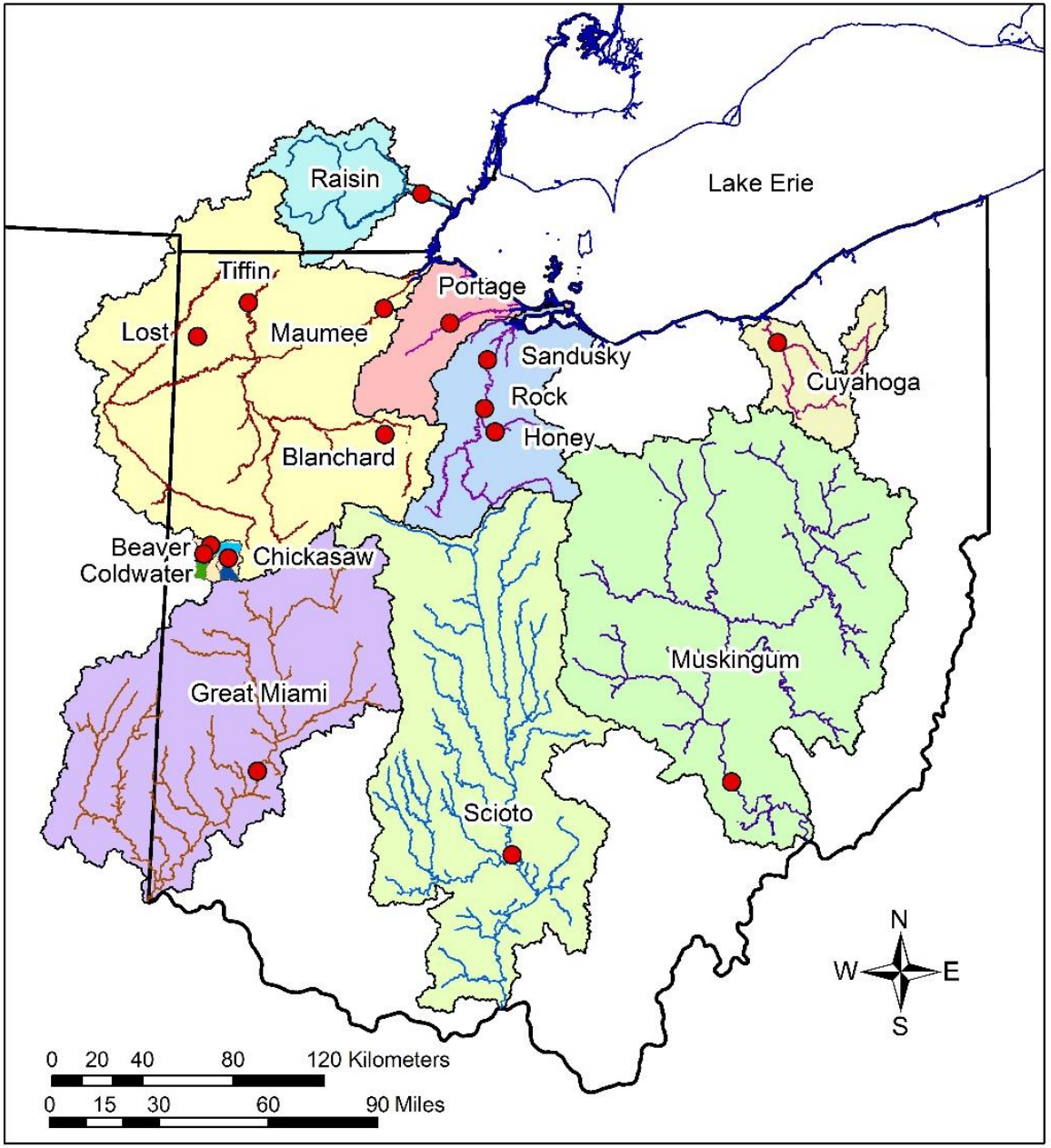
Total watershed output
- point source inputs
nonpoint source output

The Heidelberg University Tributary Loading Program

16 stations

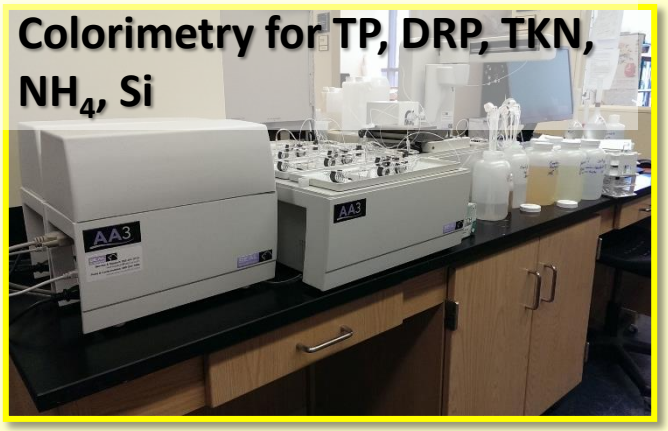
14 with automatic samplers

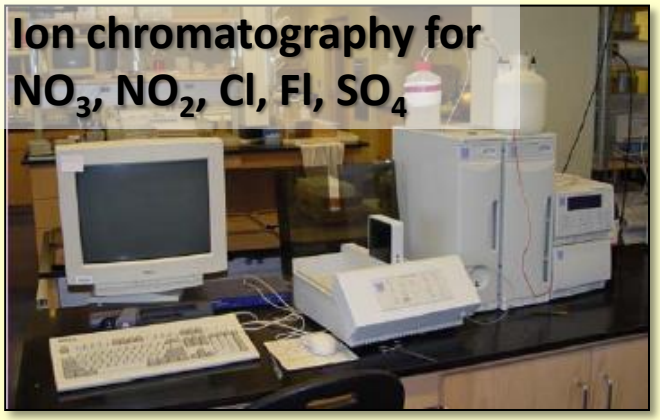
~ 50% of Ohio's land area is upstream from a Heidelberg monitoring station.



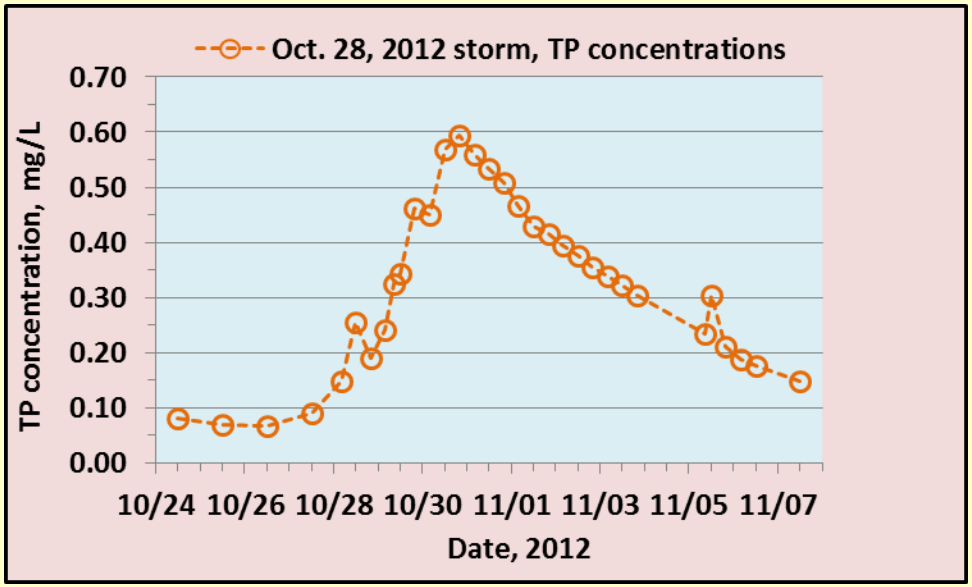
We watch the water go by!

… along with the USGS.





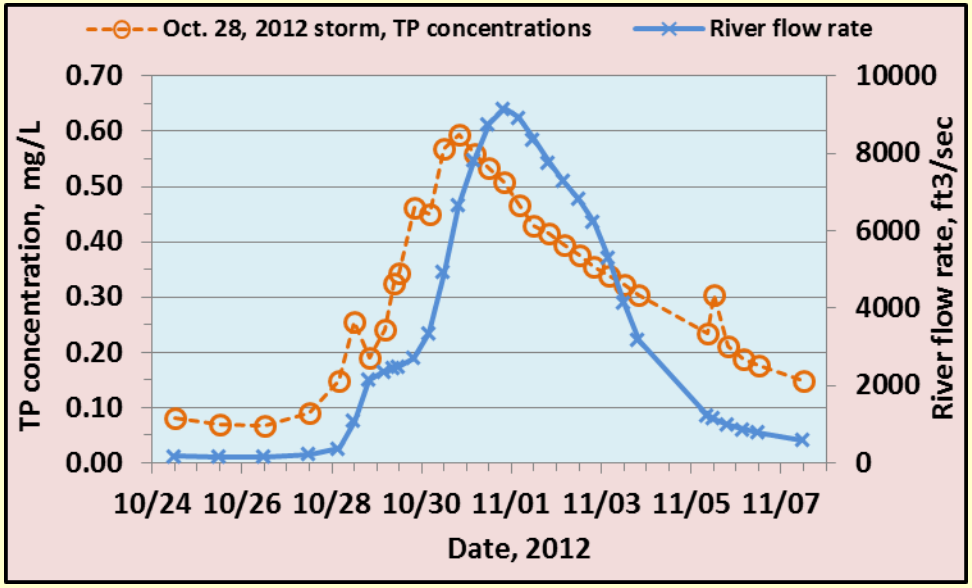
- Samples collected 3x a day
- Analyzed for all major nutrients and suspended sediments



Sandusky River

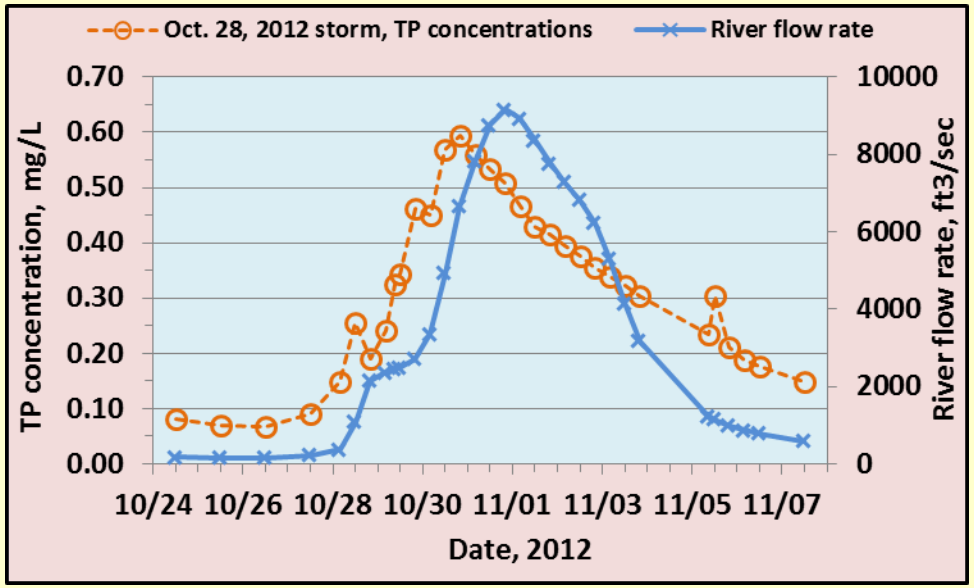
Start out with concentration data…

mg/L



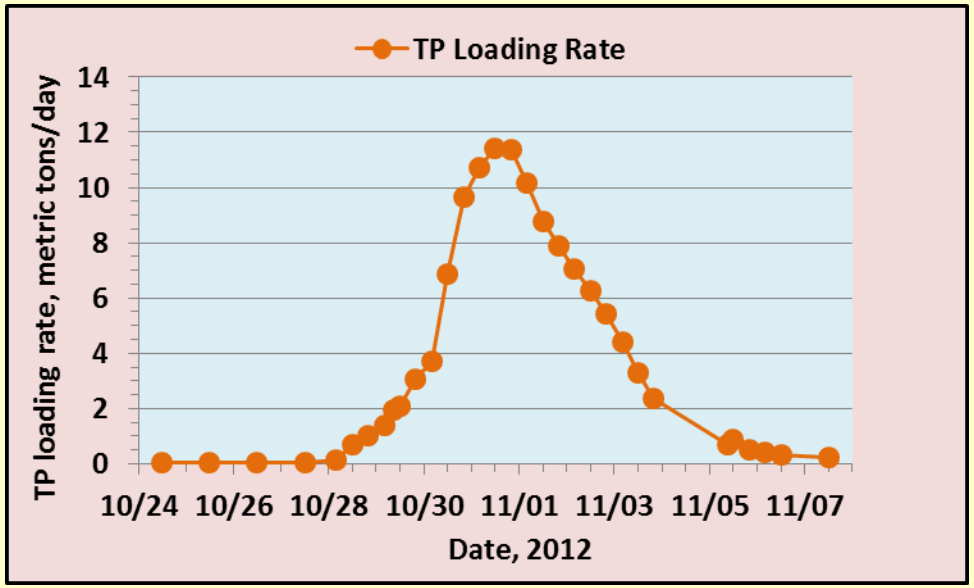
Add river flow rate data from U.S. Geological Survey…

cubic feet/second

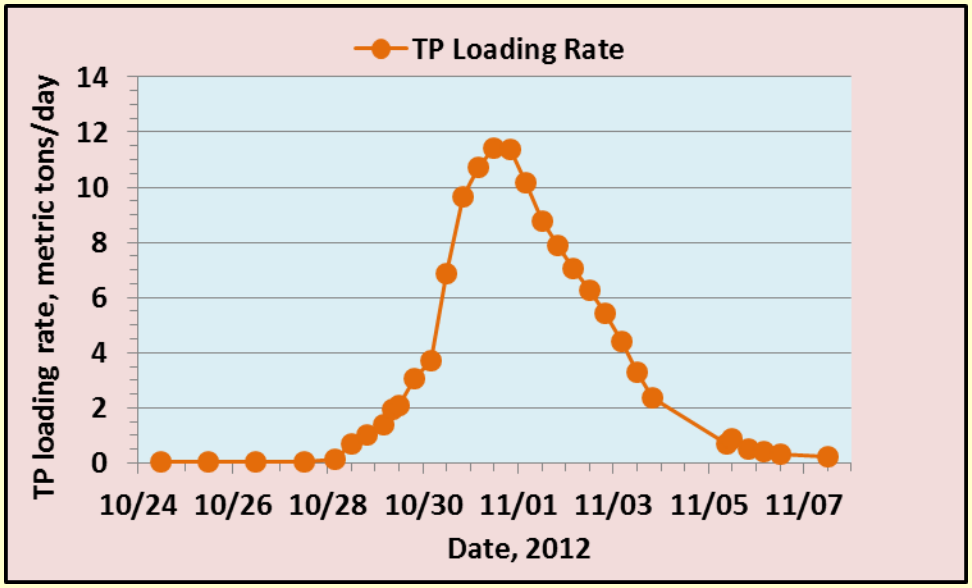


Calculate the loading rate… Amount/time

amount/unit time = amount/unit volume x volume/unit time

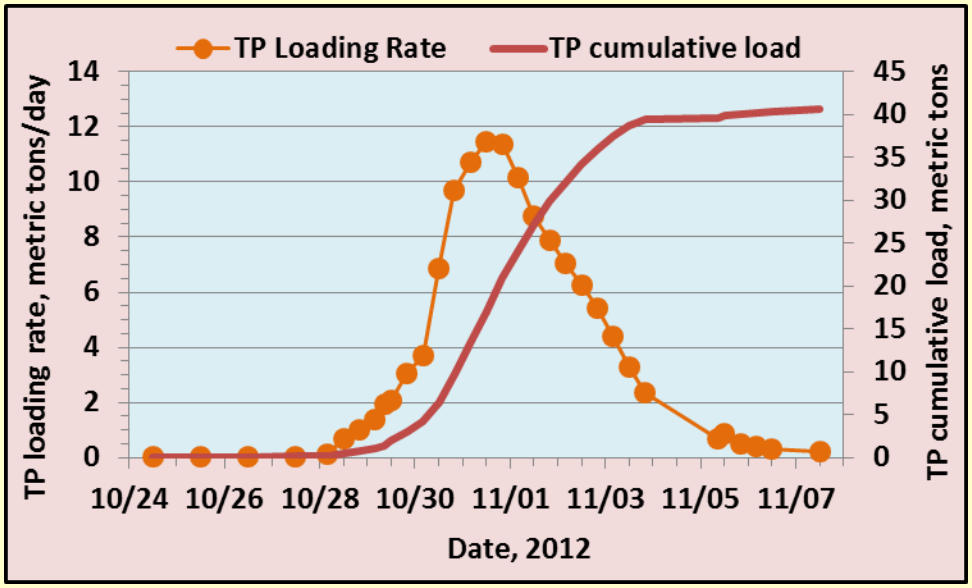


Here is the TP loading rate in units of metric tons per day



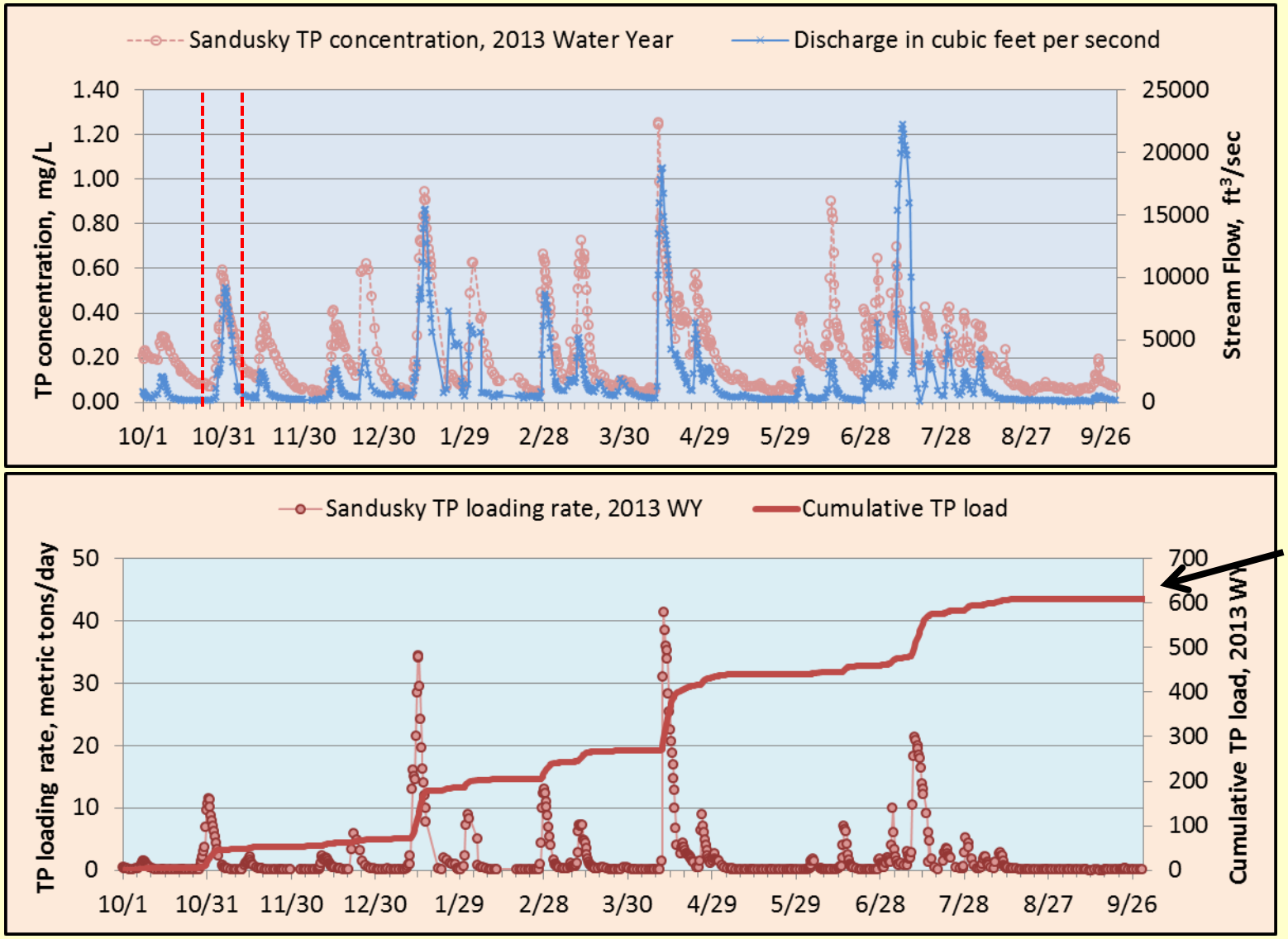
Calculate TP load over a particular time period

Metric tons/day x days = metric tons

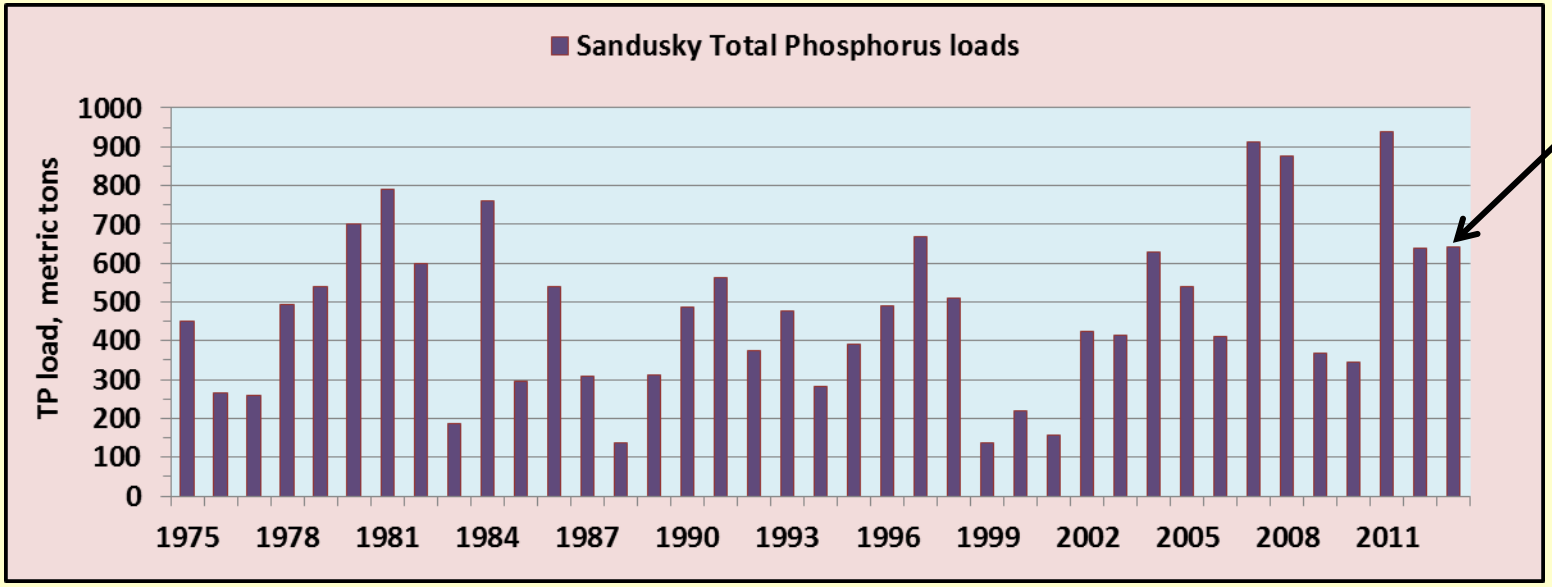


Add in each successive day to obtain cumulative loads for time period

Apply the above procedures to data for an entire year (Here the 2013 Water Year)



610 metric tons of Total Phosphorus



610 metric tons of Total Phosphorus for 2013 WY

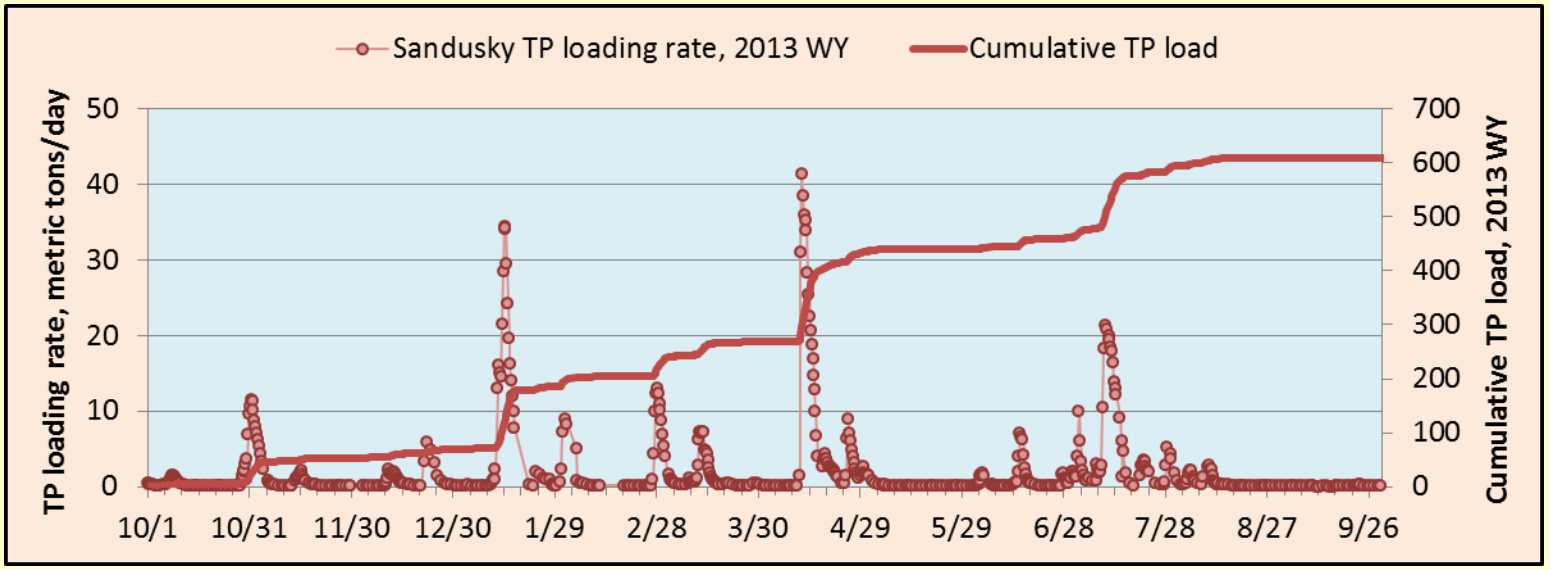
The Sandusky Fremont data set through the 2014 Water Year

- **40 Water Years (1975-2014)**
- **18,625 samples analyzed**

The Honey Creek data set through the 2014 Water Year

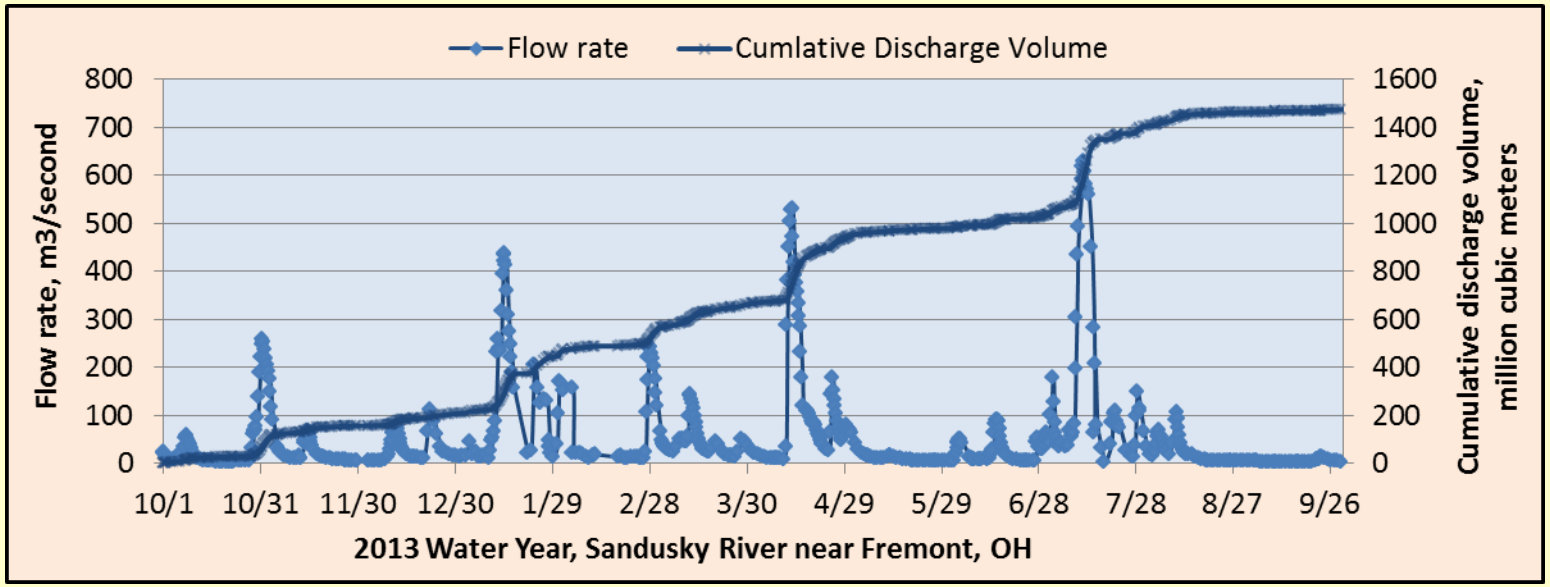
- **39 Water Years (1975-2014)**
- **19,878 samples analyzed**

These are the largest data sets of their type in the United States, and probably globally.



TP load-

610.1 metric tons



Volume discharged

1,473.9 million cubic meters

Annual Flow Weighted Mean Concentration (FWMC) of Total Phosphorus

610.1 metric tons/1,473.9 million cubic meters = 0.414 mg/L

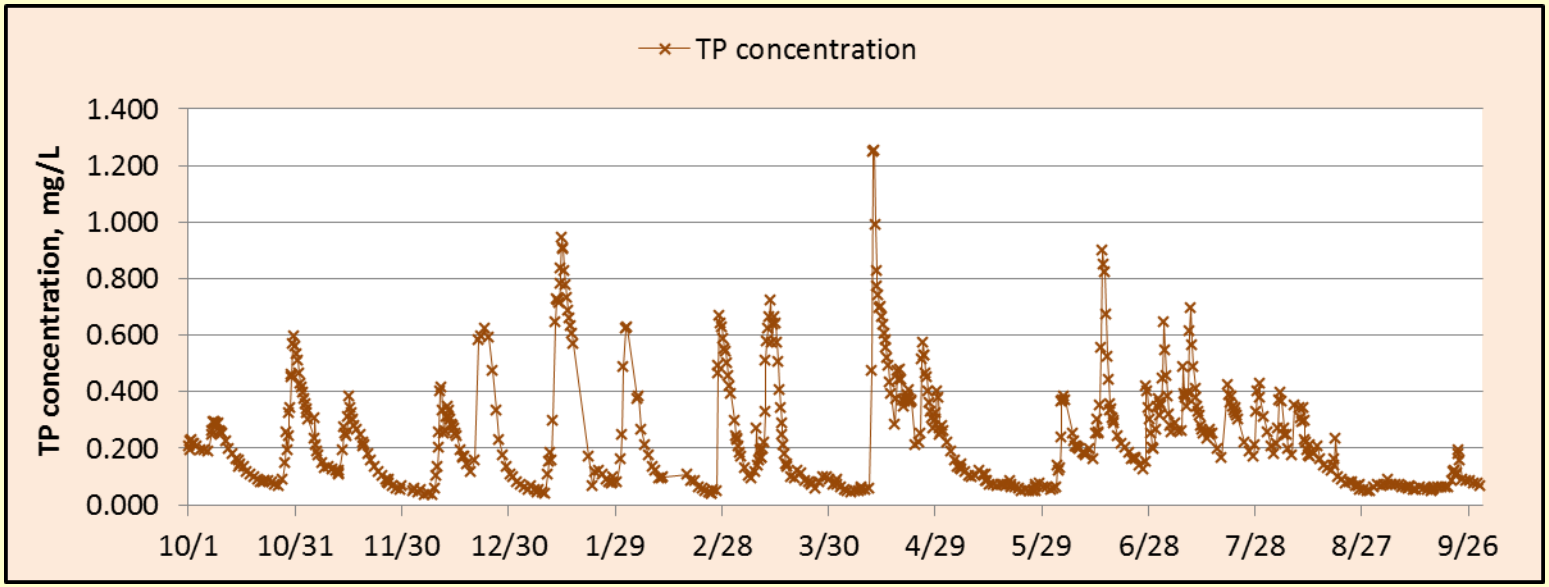
Relationship of FWMCs, discharge volumes, and loads

Annual Flow Weighted Concentration		Annual discharge volume		Annual Load
0.414 mg/L	X	1,473.9 million cubic meters	=	610.1 metric tons

Which variable can farmer's impact the most?

- **FWMCs?**
- **Annual Discharge?**

Sandusky River, Total Phosphorus concentrations, 2013 Water Year



What is the average concentration of TP at the monitoring station?

1. Add up all the samples and divide by the number of samples?
   155.75/604 = <u>0.258 mg/L</u>
2. Flow weighted mean concentration = load /volume
   610.1 metric tons/1,473.9 10^6 m3 = <u>0.414 mg/L</u>
3. Time weighted mean concentration (TWMC)
   Sum(t_i*c_i) / Sum (t_i) = <u>0.203 mg/L</u> (t = time window for each sample)

From here in the 1960s & 1970s…

With some very good years in between!

Re-eutrophication of Lake Erie

… to here in the 2000s

A blue-green algal bloom in the vicinity of the Toledo public water supply intake in 2014 resulted in a 2-day closure of the drinking water supply.

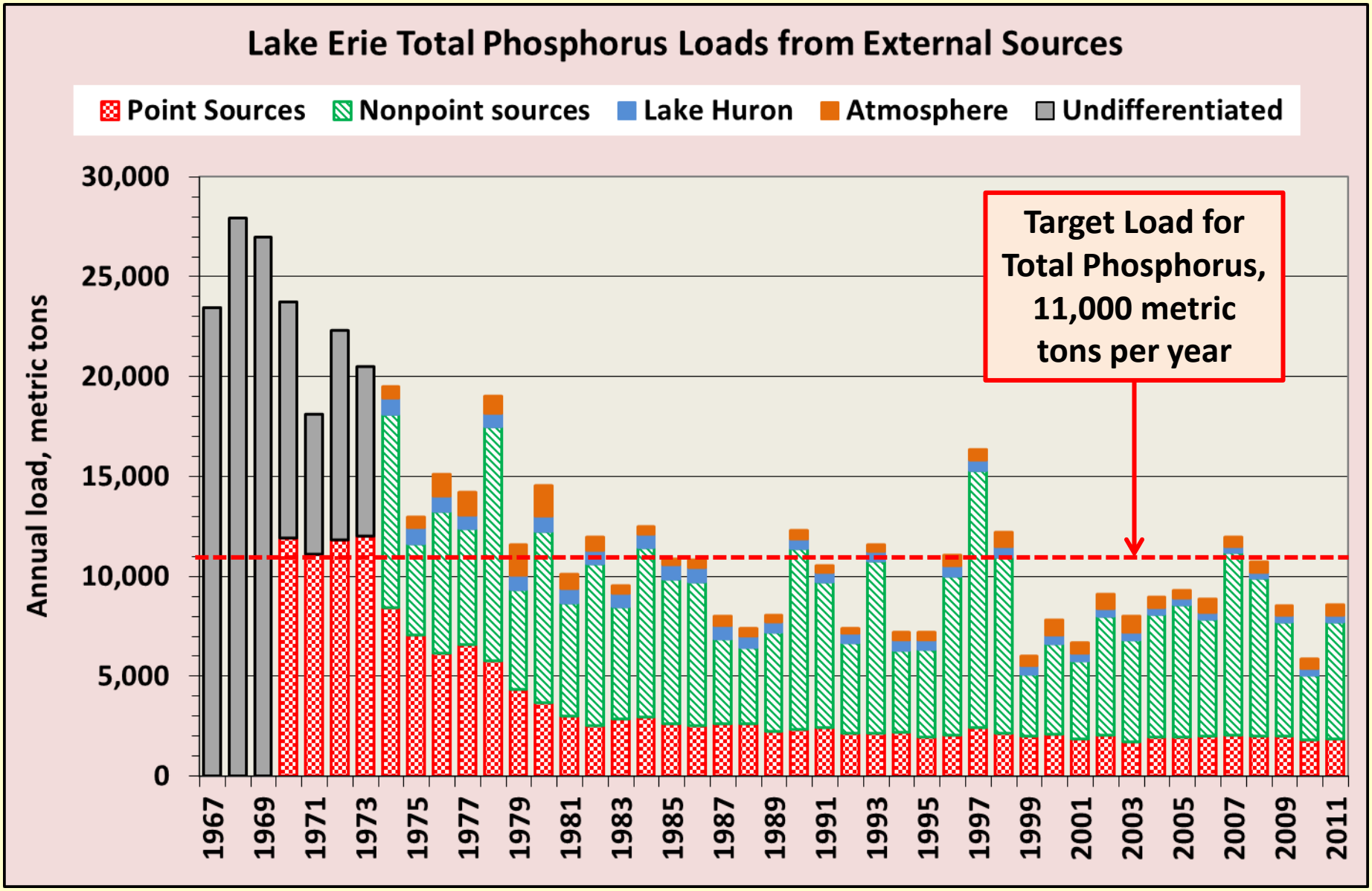
This has triggered a legislative response --- Senate Bill 1

From here in the 1960s & 1970s…

With some very good years in between!

Why?

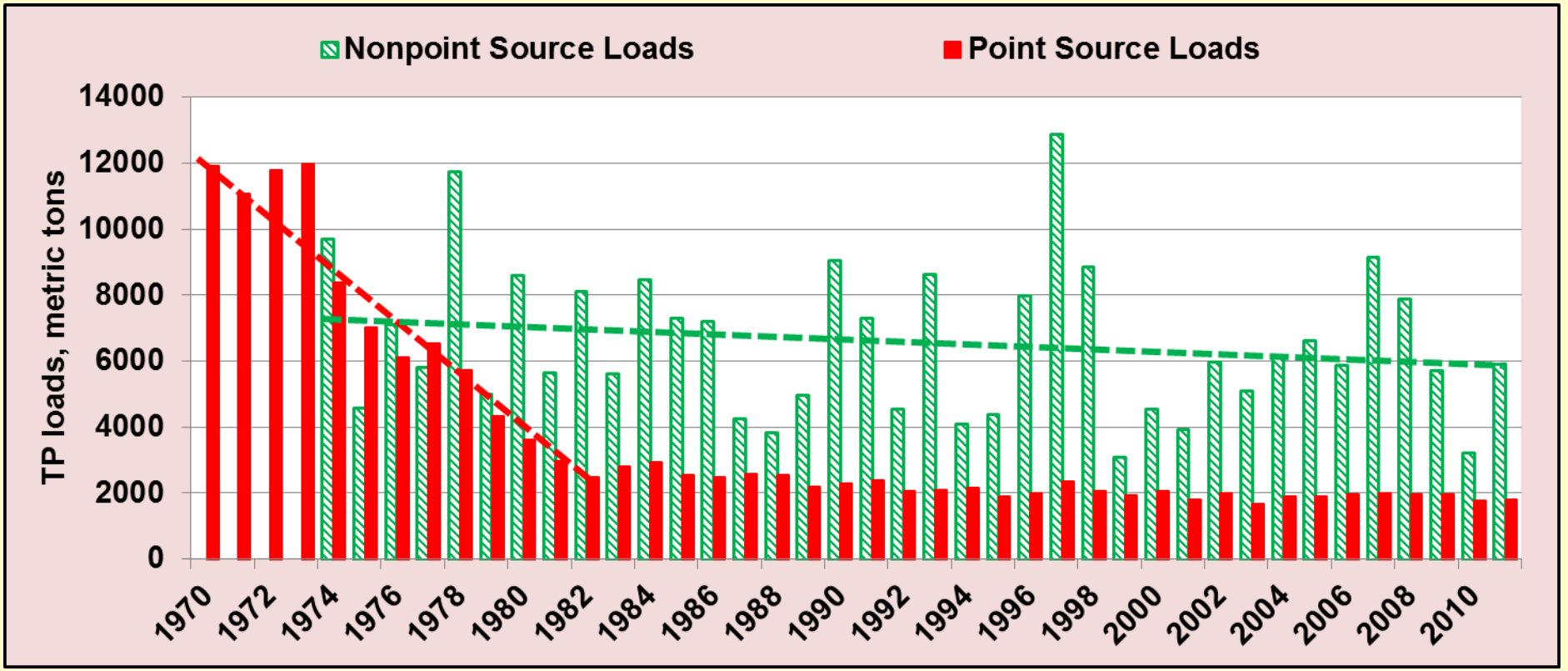
… to here in the 2000s



Target load was first met in 1981.

Now target is only exceeded in wet years with large nonpoint loads

No obvious explanation for re-eutrophication of the Lake based on total phosphorus loads.

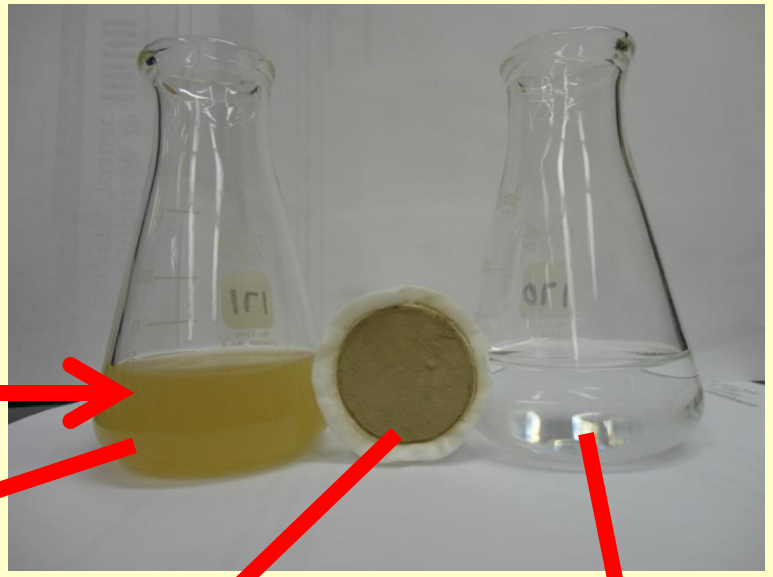


Reductions in point source loading through P-removal programs at municipal (and industrial) waste treatment plants and from bans of phosphorus in laundry detergents.

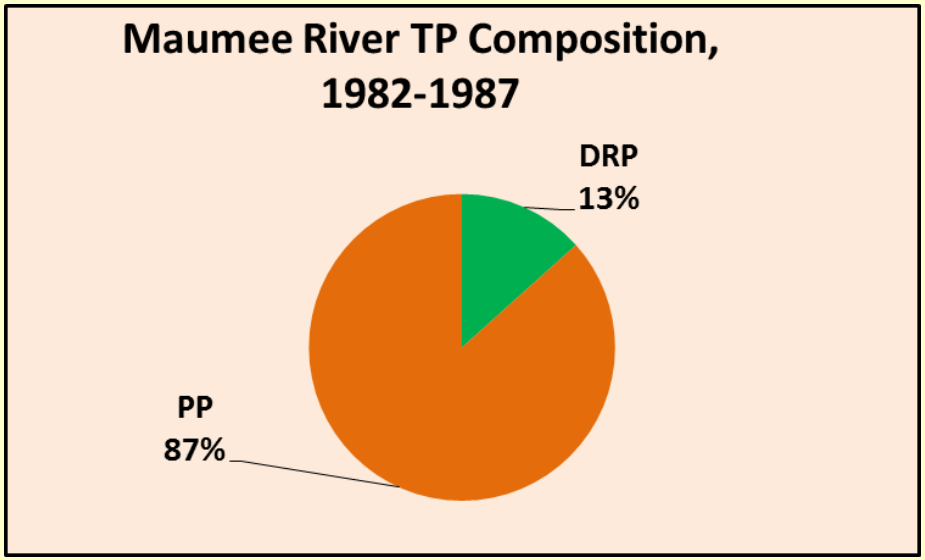
A focus on nonpoint phosphorus control was called for in the 1983 supplement to the Great Lakes Water Quality Agreement of 1978. It called for a 2000 metric ton reductions (1,700 MTA from the US and 300 MTA from Canada.

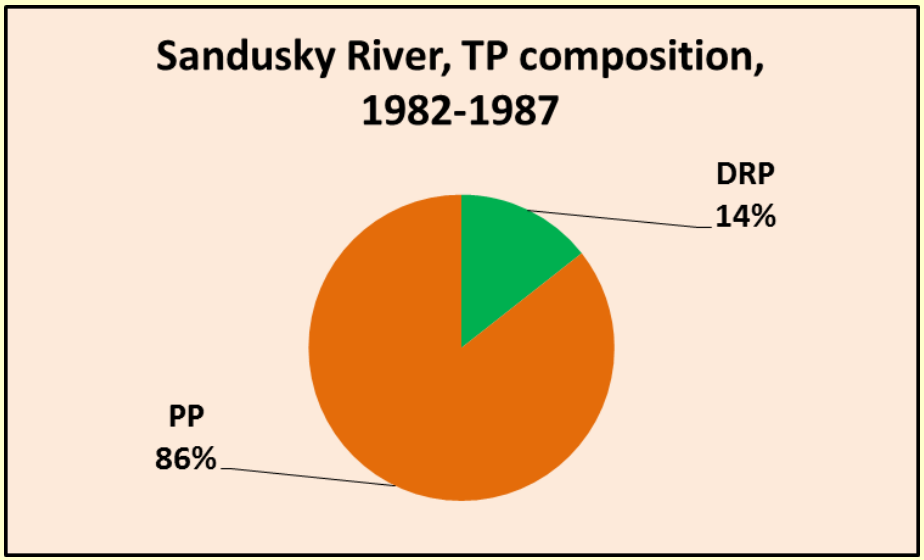
Zebra Mussels
Climate Change
Detroit
What happened?
Lawn Chemicals
Dissolved P loads
Combined Sewers
Dish Washer Detergents

What is “dissolved phosphorus”?



Total Phosphorus	=	Particulate Phosphorus	+	Dissolved Phosphorus
Measure		Calculate		Measure
Availability to algae		25% Bioavailable		100% Bioavailable

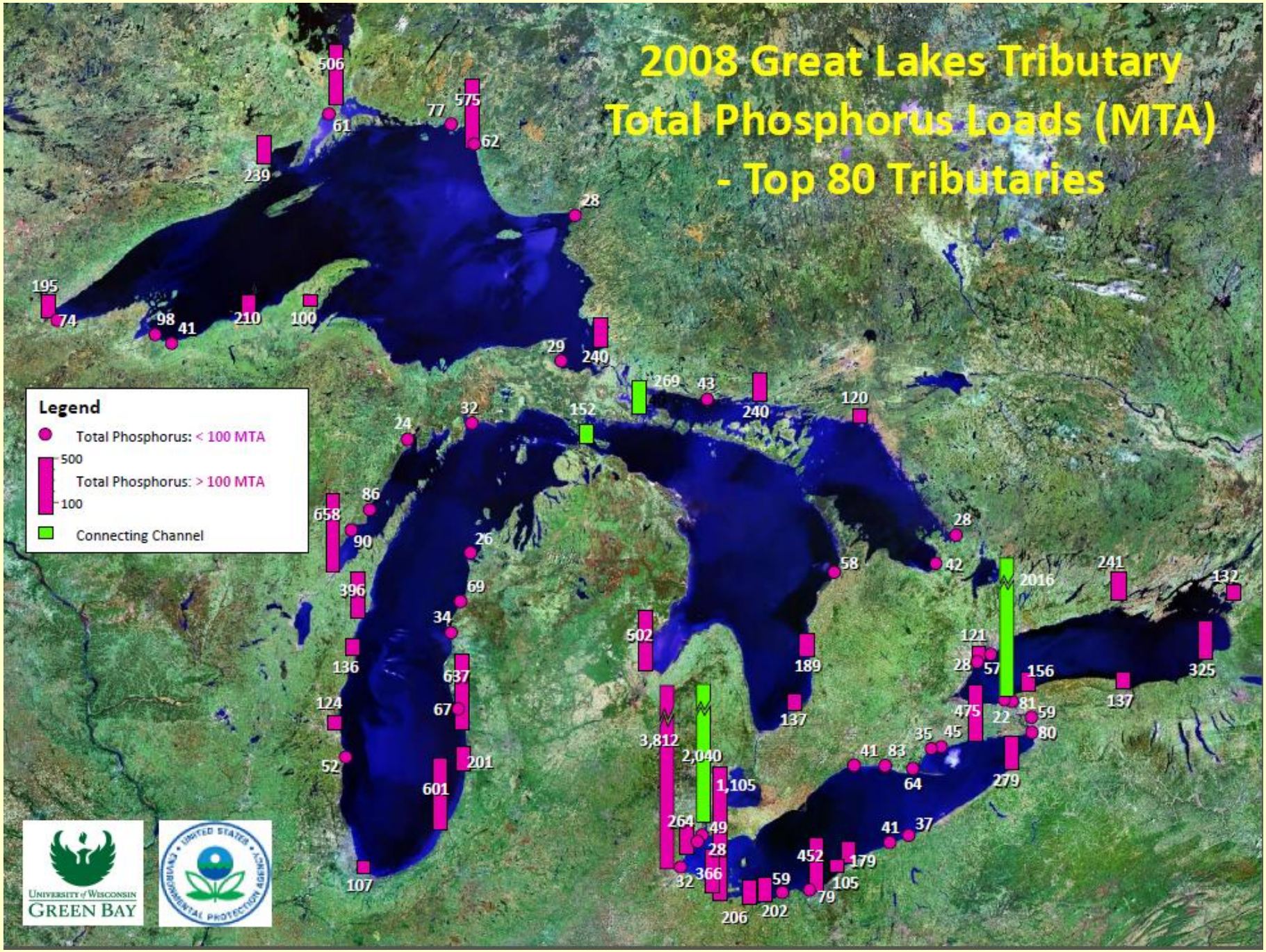




In the 1980s, total phosphorus loading was dominated by particulate phosphorus.

Particulate phosphorus loading was associated with cropland erosion of suspended sediments.

No-till and reduced till agriculture were effective in reducing erosion.


2008 Great Lakes Tributary
Total Phosphorus Loads (MTA)
- Top 80 Tributaries
Legend
Total Phosphorus: < 100 MTA
500
Total Phosphorus: > 100 MTA
100
Connecting Channel
506
61
77
575
62
239
28
195
74
98
41
210
100
29
240
269
43
240
120
32
152
24
86
658
90
26
28
58
42
2016
241
132
396
69
34
502
121
28
57
156
325
136
637
189
137
124
67
137
475
22
81
59
80
3,812
2,040
35
45
41
83
52
201
64
279
601
1,105
264
49
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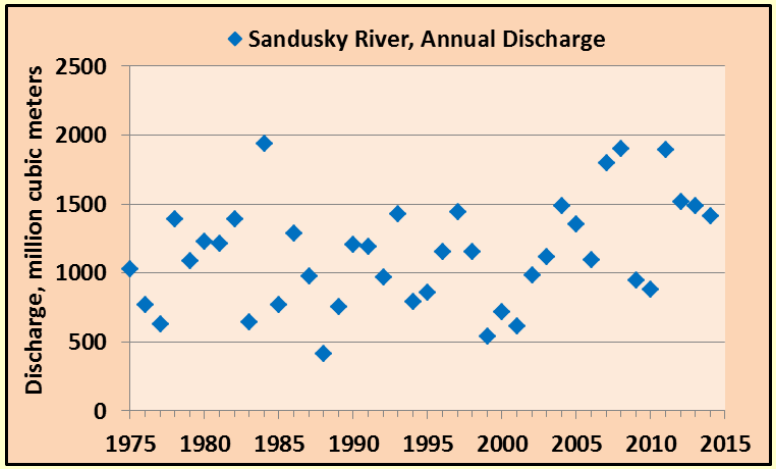
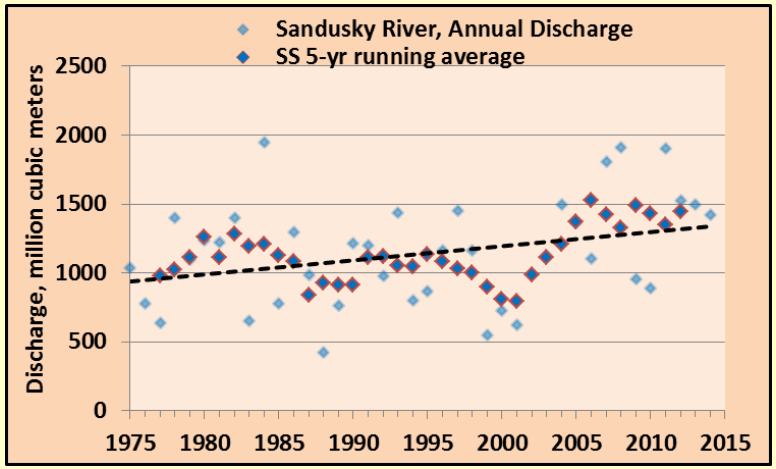
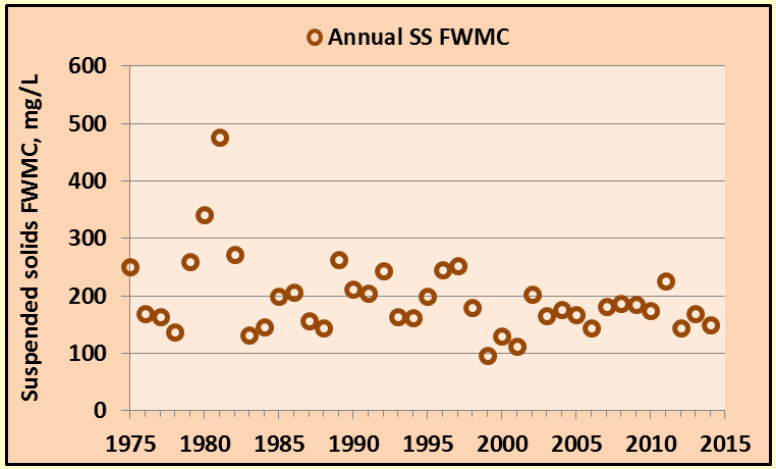
107
206
202
University of Wisconsin
Green Bay
United States Environmental Protection Agency

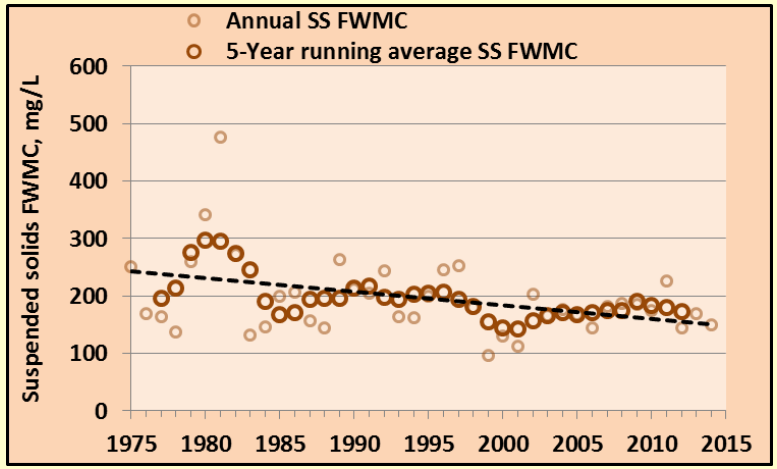


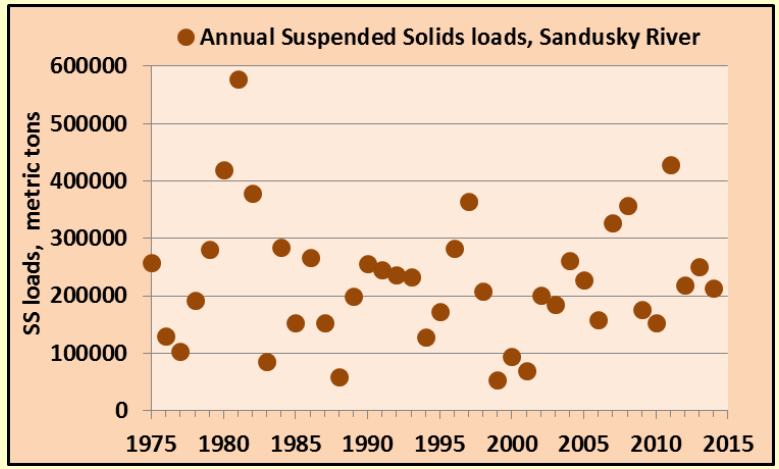
Annual Discharge



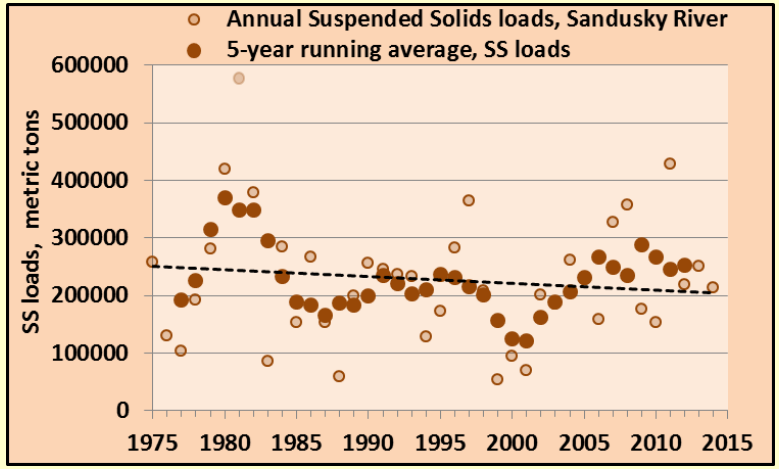


Annual Flow Weighted Mean Concentration Suspended Solids

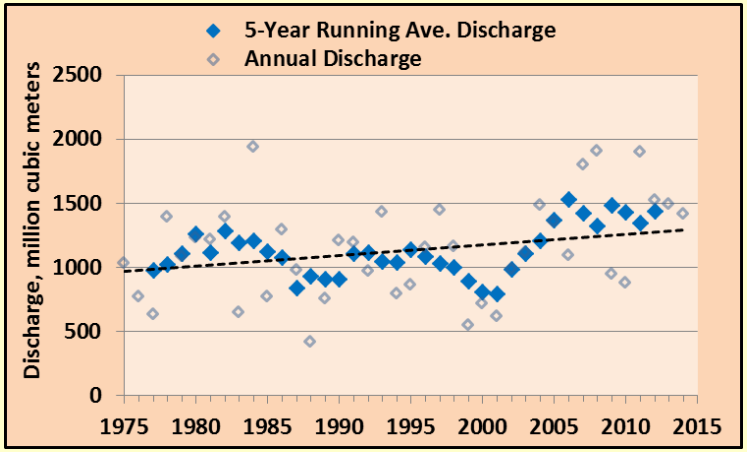




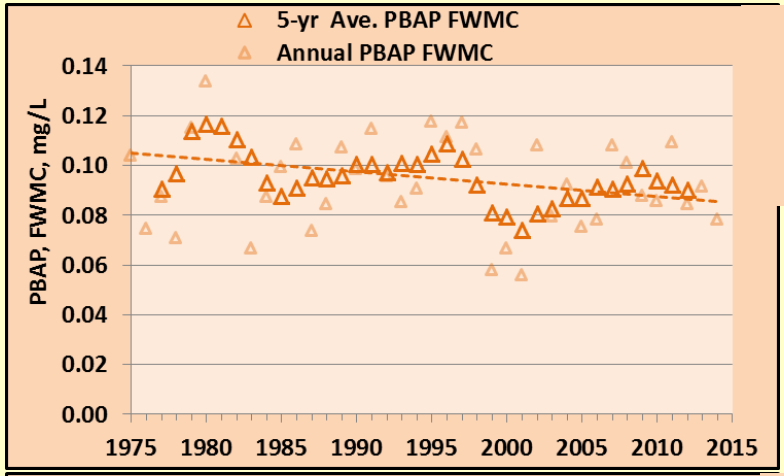
Annual loads Suspended Solids



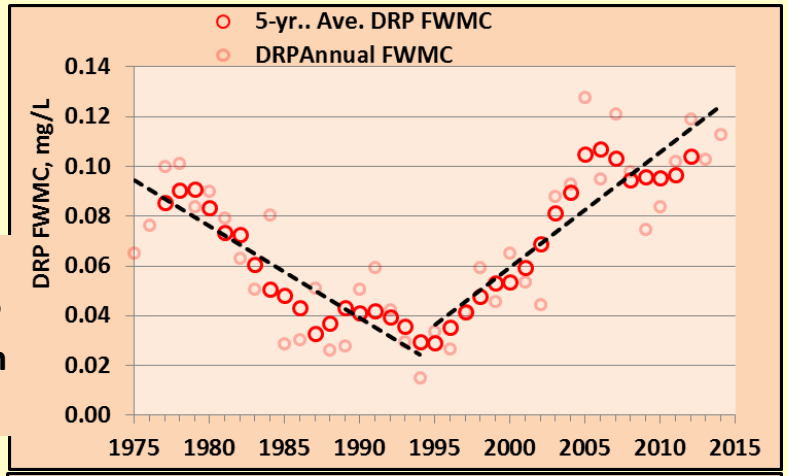
Sandusky River 1975-2014 Trends in discharge and in phosphorus concentrations and loads.



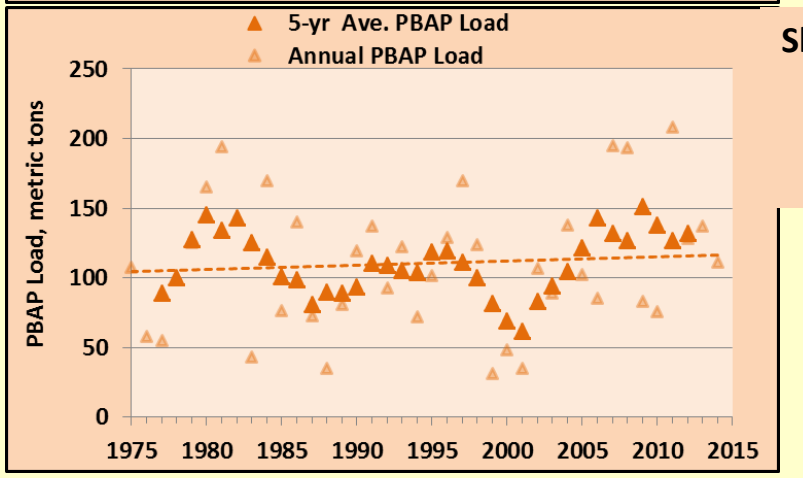
Increase in Discharge



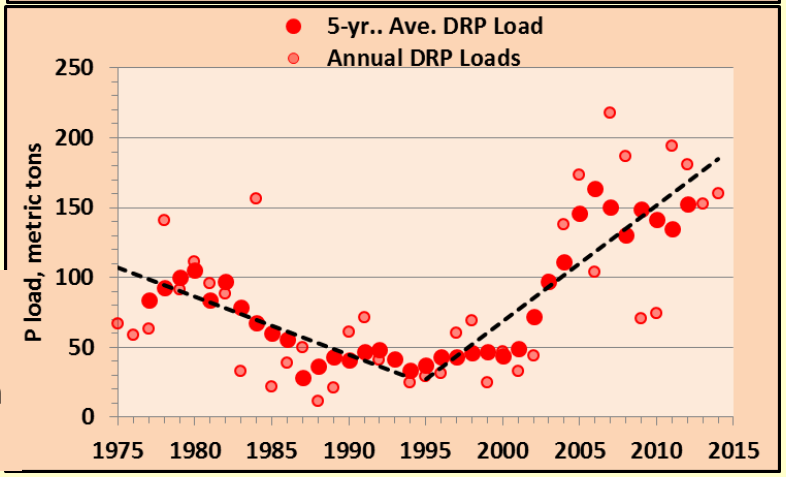
Decrease in FWMC of Particulate BAP



Large decrease in FWMC of DRP followed by even larger increase

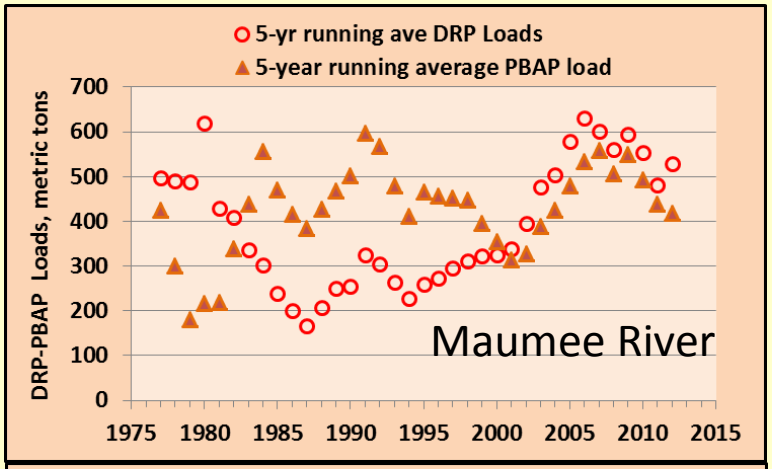


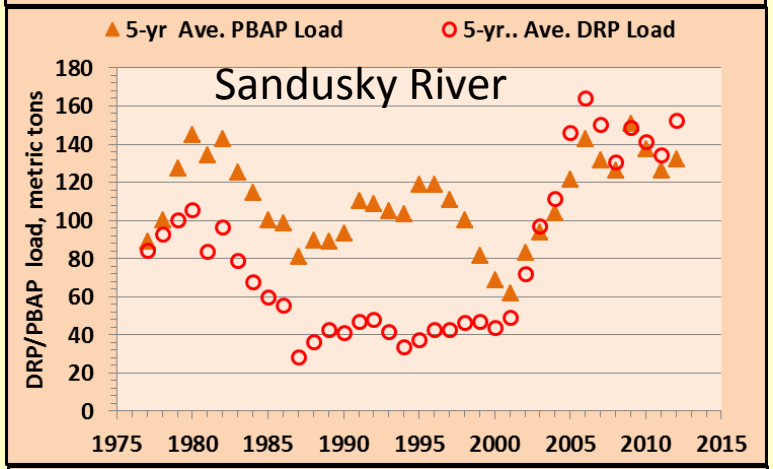
Slight increase in Load of Particulate BAP

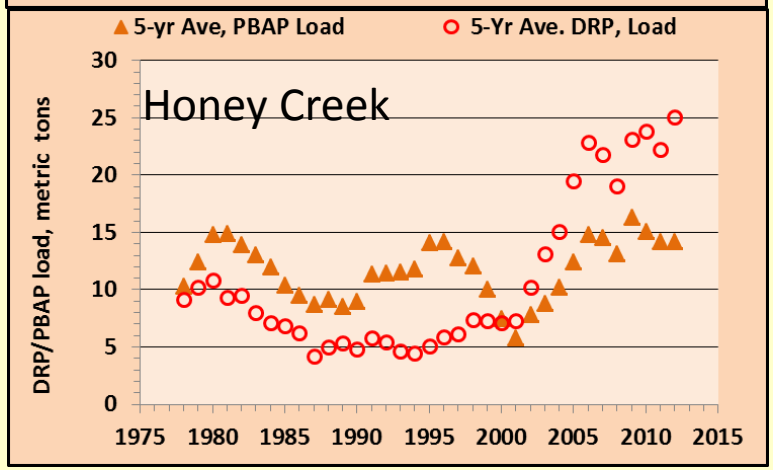


Large decrease in DRP load followed by even larger increase

Trends in PBAP and DRP loads for three Ag watersheds







All three of our long-term agricultural watersheds have shown similar patterns in particulate bioavailable P loading and DRP loading:

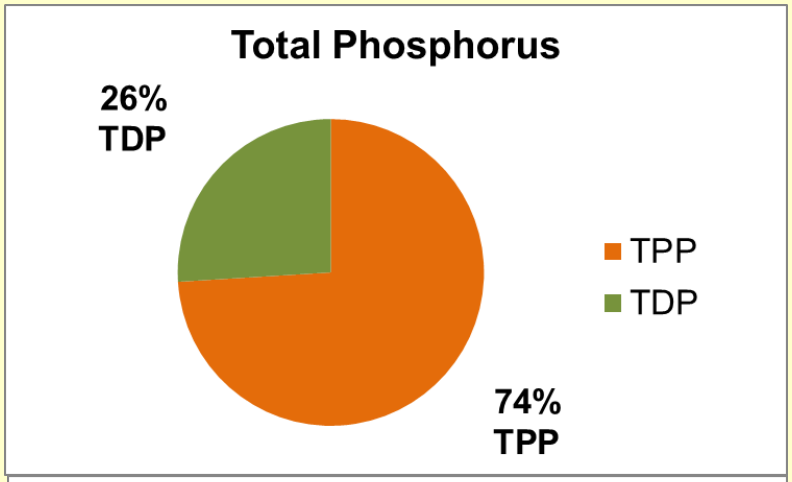
- Particulate BAP loads have fluctuated with discharge patterns and shown a small overall increase through 2014.
- DRP loads decreased substantially from the mid-1970s to the mid-1990s, then increased by large amounts through the mid-2000s followed by a leveling off to the 2014.
- In terms of bioavailable P loading, DRP now exceeds PBAP in all three rivers.

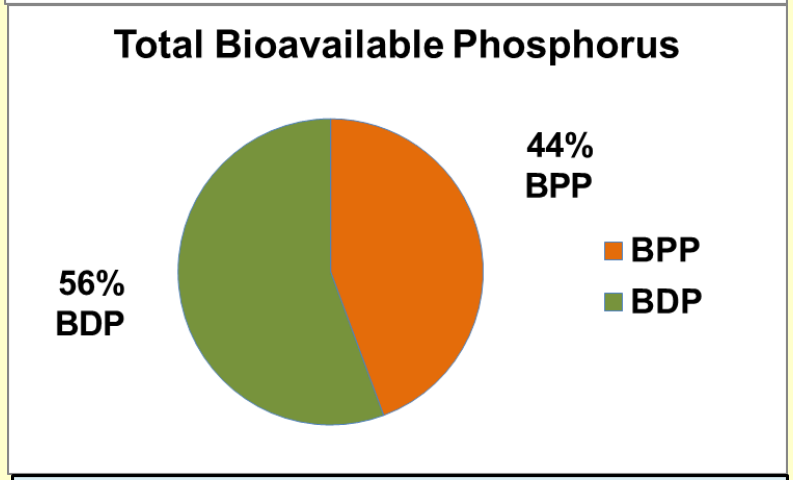
Why the emphasis on dissolved reactive phosphorus (DRP)?

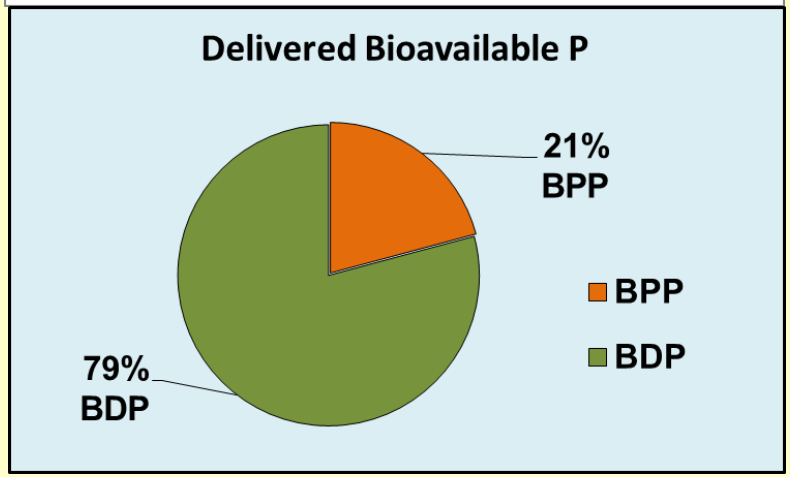
(It's a small part of the total phosphorus load)

1. **Bioavailability**

2. **Delivery**







Maumee River at Waterville, Average Annual Loads, 2003-2012 WYs

Total Phosphorus at Waterville
2,437 metric tons/year

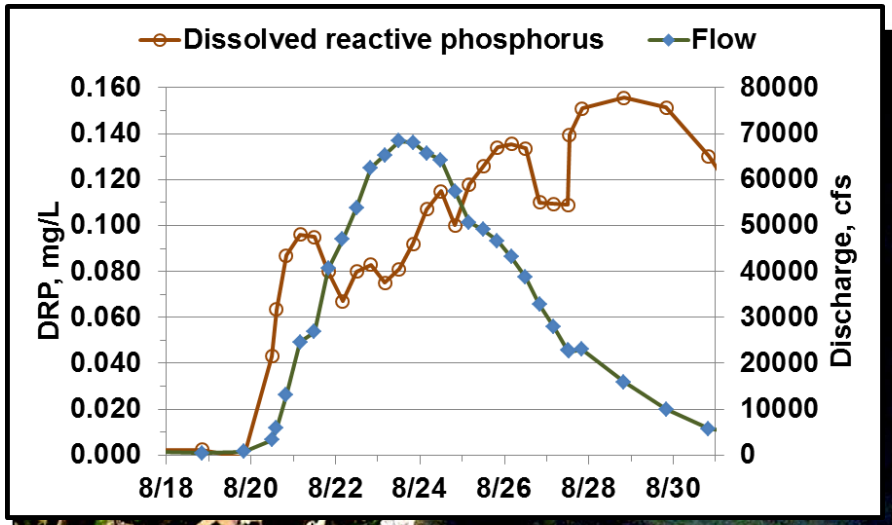
Chemically Bioavailable Phosphorus at Waterville
1,098 metric tons/year
(45% of TP load at Waterville)

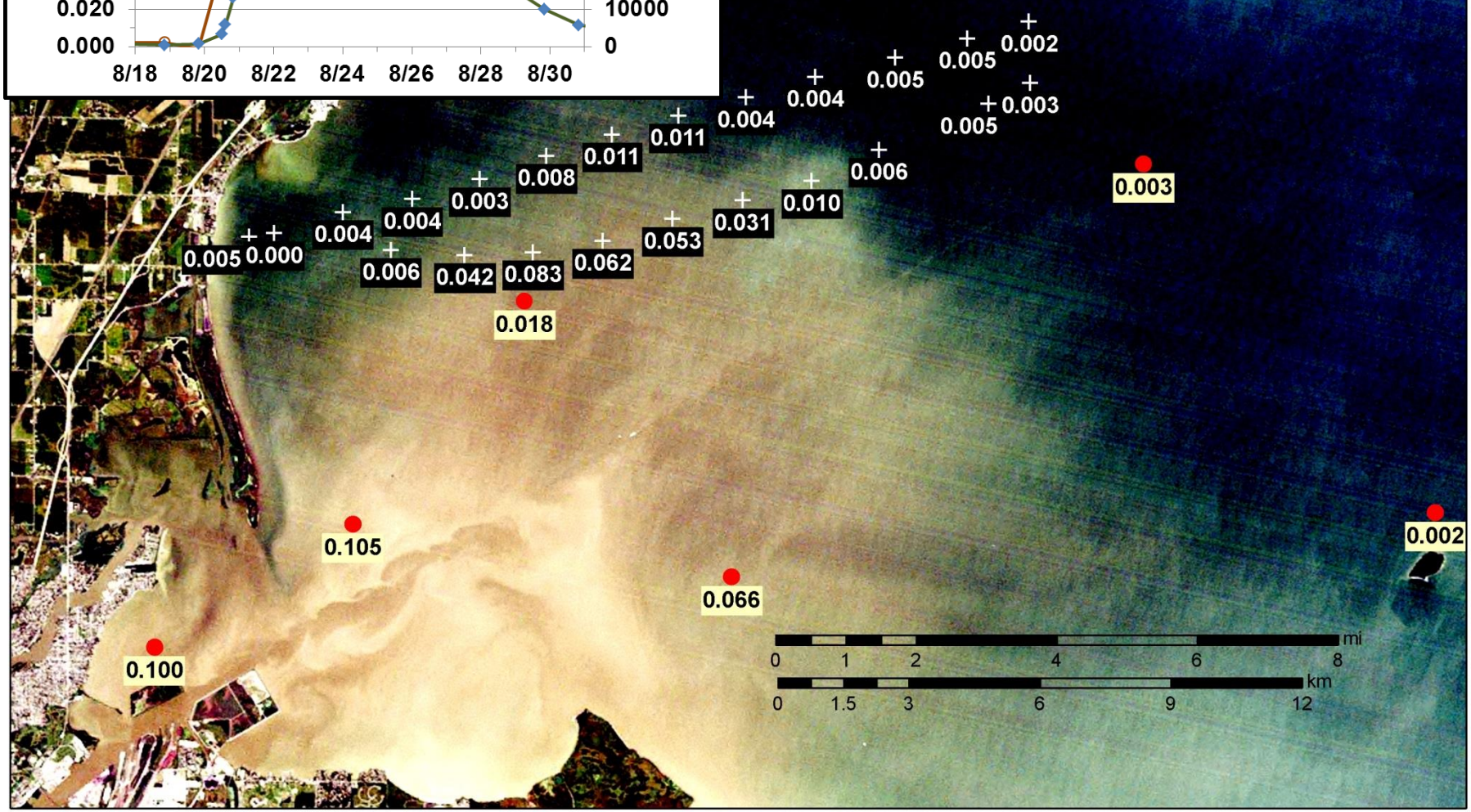
Delivered Bioavailable Phosphorus
772 metric tons/year
(32% of TP load at Waterville)

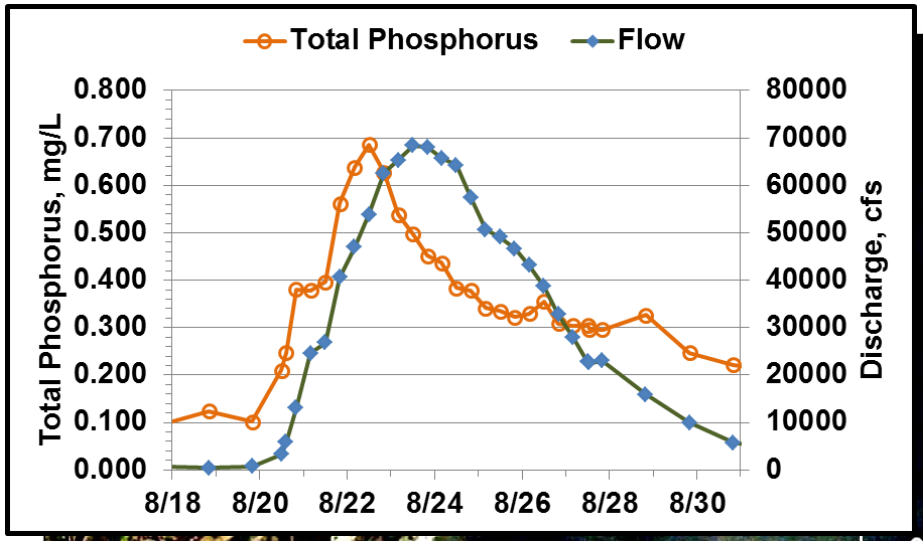
Assumes 33% delivery of TPP between tributary monitoring station and Western Basin

Dissolved Reactive P.

08/28/2007 – Bridgeman (6 stations)
08/29/2007 – Landsat Image
08/30/2007 – Vincent Transect







Total Phosphorus

08/28/2007 – Bridgeman (6 stations)
08/29/2007 – Landsat Image
08/30/2007 – Vincent Transect

0.050 0.056 0.056 0.064 0.062 0.061 0.070 0.043 0.060 0.039 0.032 0.026 0.024 0.028 0.023 0.039 0.070 0.084 0.107 0.069 0.096 0.100 0.113 0.080 0.014

0.083 / 0.100

0.062 / 0.113

0.053 / 0.107

DRP / TP

0.181

0.105 / 0.181

0.139

0.066 / 0.139

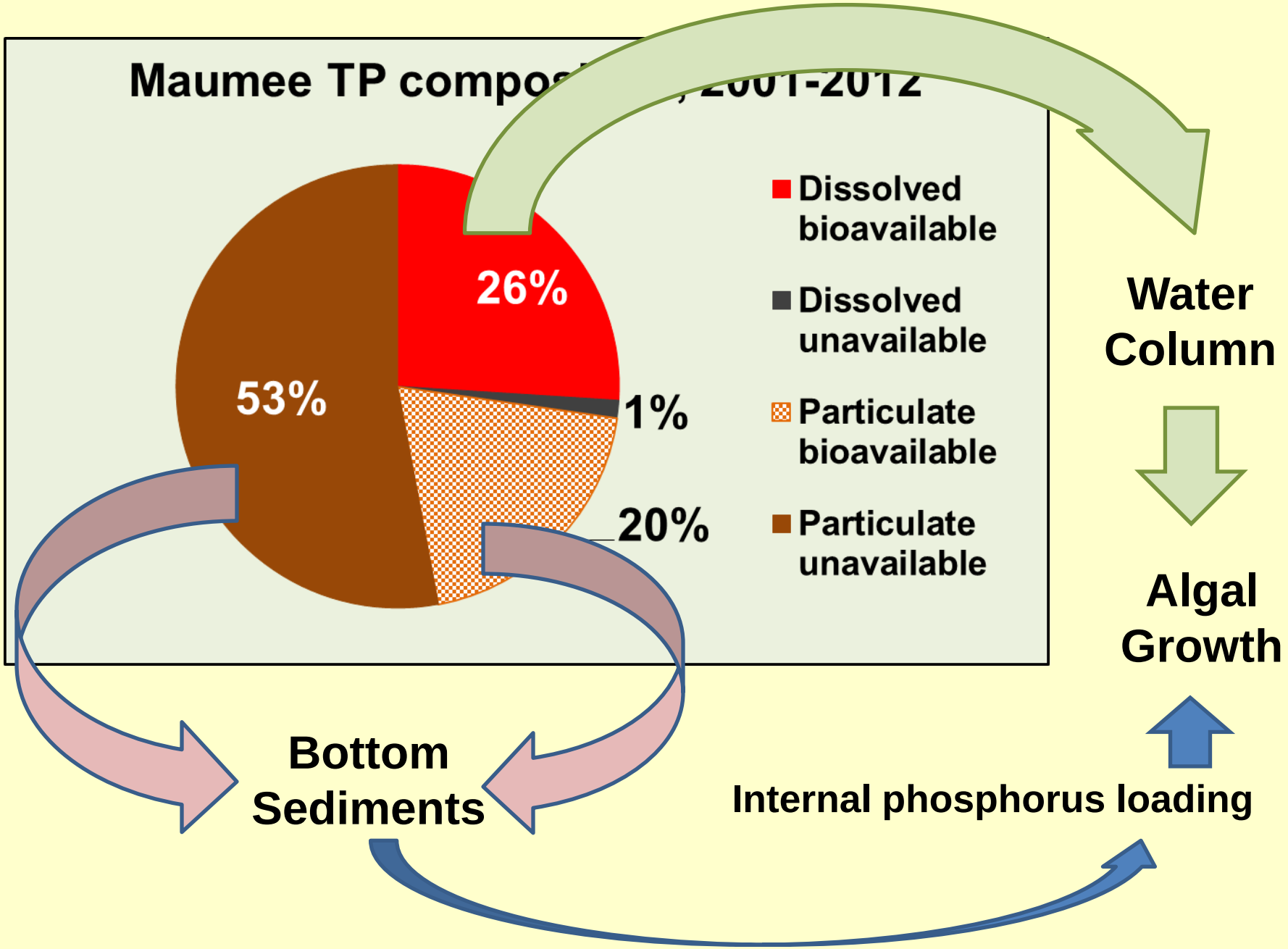
0.023

0.206

0.100 / 0.206

mi 0 1 2 4 6 8

km 0 1.5 3 6 9 12


Maumee TP compos
2001-2012
26%
1%
20%
53%
Dissolved bioavailable
Dissolved unavailable
Particulate bioavailable
Particulate unavailable
Water Column
Algal Growth
Internal phosphorus loading
Bottom Sediments

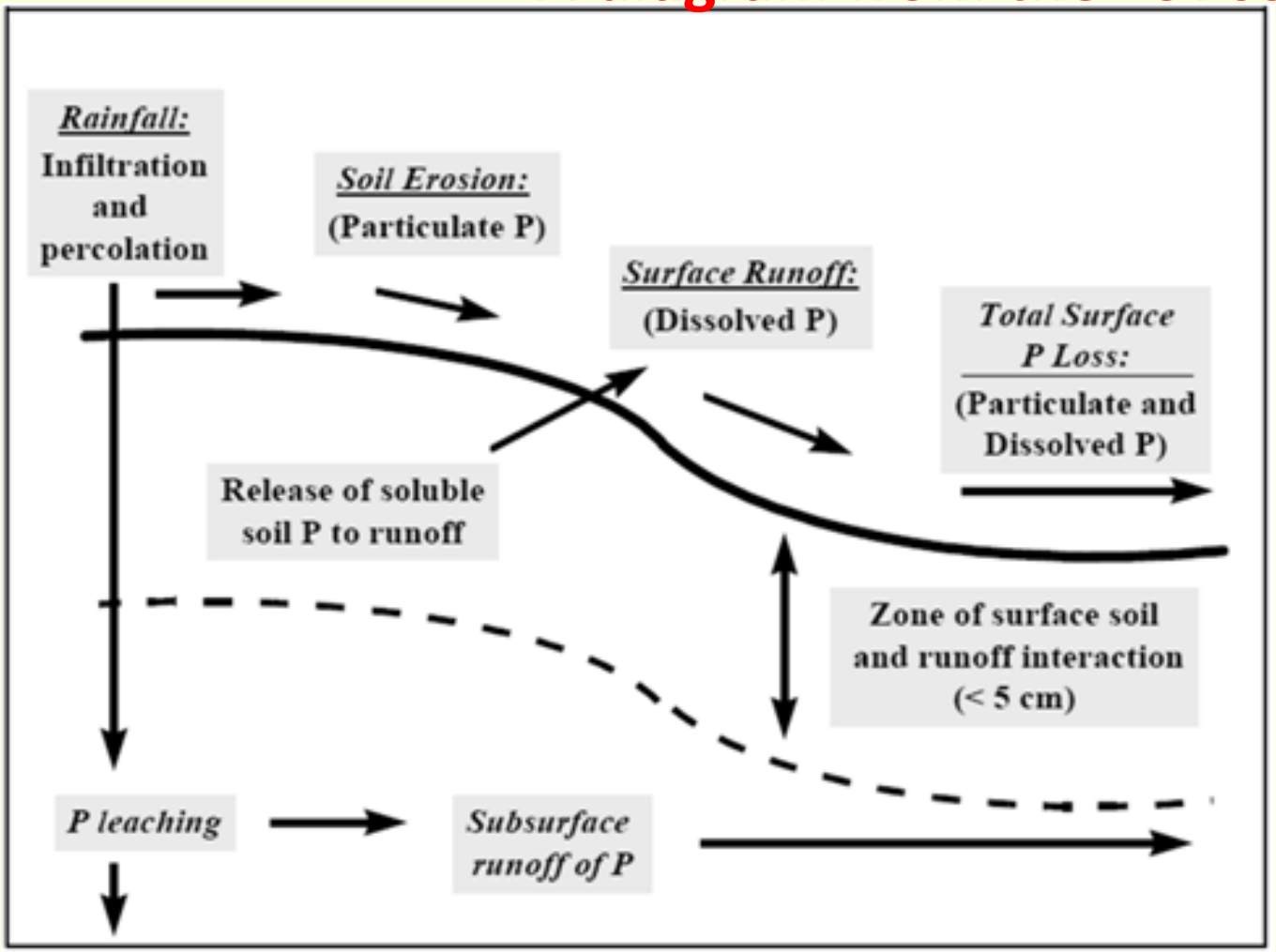
Why did the concentrations of dissolved phosphorus in storm water from agricultural watersheds increase?

- **Increased broadcasting of fertilizers**
- **Phosphorus stratification in cropland soils**
- **Increased tile drainage**
- **Increasing phosphorus soil test levels**

A quick look at stratification and direct runoff of broadcast fertilizers….

How does phosphorus move from cropland to streams, rivers and lakes?

A diagram from the 1970s …

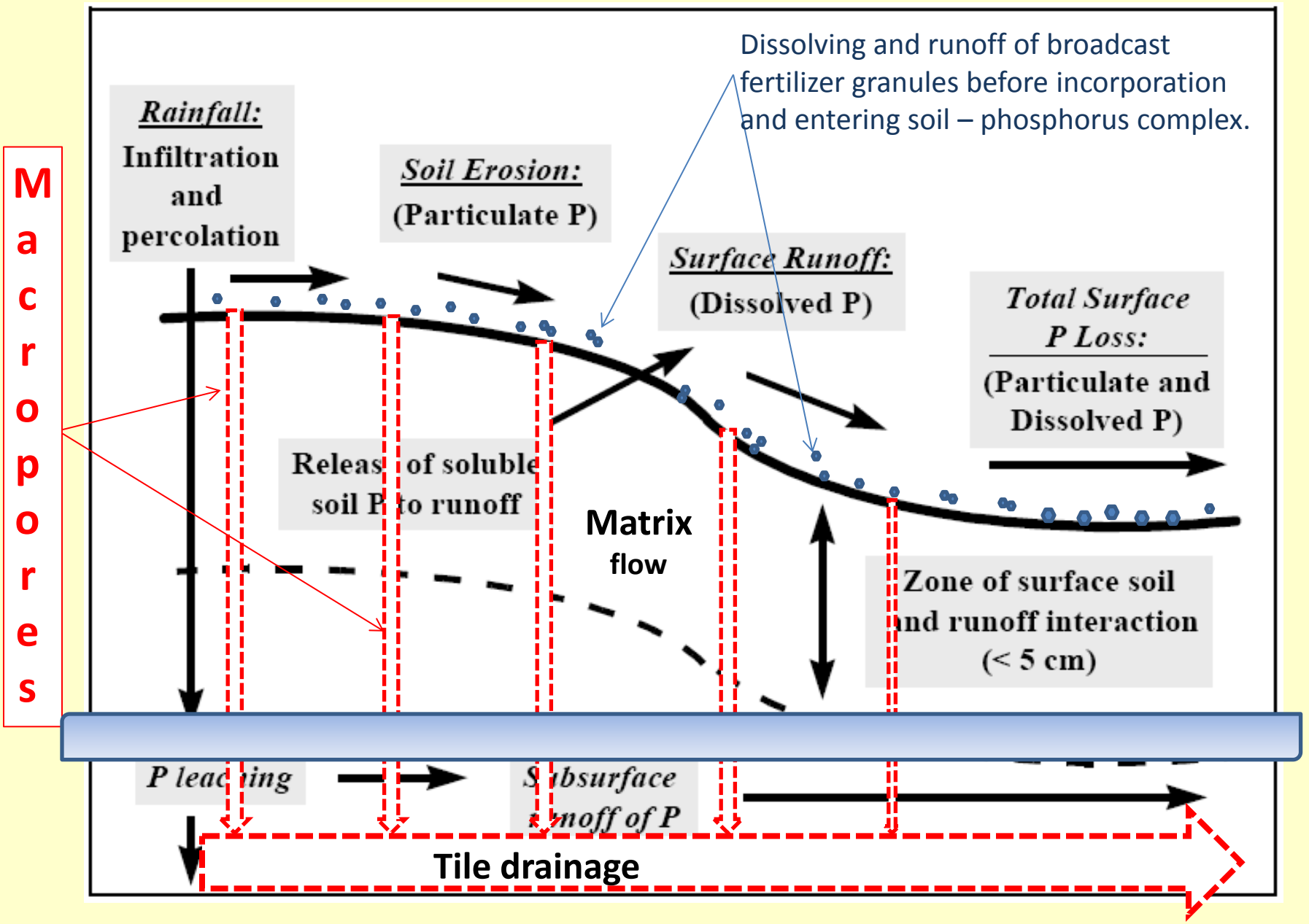


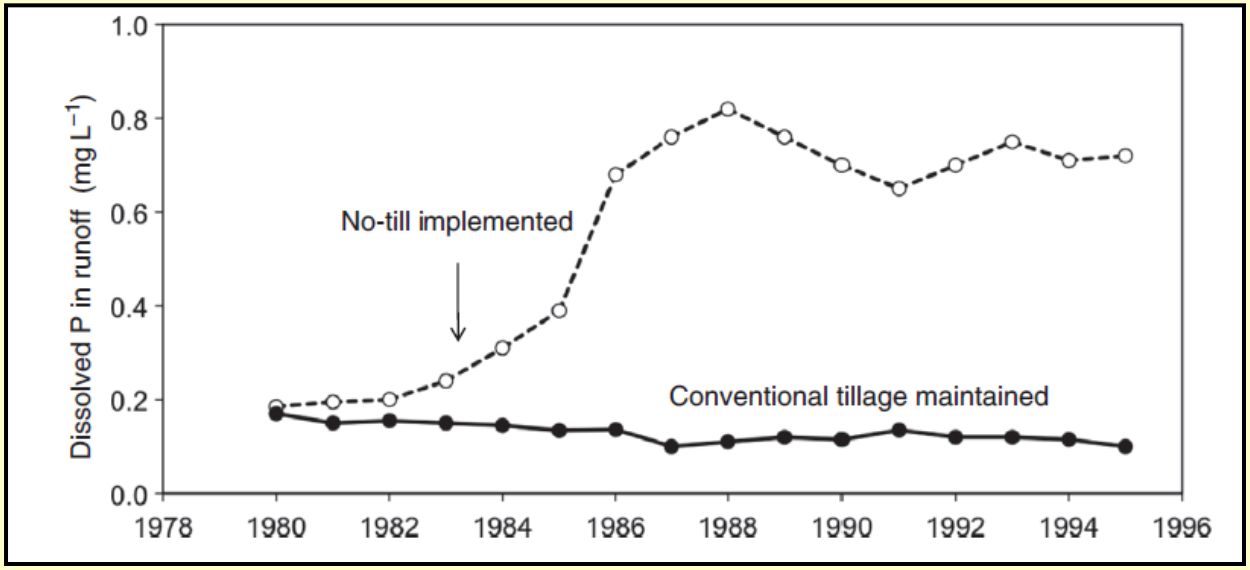
Particulate P

Dissolved P

Interaction of hydrological cycle and land use activities → **Nonpoint source pollution**

Have views of phosphorus pathways to water changed?

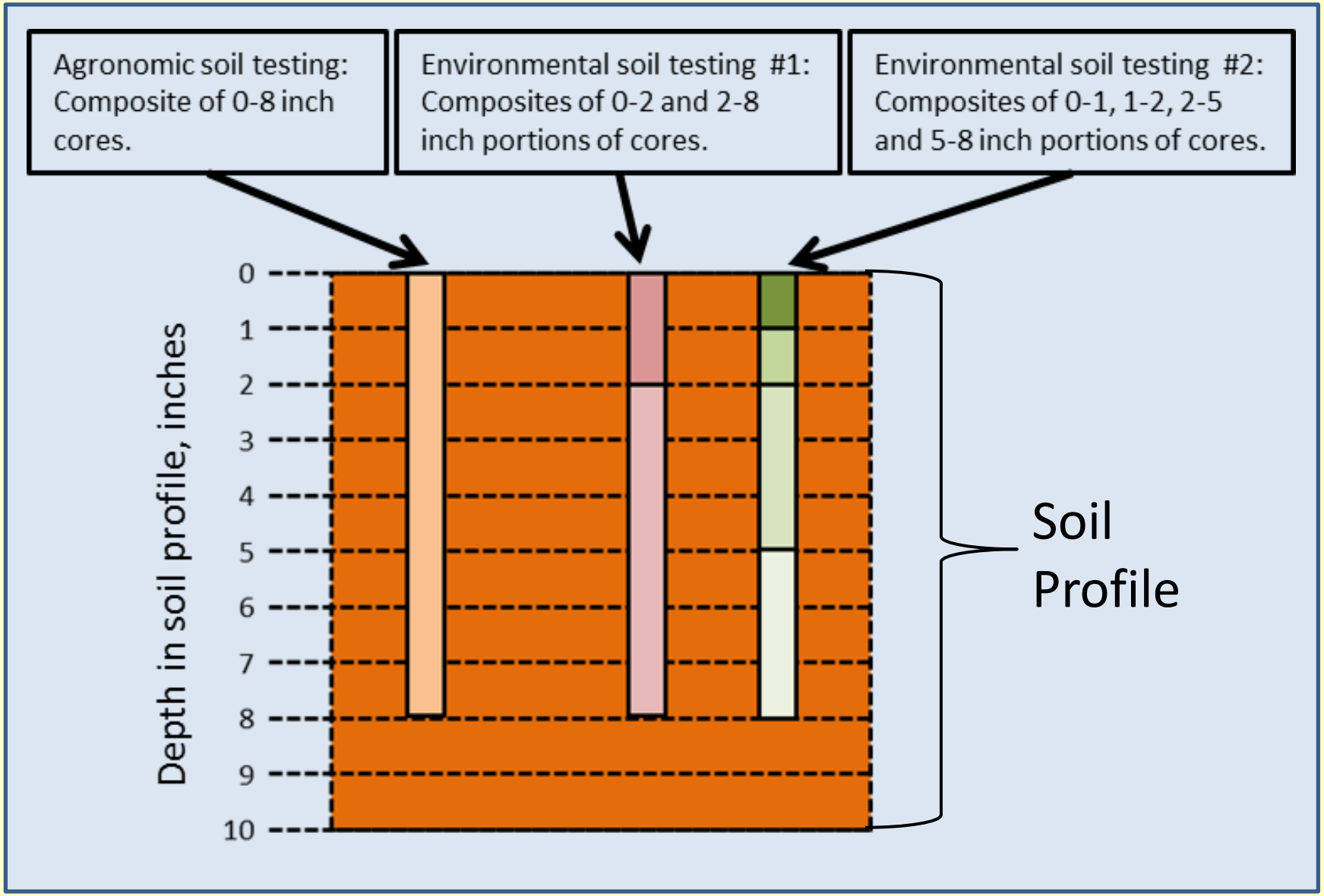


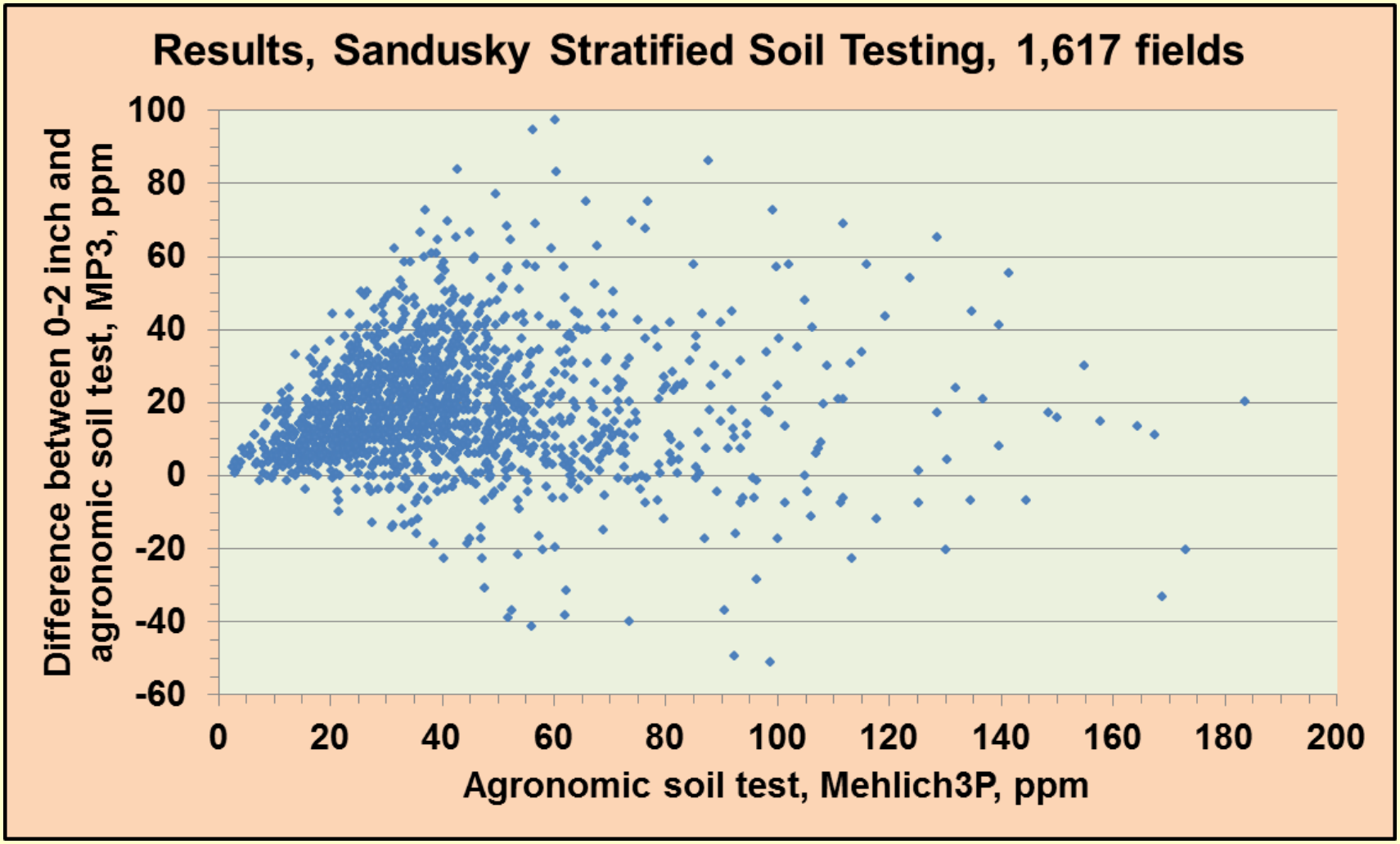


From Kleinman et al. 2011

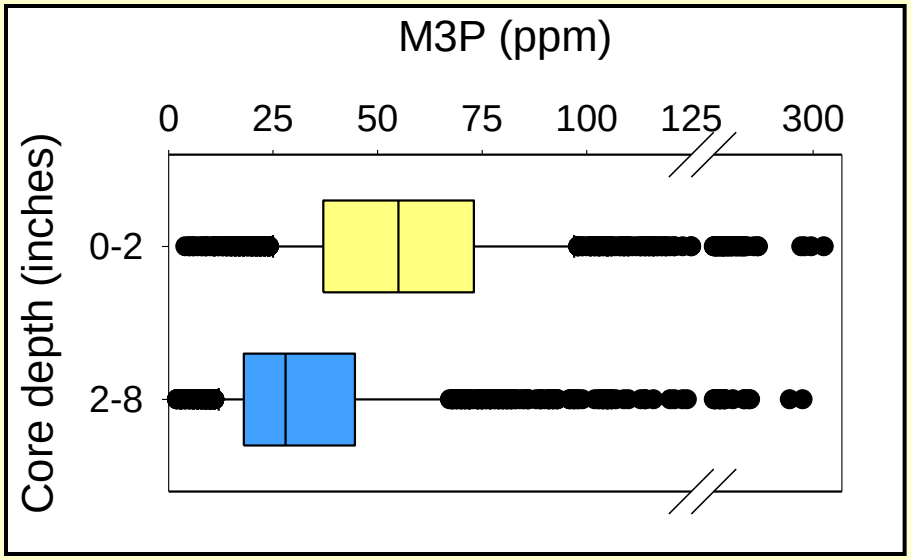
Dissolved P in runoff can increase under no-till management

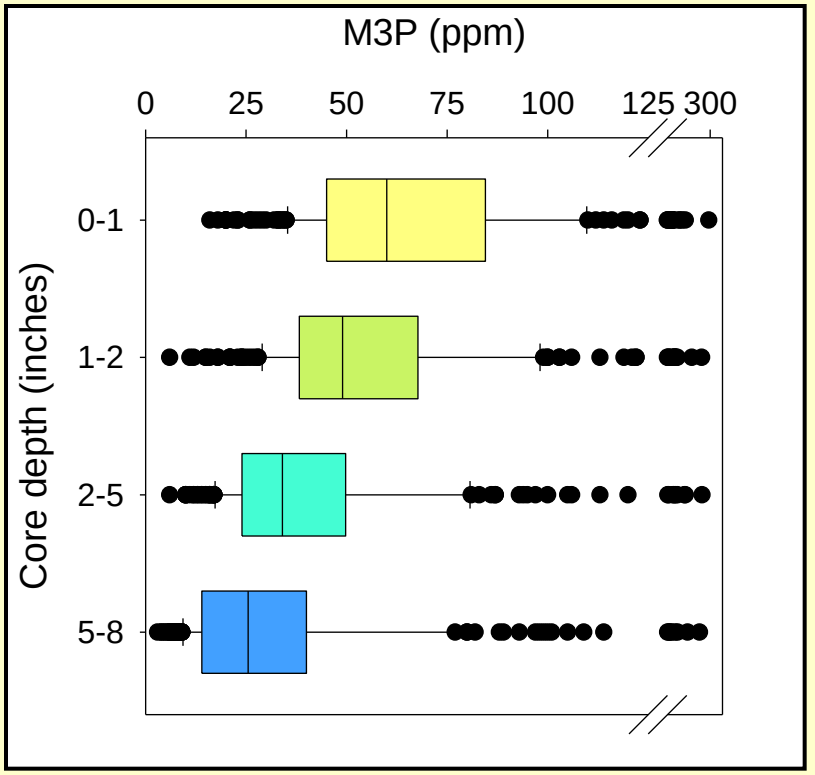
Sandusky Watershed Stratified Soil Testing Program, supported by GLPF



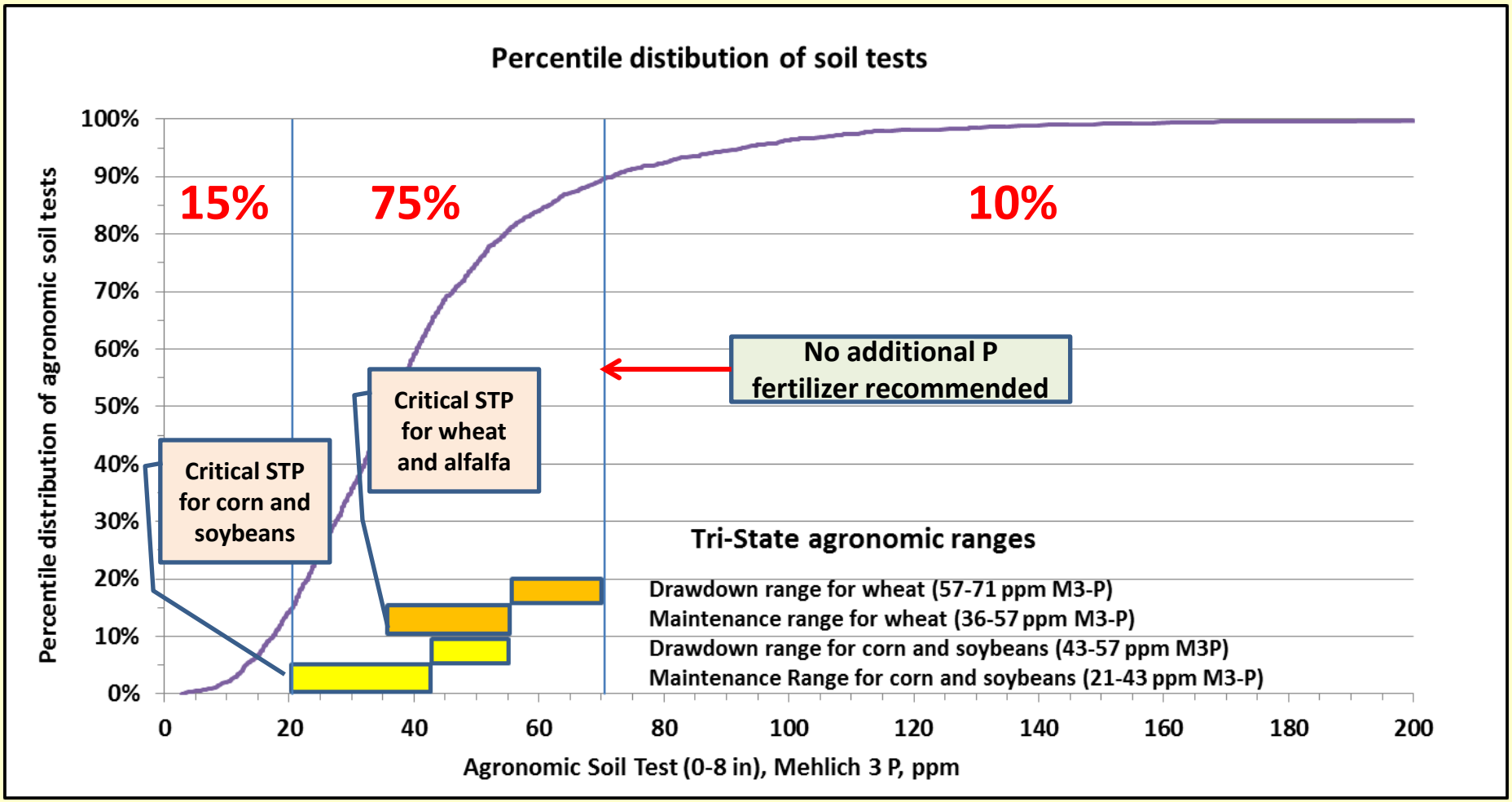

Results, Sandusky Stratified Soil Testing, 1,617 fields
Difference between 0-2 inch and agronomic soil test, MP3, ppm
100
80
60
40
20
0
-20
-40
-60
0
20
40
60
80
100
120
140
160
180
200
Agronomic soil test, Mehlich3P, ppm

The extent of P stratification





Tri-State Fertilizer Recommendations



How do soil test values in Ohio compare with these ranges?

Compared to most areas, Ohio's soil test levels are not excessive!

Phosphorus control programs: Phase 3 –

… reducing the concentrations of dissolved phosphorus in agricultural runoff.

Where are we in the Phase 3 process?

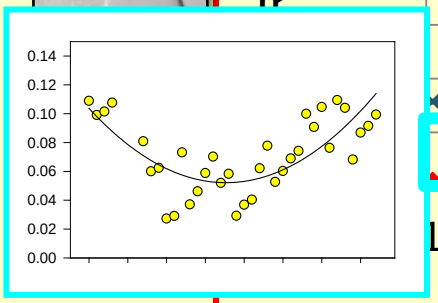
- Planning phase
- Early implementation

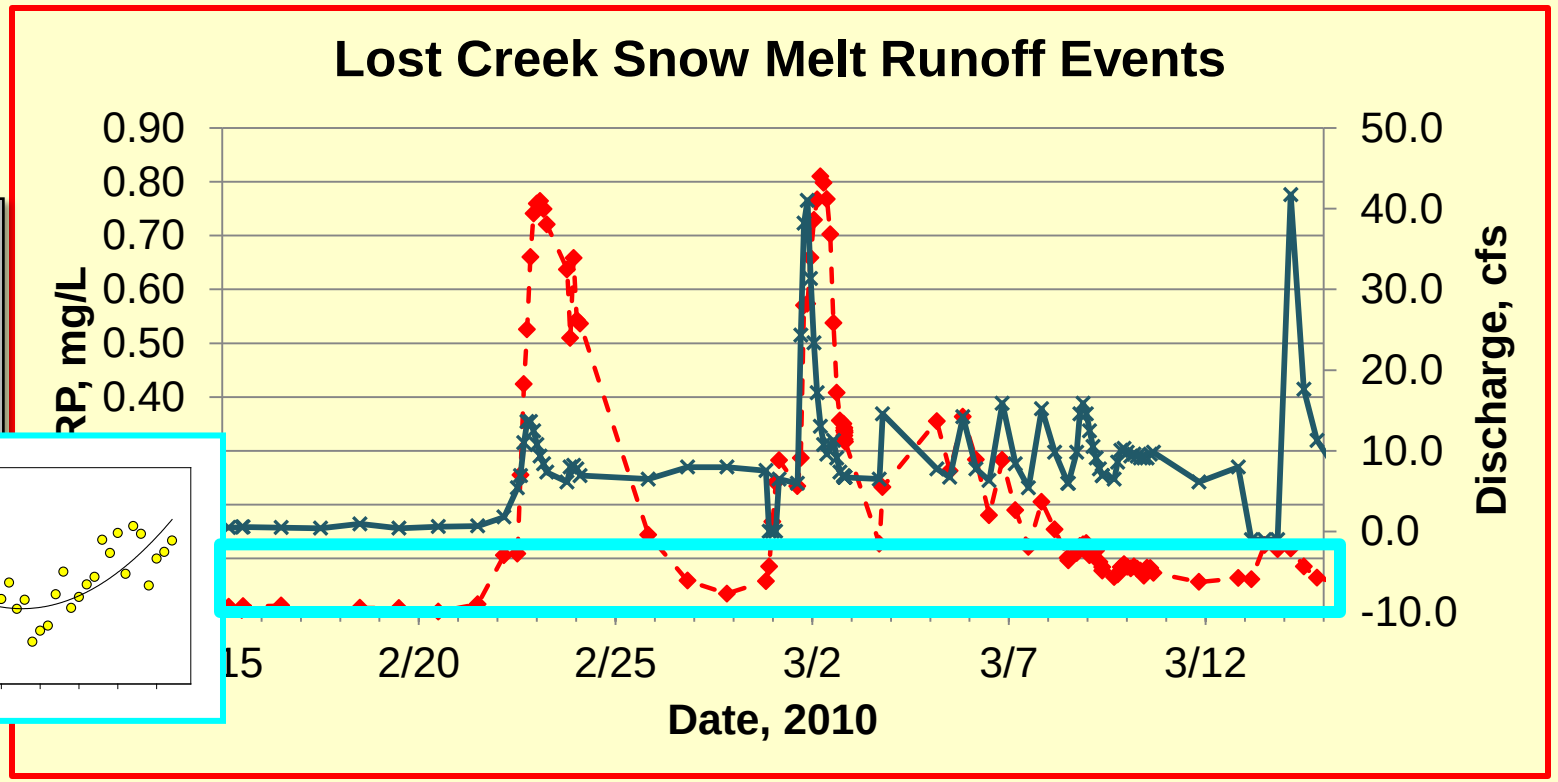
Likely components of Phase 3

- Nutrient management – the 4-Rs
- Water management
- No-till/reduced till management
- Cover crops
- Conservation cropping systems
- Comprehensive soil health
- Targeting
- Off-field treatment (wetlands, etc.)

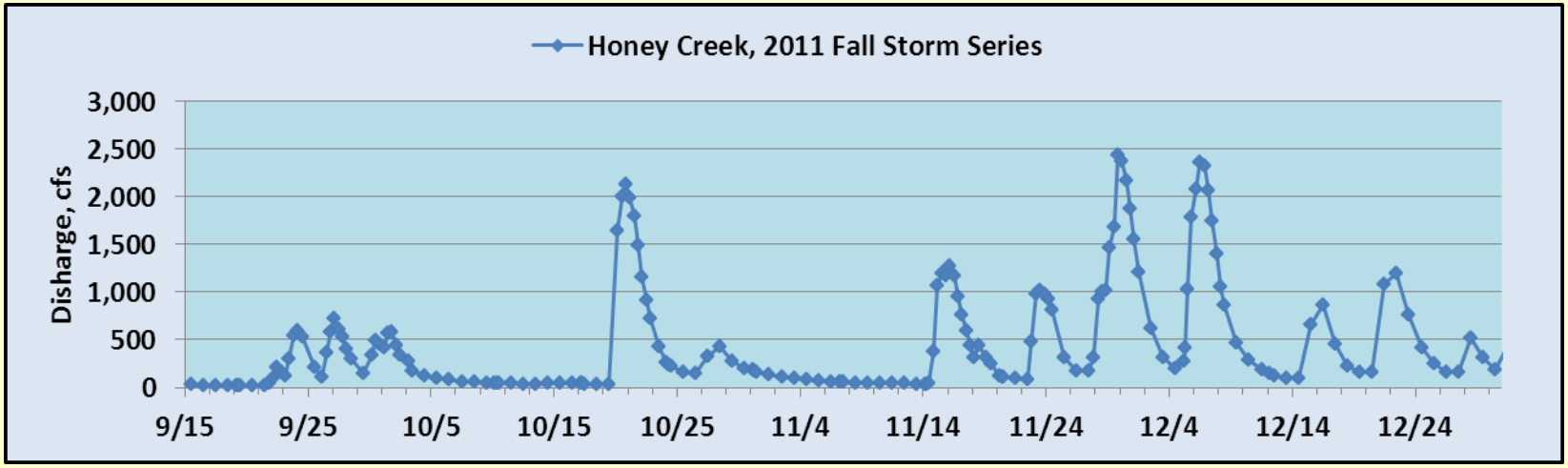
Shifts in multiple components of crop production systems … no silver bullet.

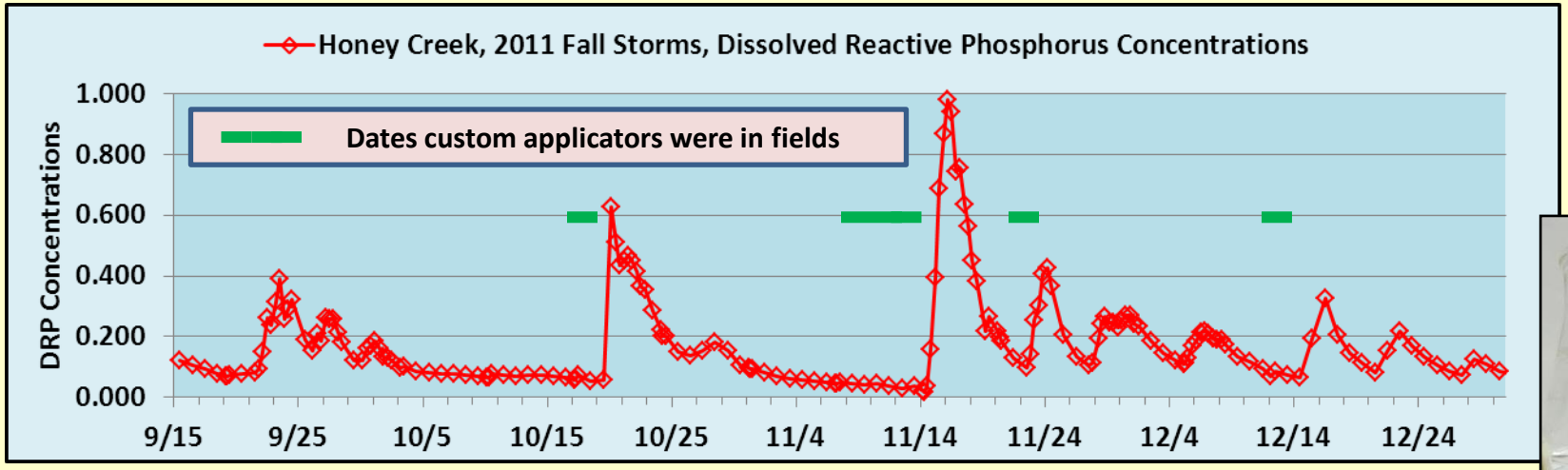
Fertilizer application on frozen ground

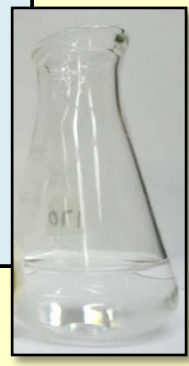




Fertilizer application just before precipitation







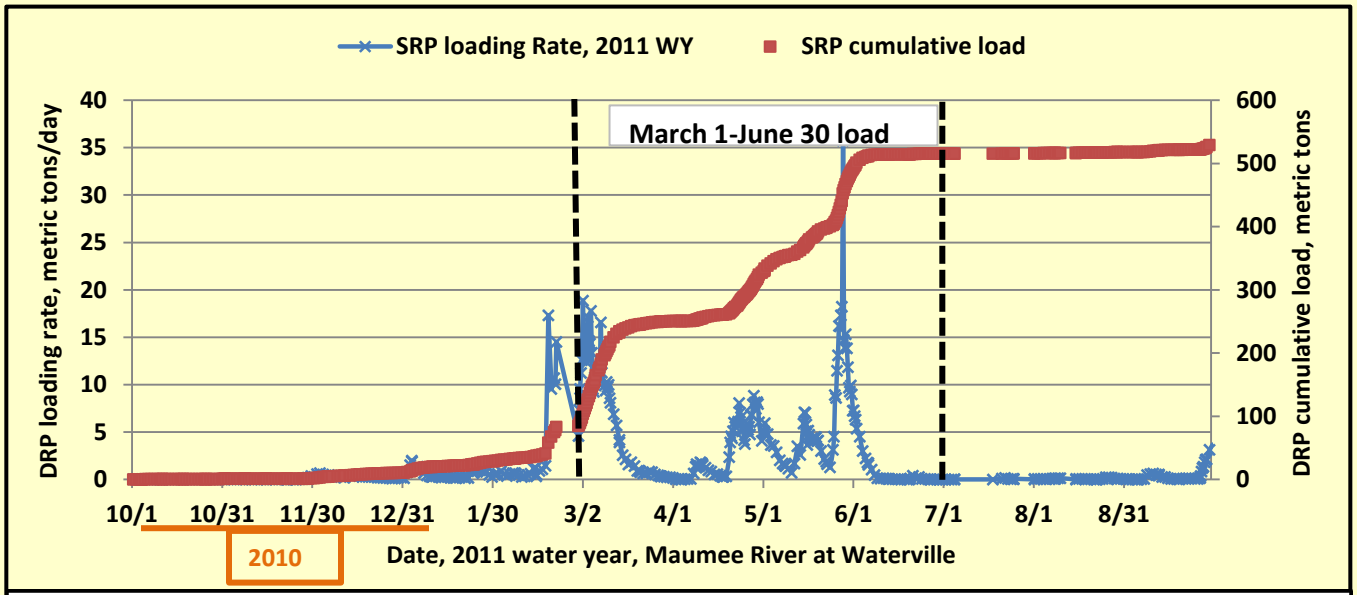
Fertilizer application rates versus watershed export rates --

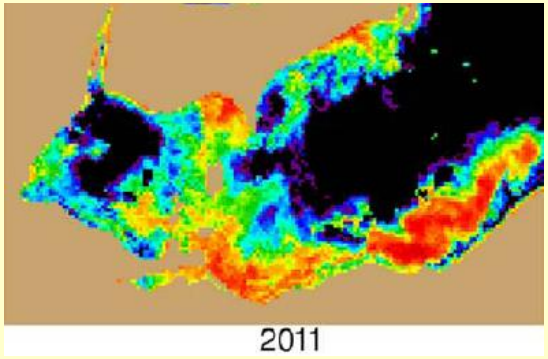
Watershed	TP export rate for whole watershed lbs/acre/year	DRP export rate for whole watershed lbs/acre/year	Agricultural land as fraction of watershed area	Non-ag-land as fraction of watershed area	TP export rate from cropland[1]	DRP export Rate from cropland[1]	TP runoff as % of maintenance[2]	DRP runoff as % maintenance[2]
Sandusky	1.53	0.35	0.776	0.224	1.72	0.392	8.3%	1.9%
Honey Cr.	1.47	0.44	0.811	0.189	1.62	0.488	7.8%	2.3%
Rock Cr.	1.63	0.29	0.719	0.281	1.89	0.334	9.1%	1.6%
Maumee	1.24	0.29	0.733	0.267	1.44	0.333	6.9%	1.6%
1. Assumes that the loss rate from non-cropland is 50% of that from cropland.								
2. Maintenance rate from NRCS Rapid Assessment of Sandusky Watershed (47.5 lbs P_2O_5 per acre, 20.8 lbs P per acre)								

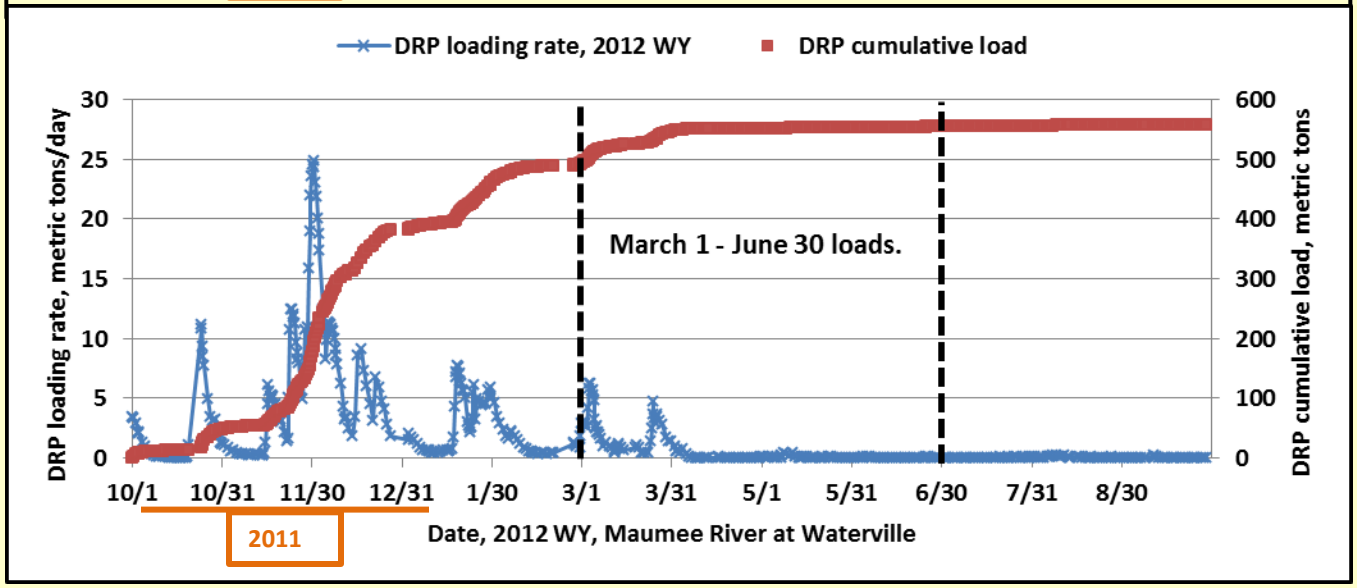
Can we reduce a current loss rate of <2% by 40-80%?

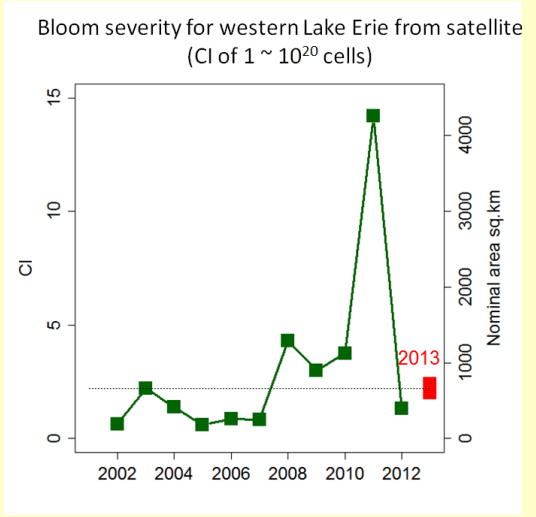
… no small task.

Maumee River, DRP loading rate and cumulative loads, 2011 and 2012 WY









Questions?

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