USGS
science for a changing world

Flux of water, nutrients, and sediment from the Susquehanna River to the Bay.

What we can learn from the Tropical Storm Lee event.

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Research Hydrologist, USGS
April 19, 2012

How unusual was the Tropical Storm Lee event?

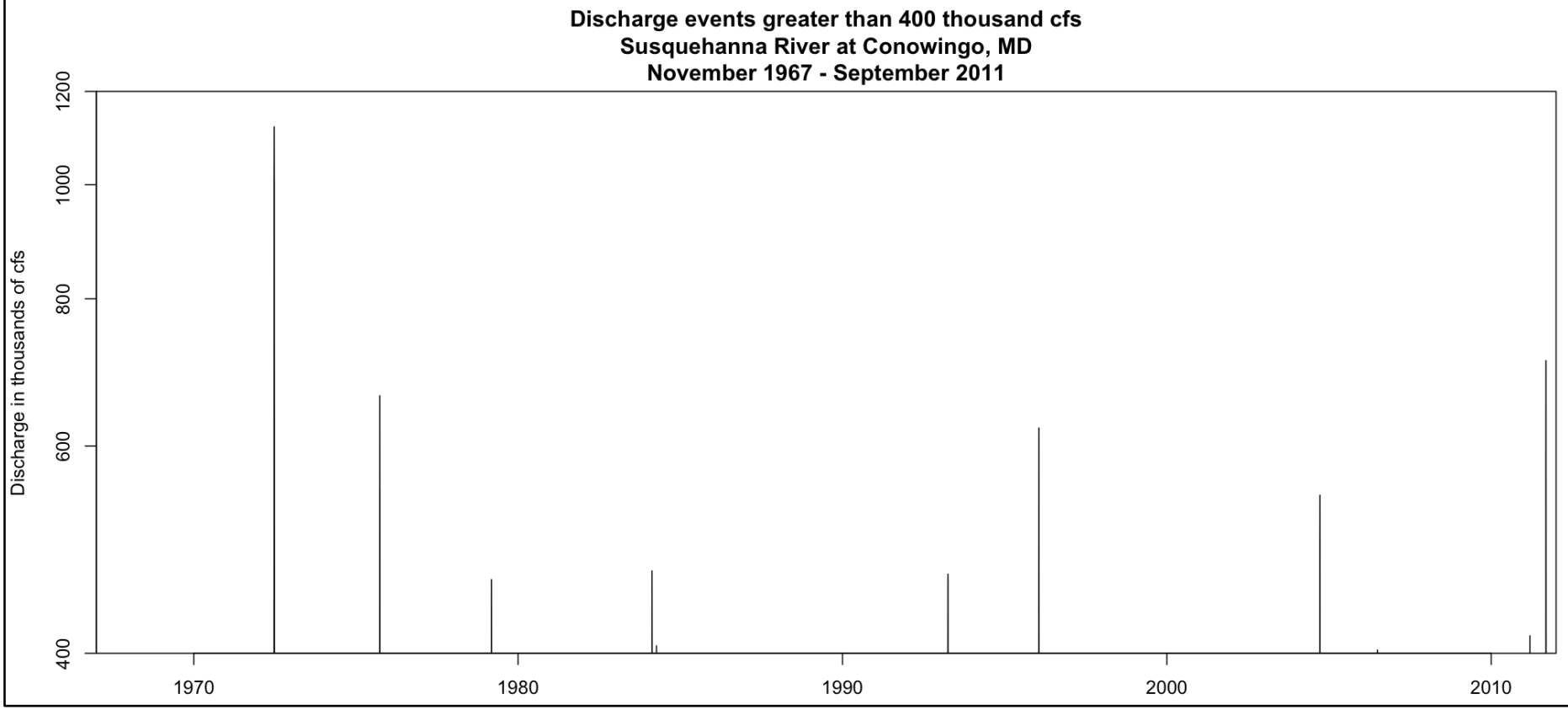
Flows larger than 400,000 cfs have happened:

3 times from 1970-1979 (10 years)

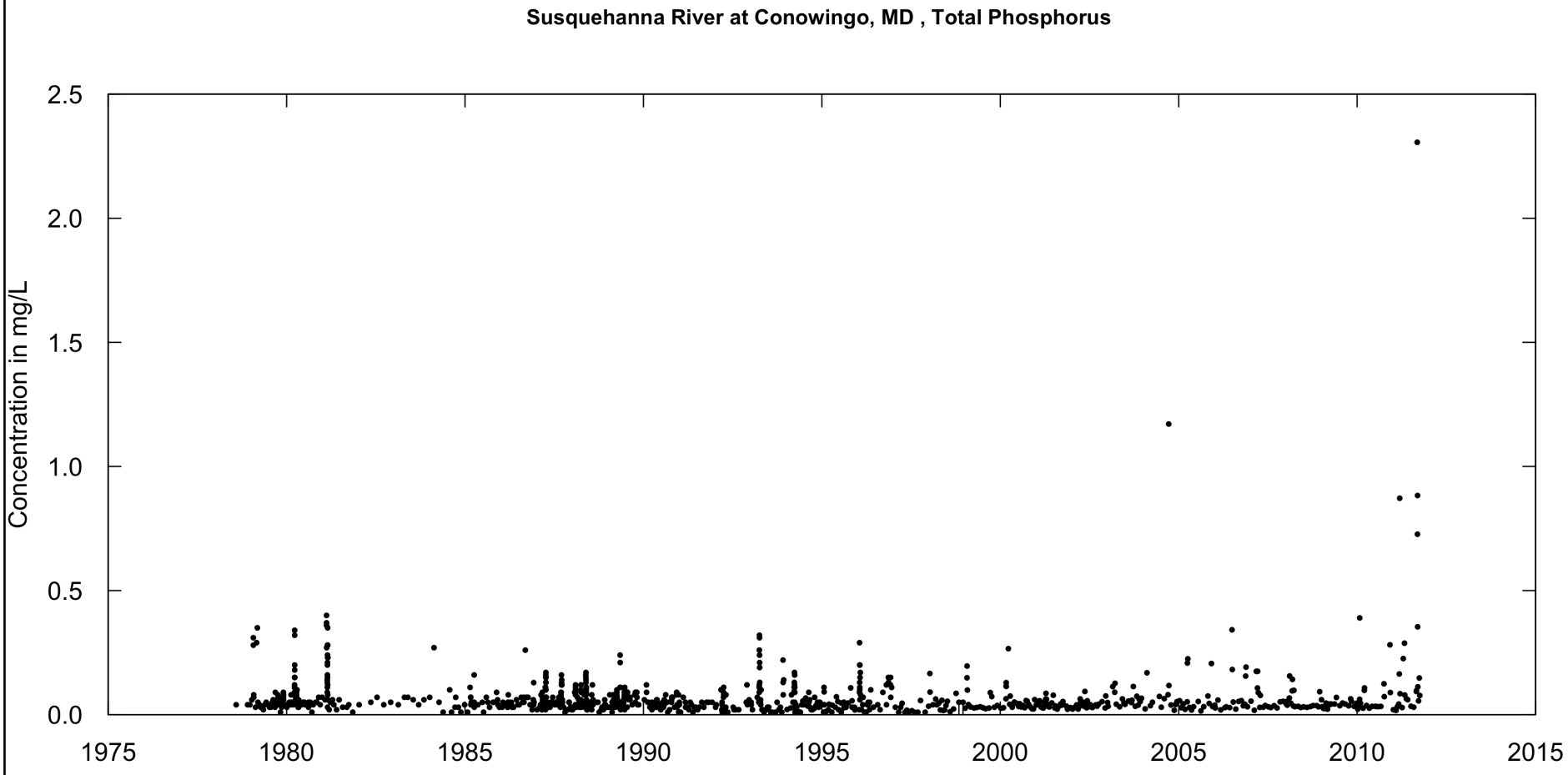
2 times from 1980-1989 (10 years)

2 times from 1990-2000 (10 years)

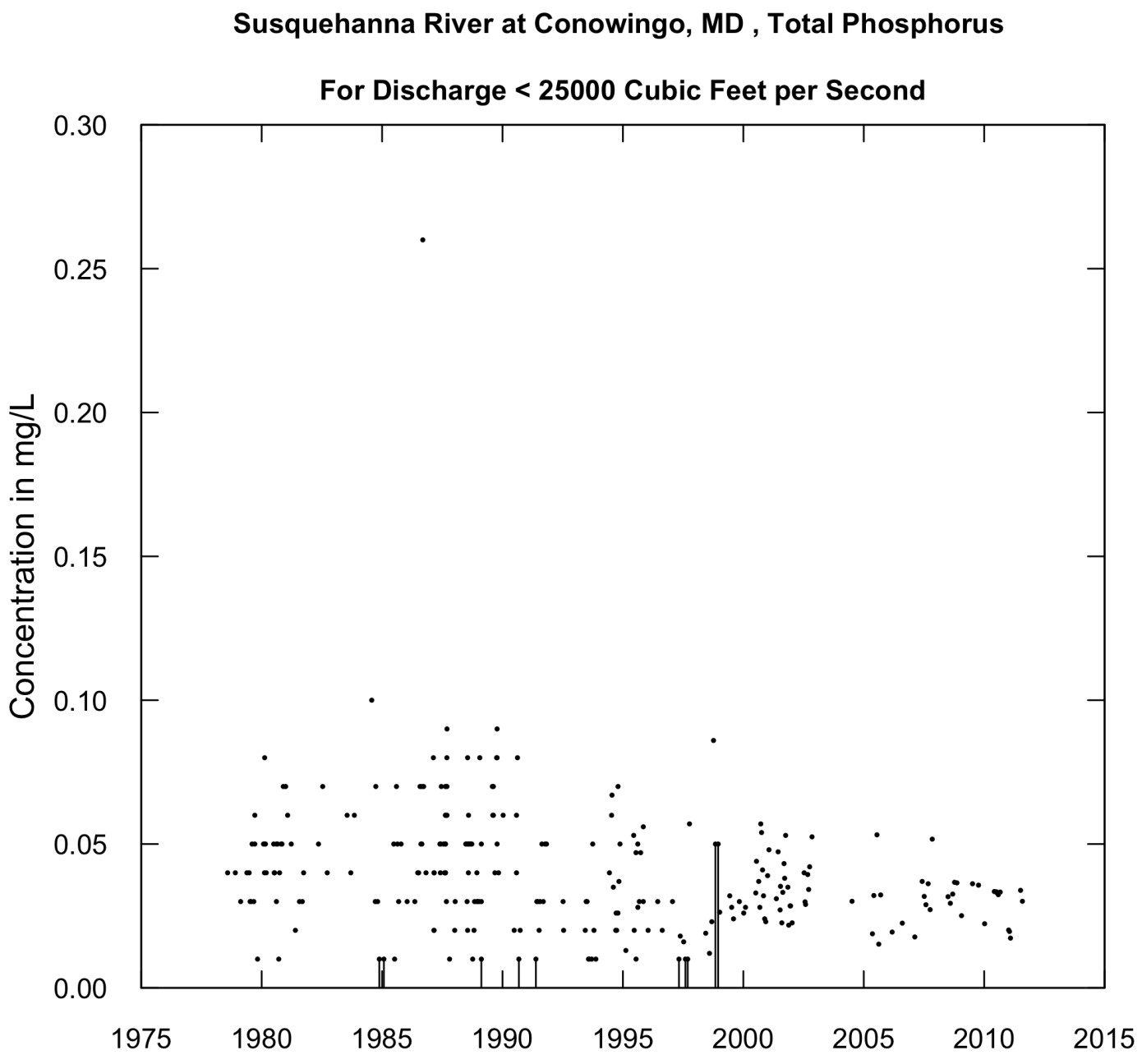
4 times from 2000-2011 (12 years)



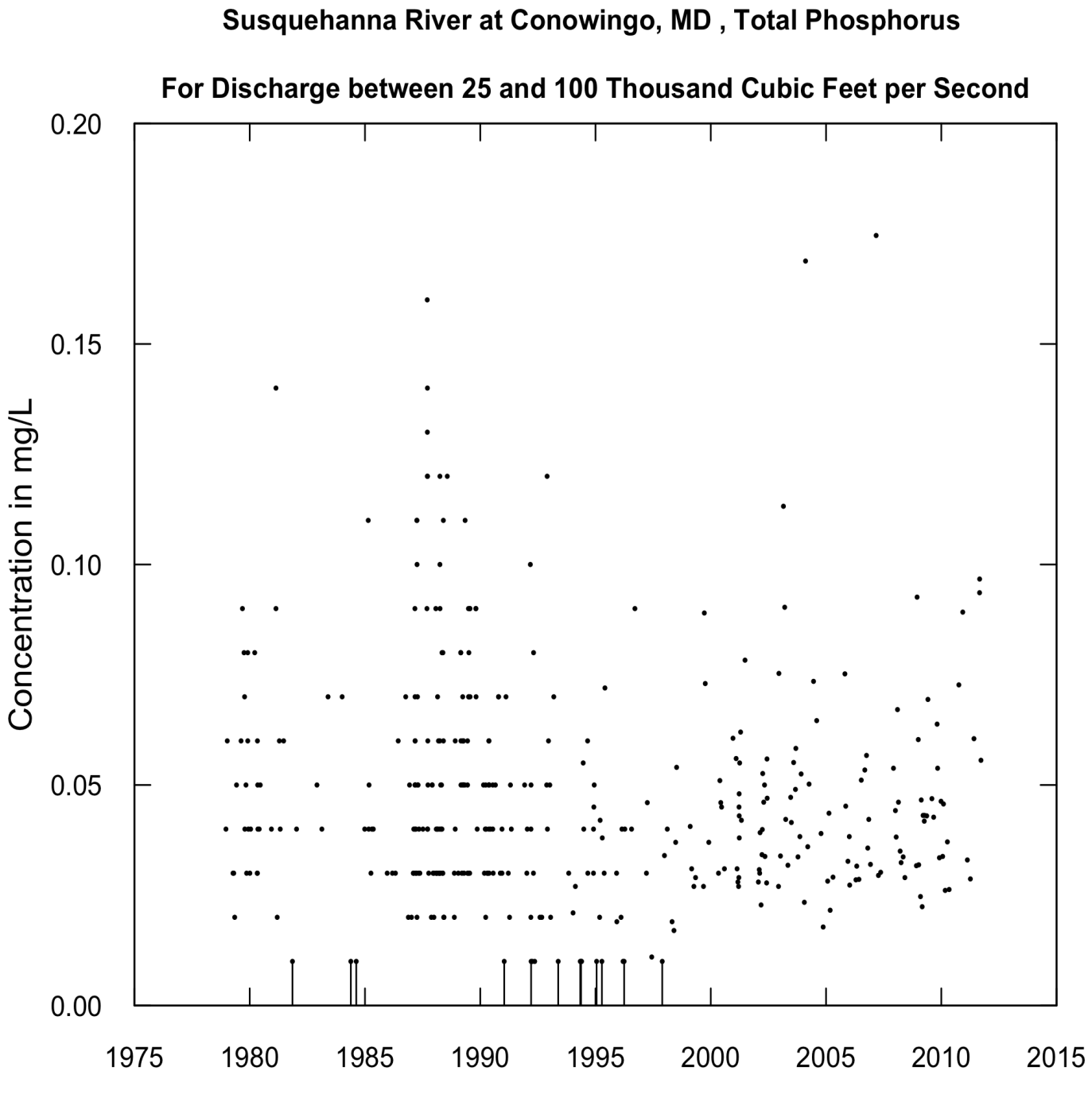
Let's look at the full history of Total Phosphorus data collected from the USGS RIM station at Conowingo Dam



Samples Below 25,000 cfs



Samples Between 25,000 cfs and 75,000 cfs

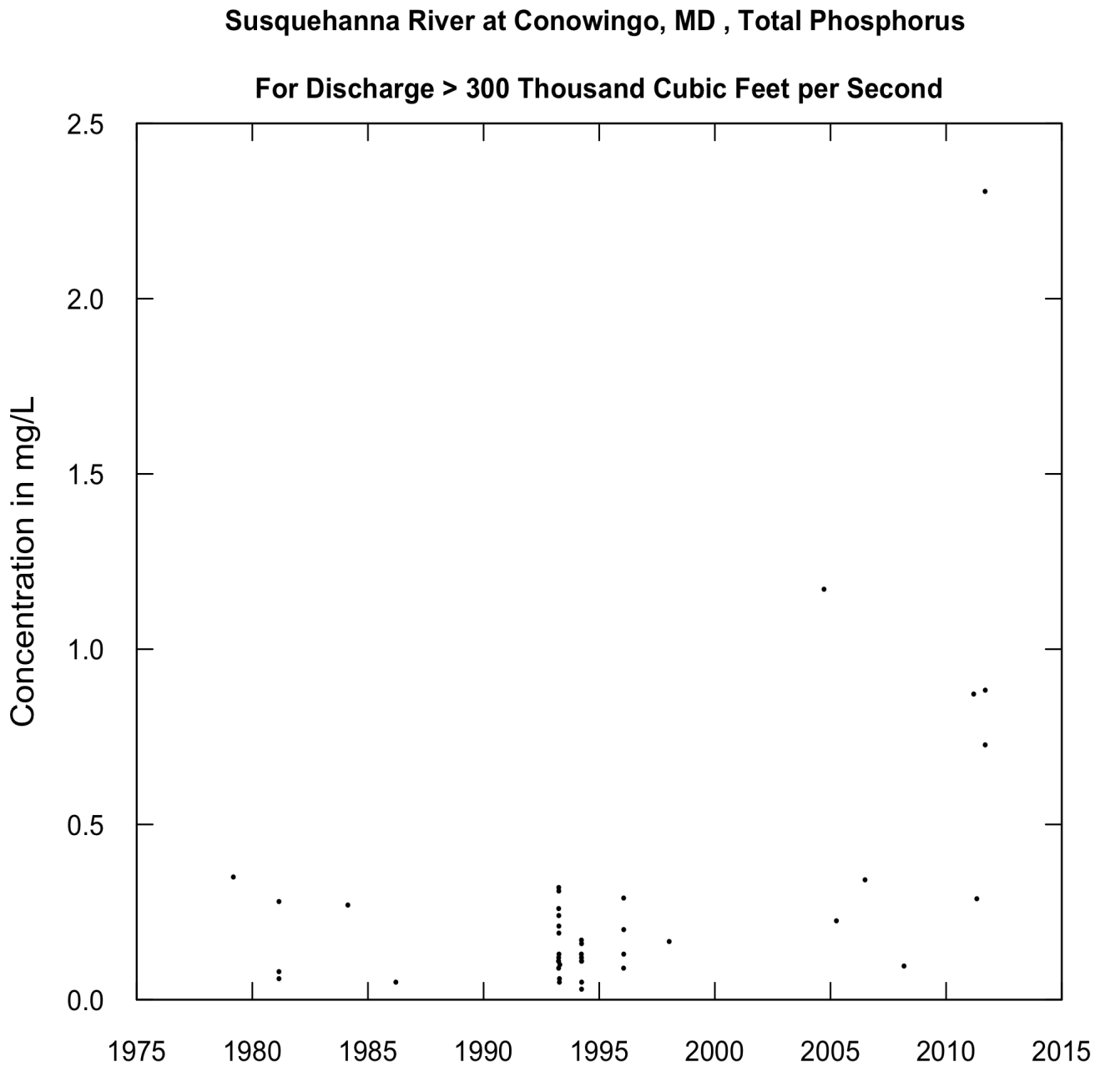


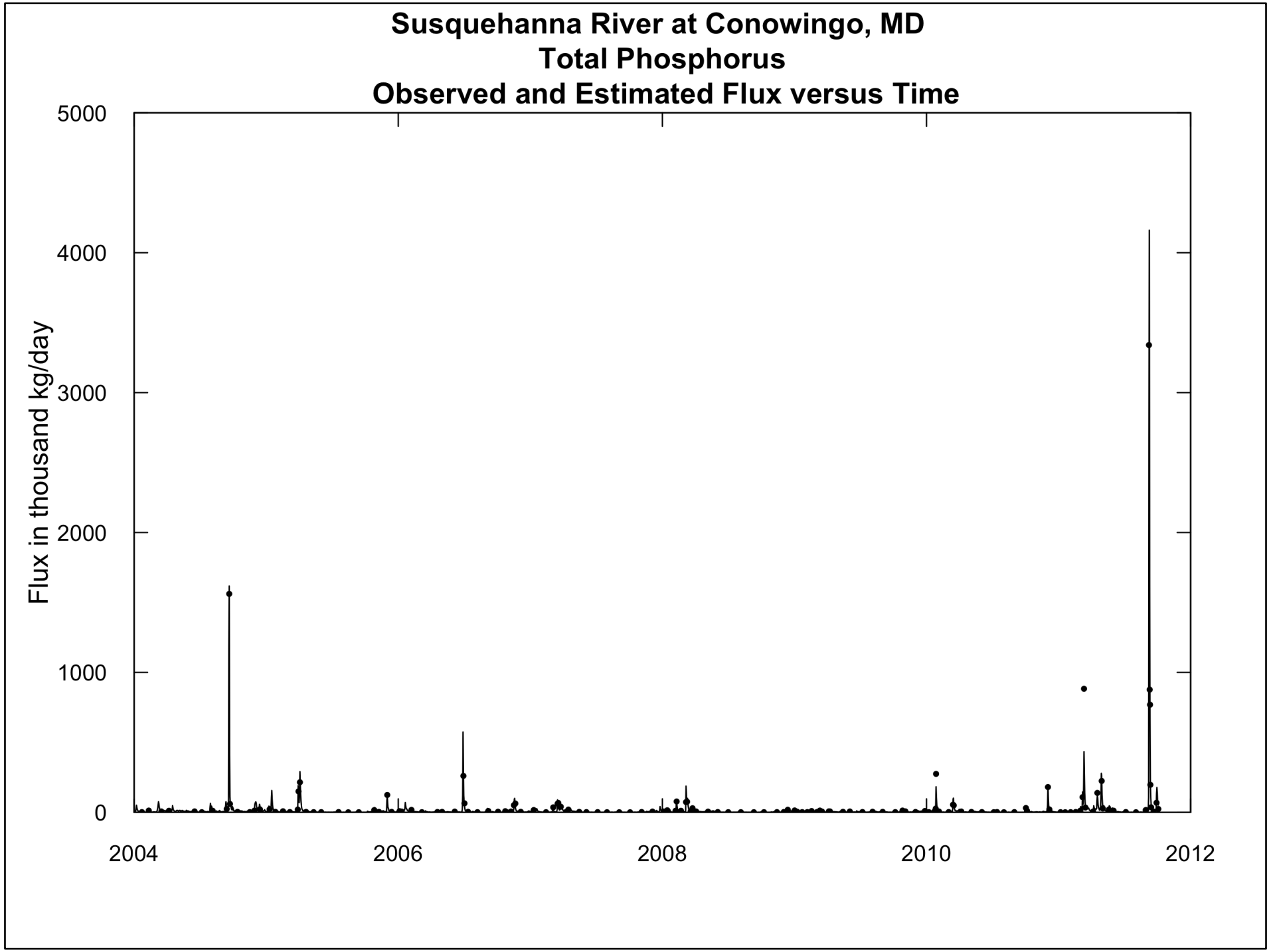
Samples Above 300,000 cfs

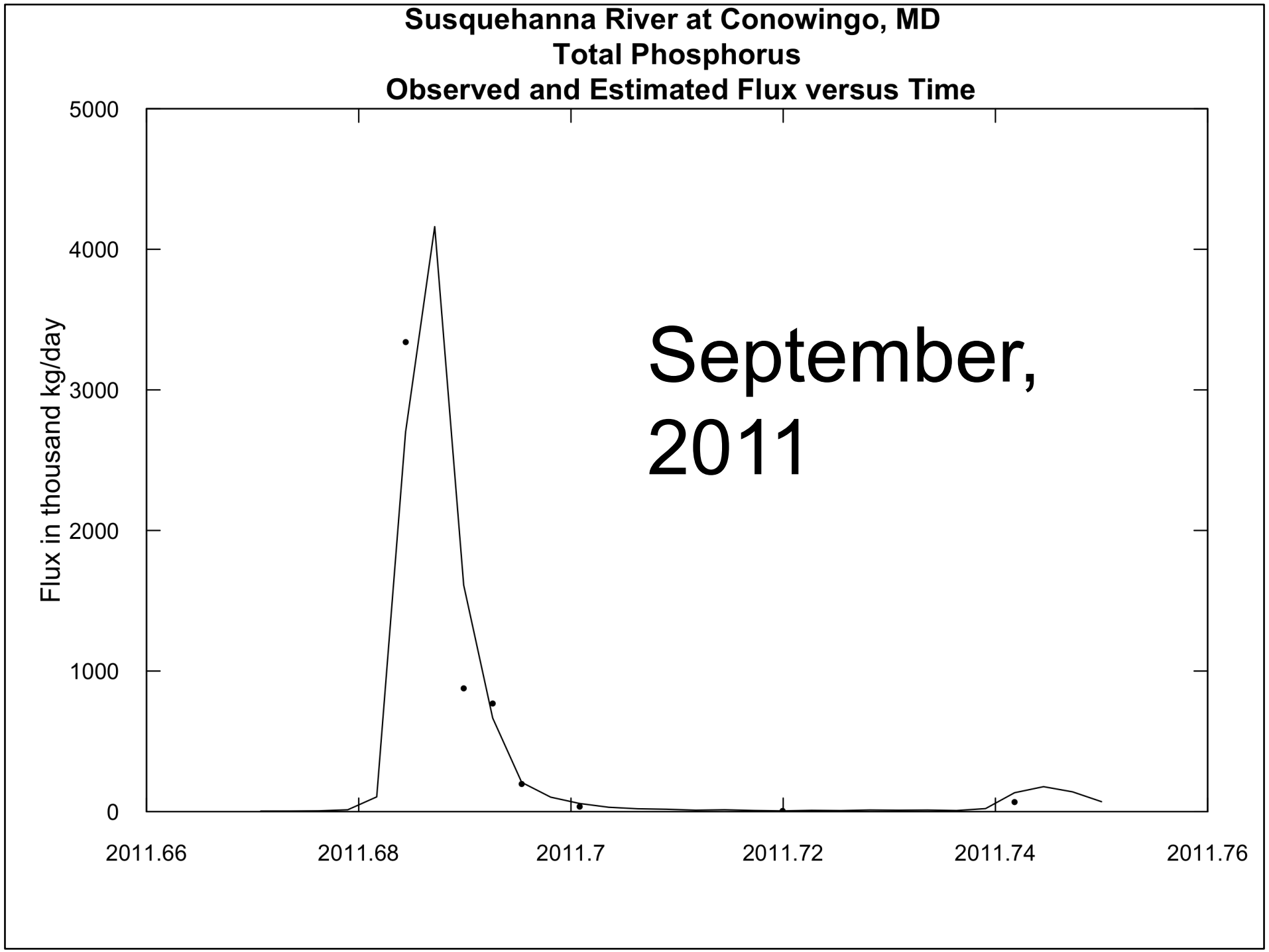
In this range:

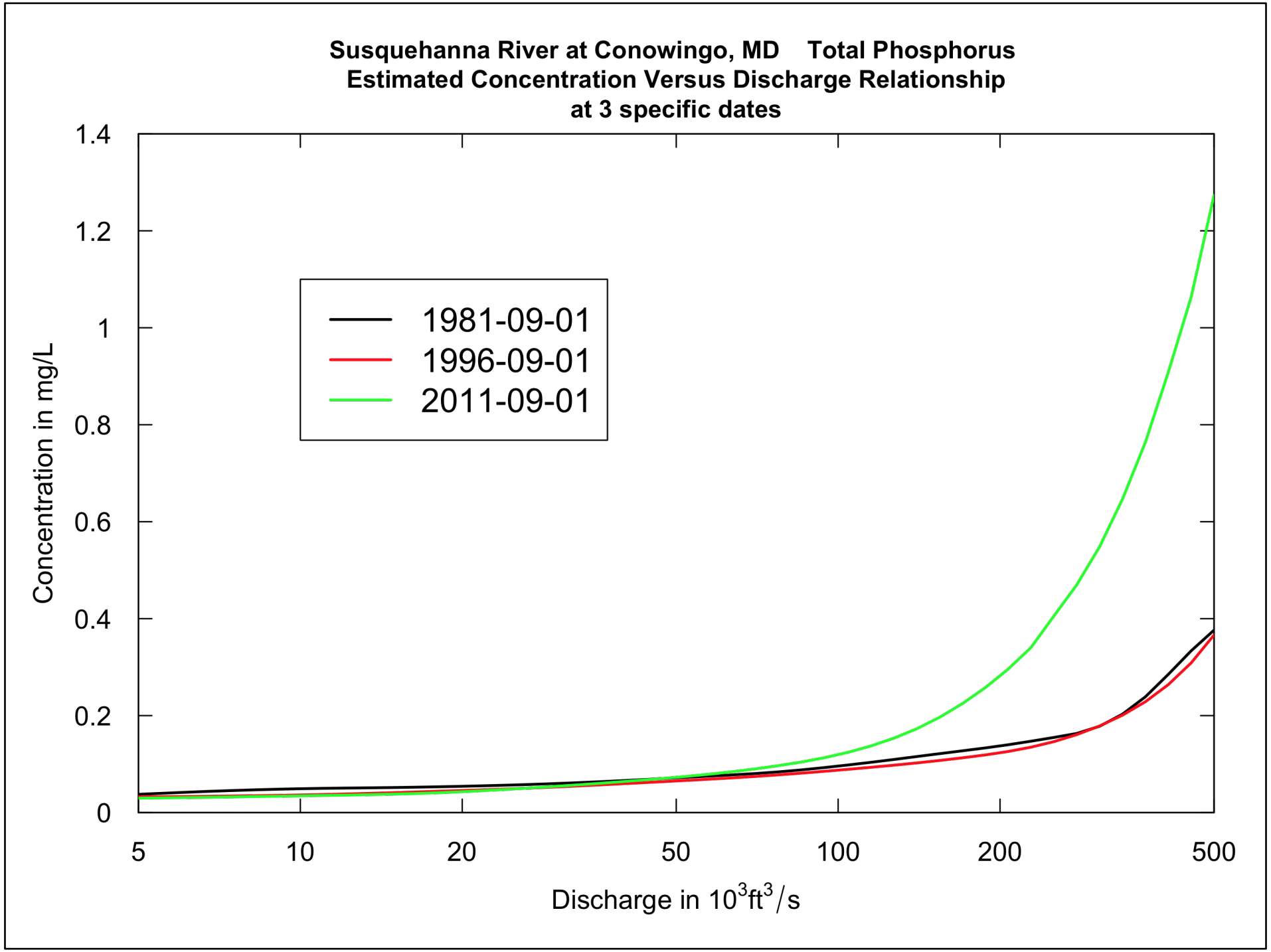
Prior to 2000 100% of the values were below 0.4

Since 2000 only 44% were below 0.4

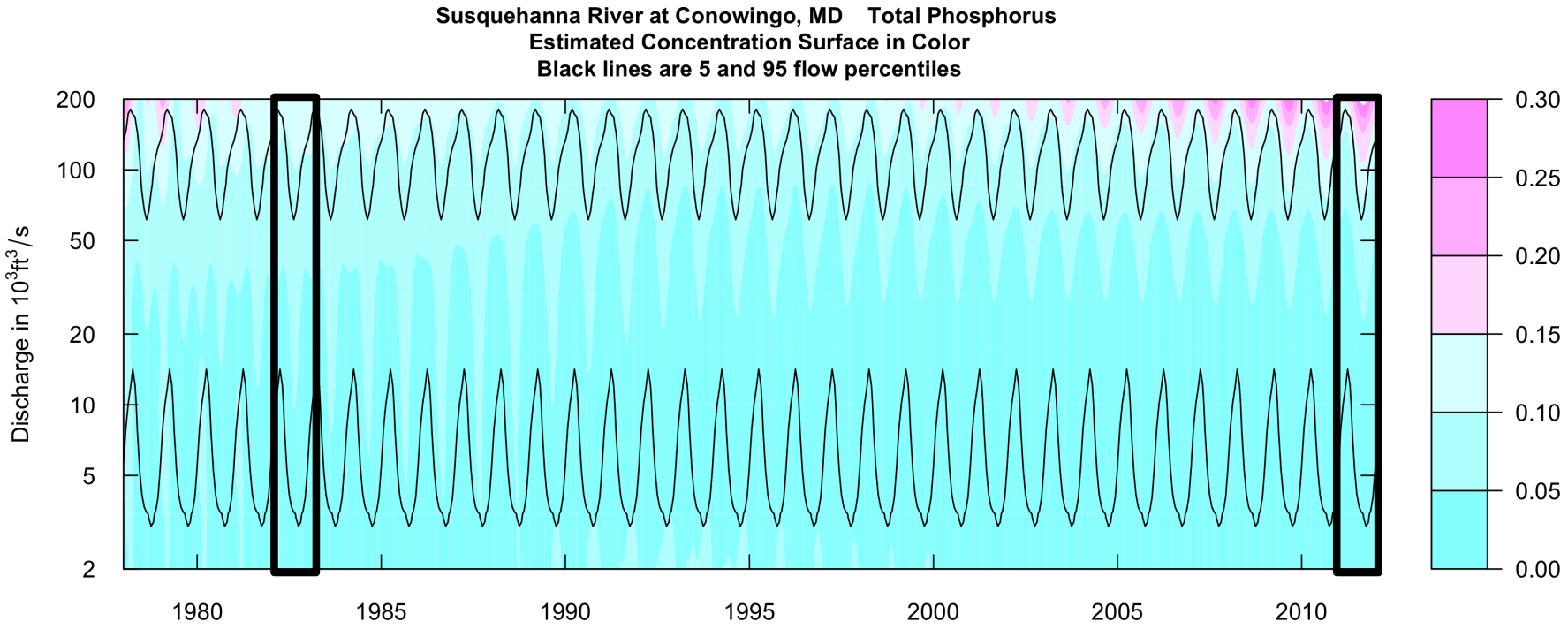



Susquehanna River at Conowingo, MD
Total Phosphorus
Observed and Estimated Flux versus Time
Flux in thousand kg/day
5000
4000
3000
2000
1000
0
2004
2006
2008
2010
2012


Susquehanna River at Conowingo, MD
Total Phosphorus
Observed and Estimated Flux versus Time
Flux in thousand kg/day
5000
4000
3000
2000
1000
0
2011.66
2011.68
2011.7
2011.72
2011.74
2011.76
September,
2011

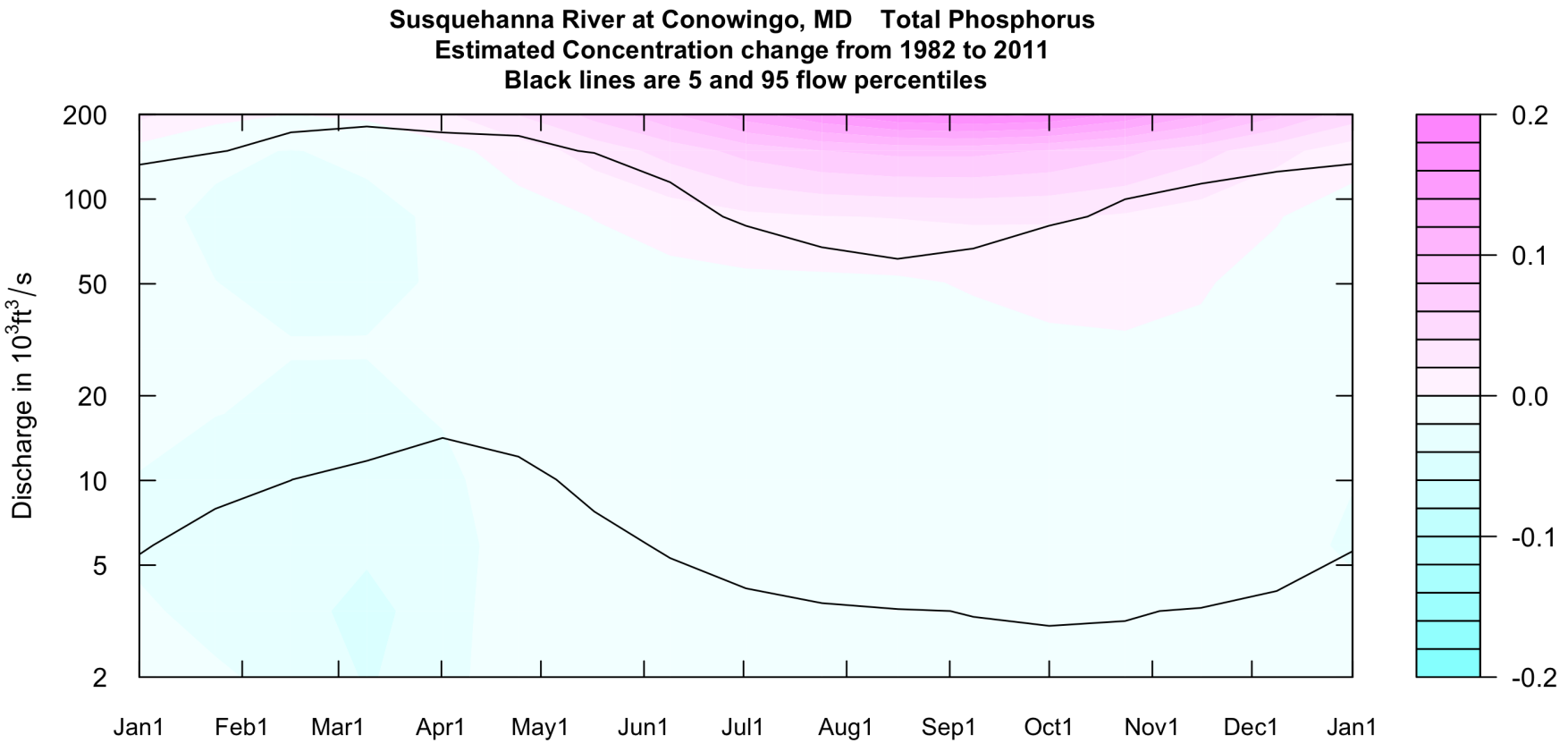

Susquehanna River at Conowingo, MD Total Phosphorus
Estimated Concentration Versus Discharge Relationship
at 3 specific dates
1981-09-01
1996-09-01
2011-09-01
Concentration in mg/L
0
0.2
0.4
0.6
0.8
1
1.2
1.4
5
10
20
50
100
200
500
Discharge in $10^3 ft^3/s$

The changing behavior of Total Phosphorus concentrations at Conowingo over the 34-year monitoring period



Let's compare 1982 and 2011

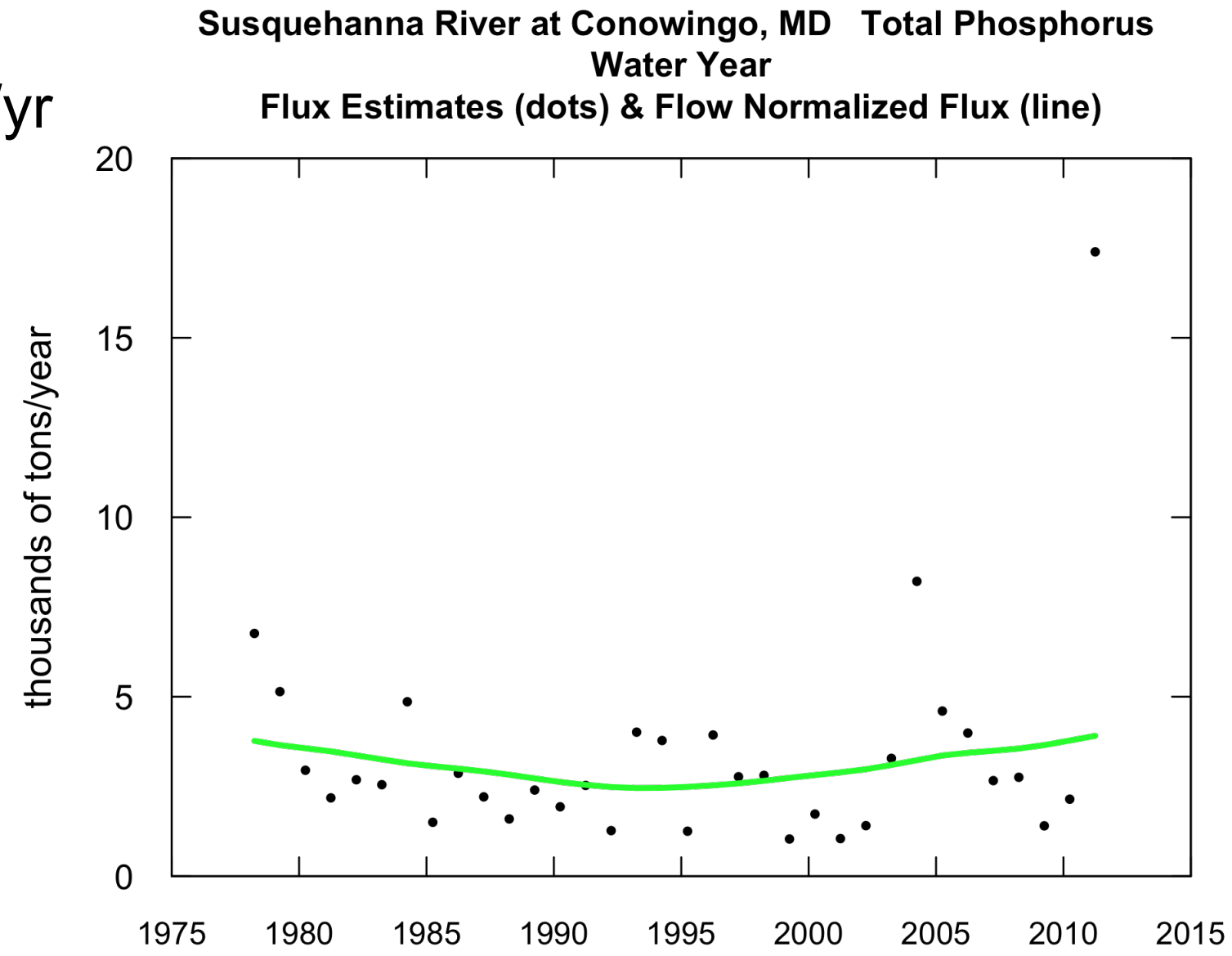
Total Phosphorus concentrations at Conowingo comparing the behavior around 2011 to what it was around 1982



Annual
Flux
In 10^3 tons/yr

2011=17
2010= 2
2004= 8

Flow
Normalized
Flux
Up 57%
Since 1995



Total Phoshporus flux estimates using WRTDS

- T.S. Lee flux about 10,600 tons
- The 2011 water year 17,400 tons
- The past decade average was 4,800 tons/yr
- The past 34 year average was 3,300 tons/yr

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Take home messages

- Total phosphorus concentrations are steady to declining at moderate flows
- But at very high flows they have increased greatly in the past decade
- TP flux continues to rise – but is becoming more and more episodic
- These changes almost certainly are related to the decreasing capacity of Conowingo reservior

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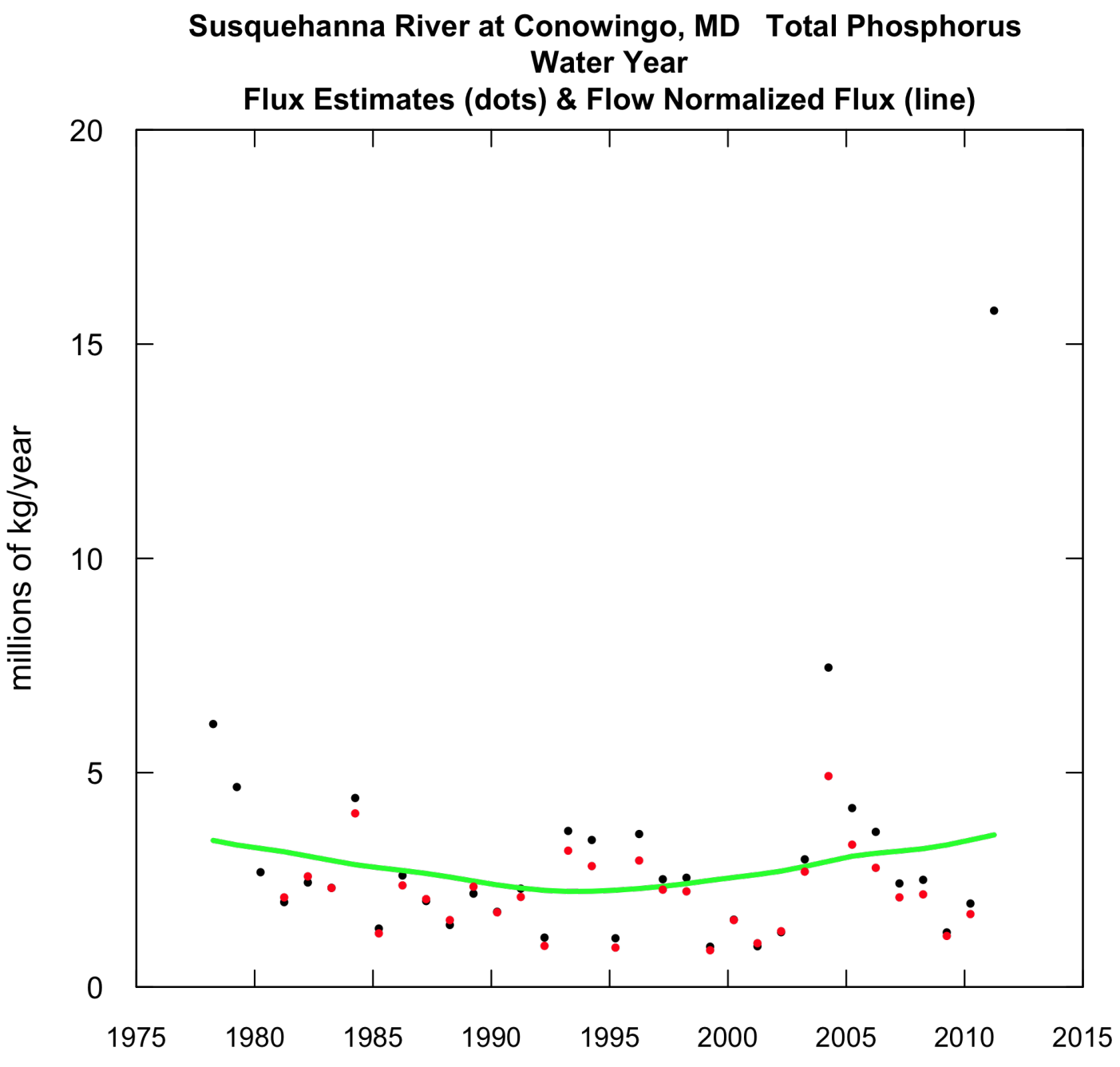
Red dots
Are USGS
Published
Estimates
Made after
WY 2010



Why the 50% increase in our 2004 estimate?

- We excluded a very high value in 2004 which we now believe to be correct.
- Addition of the 2011 event changes our understanding of the behavior at high flow and feeds back to 2004.
- Estimator is biased low in wet years, not able to capture the steep curvature at the high end, new method is WRTDS

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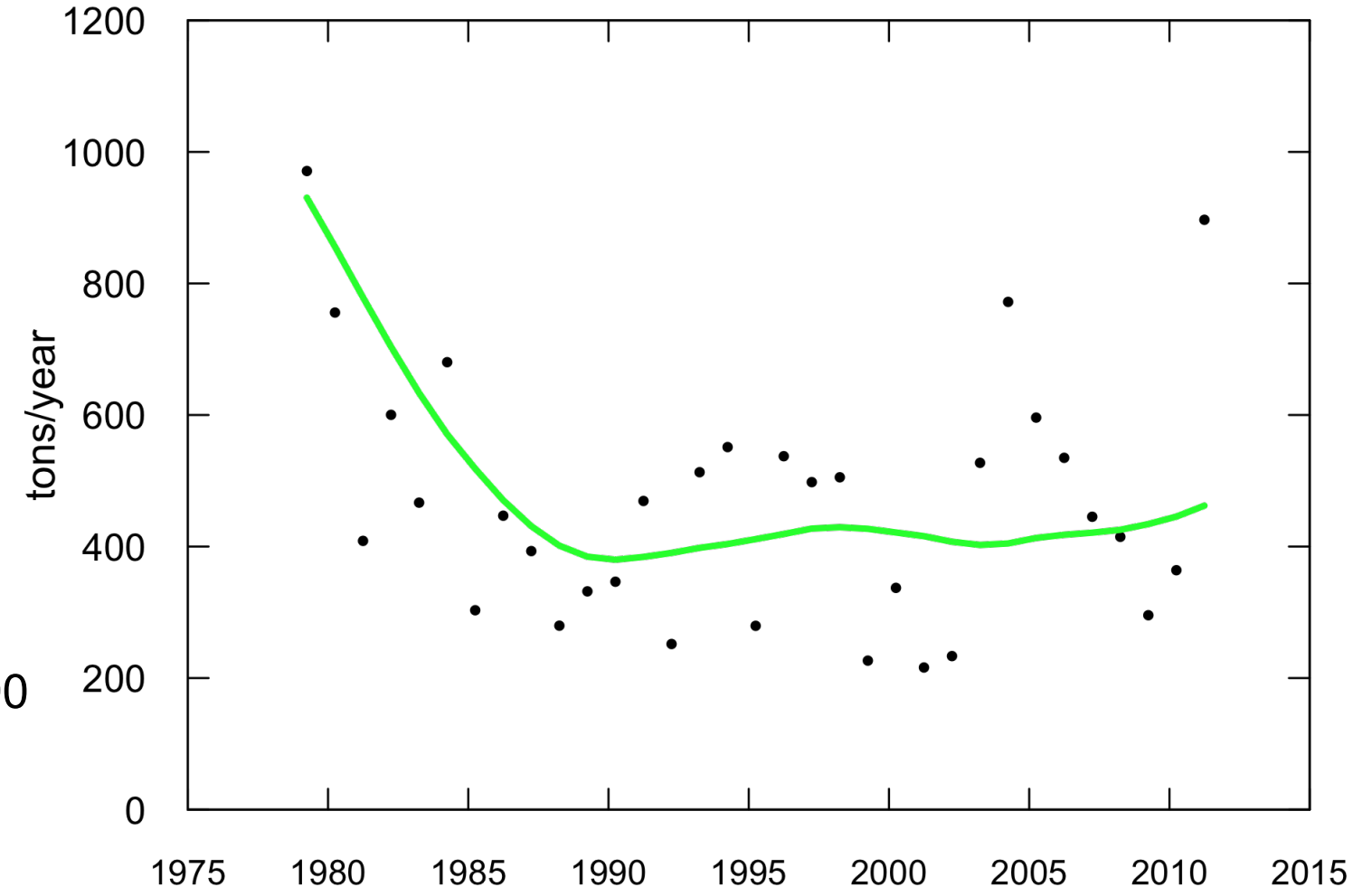
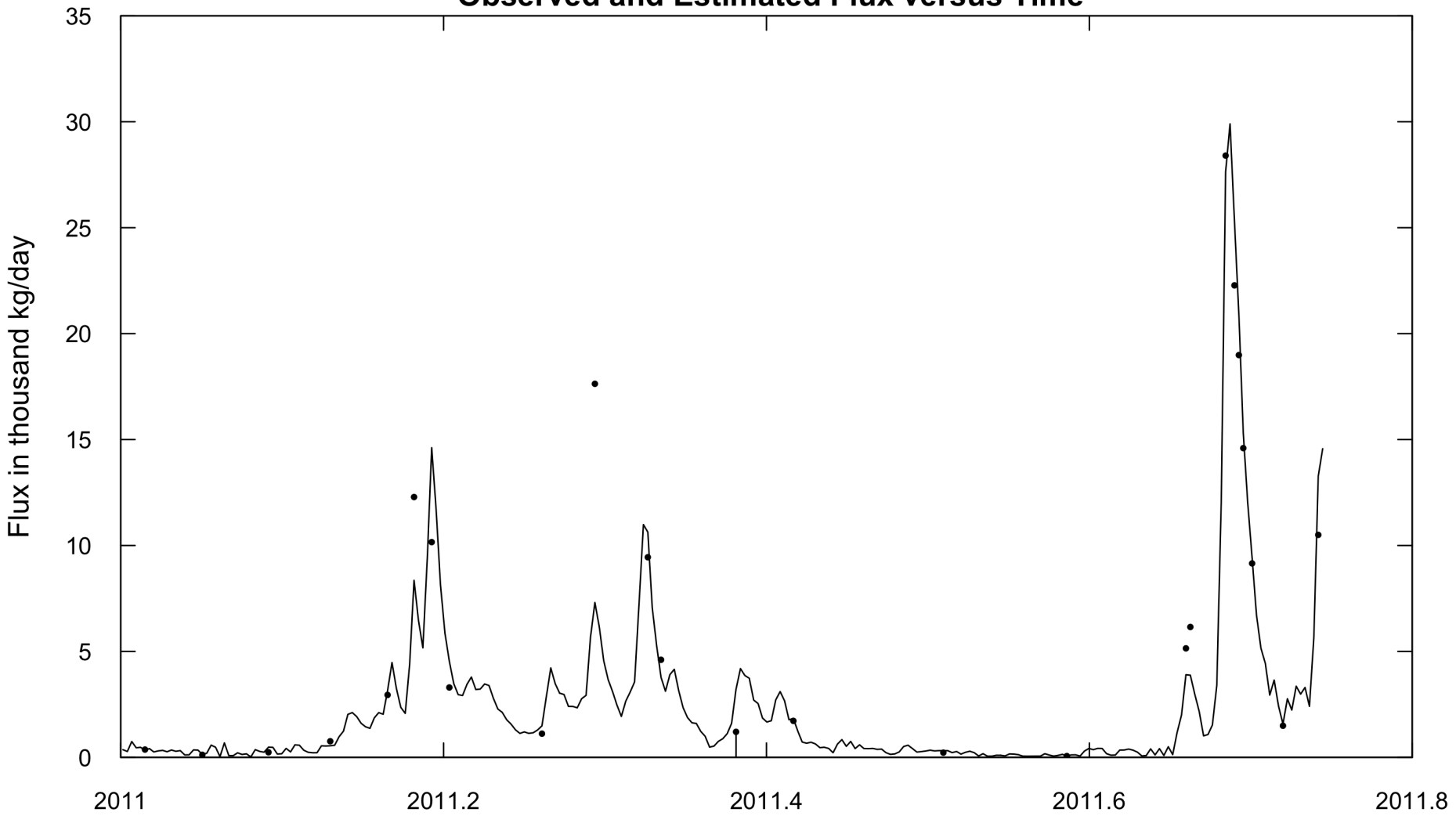
Annual Flux In tons/yr

2011=900
2010=360
2004=770

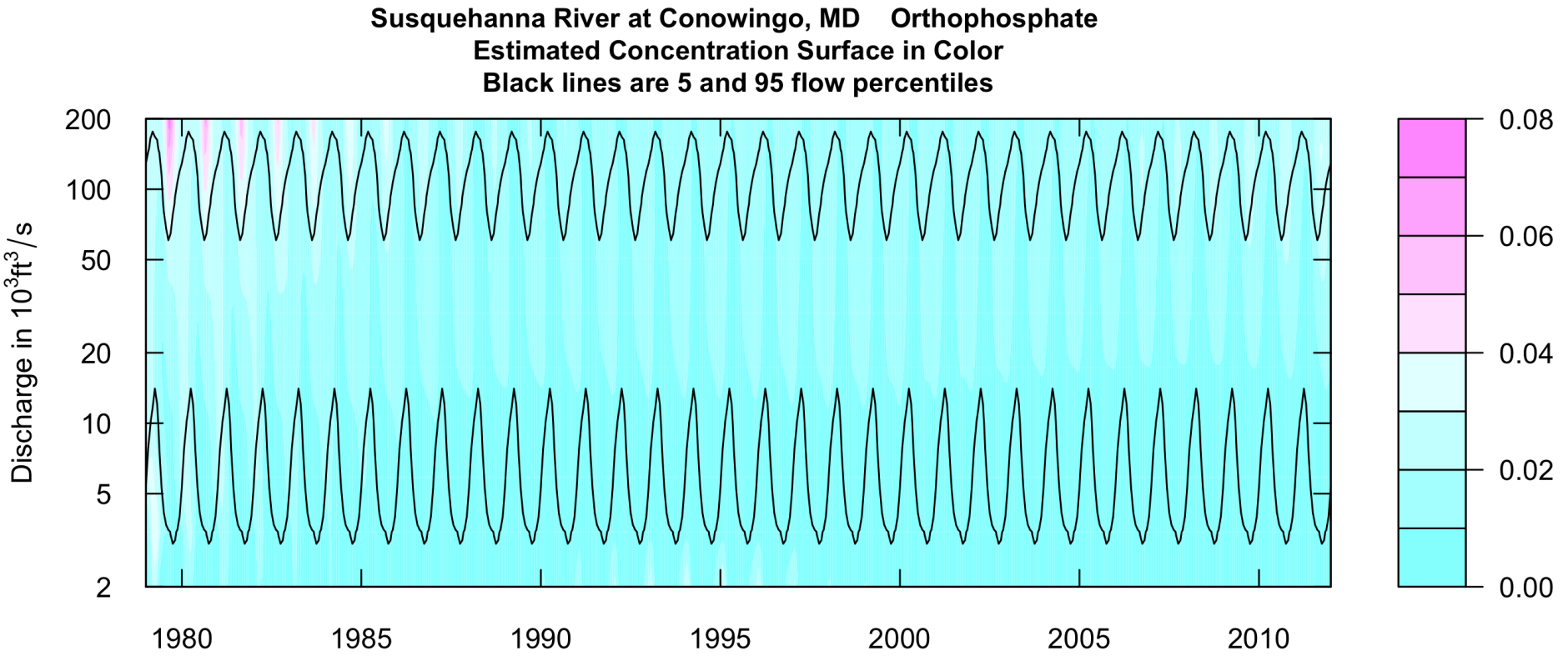
Flow Normalized Flux Down 59% from 1979-1990 Back up 21% since then



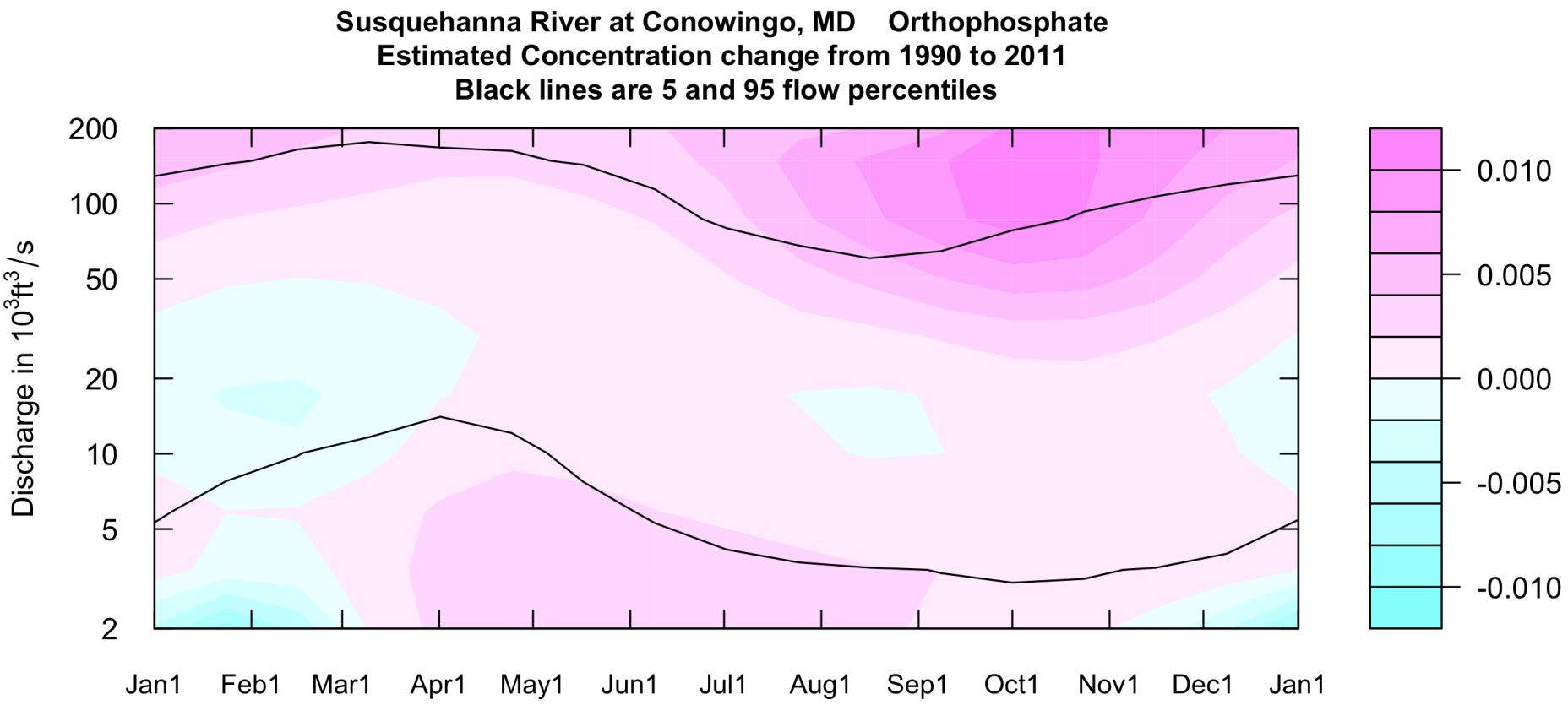
March, April and May of 2011 combined, contributed 32% more orthophosphate than the month of September



Early in the record, very high orthophosphate at the highest discharges. What's the change from 1990 to today?



- **Since 1990 Orthophosphate has been increasing at most flows in most seasons**
- **Slight improvement in winter**
- **Very slightly worse in spring**
- **Substantially worse at high flows in tropical storm season**



Orthophosphate flux estimates using WRTDS

- T.S. Lee flux about 180 tons
- The 2011 water year 900 tons
- The past decade average was 510 tons/yr
- The past 34 year average was 470 tons/yr

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Ratio of Orthophosphate to Total Phosphorus

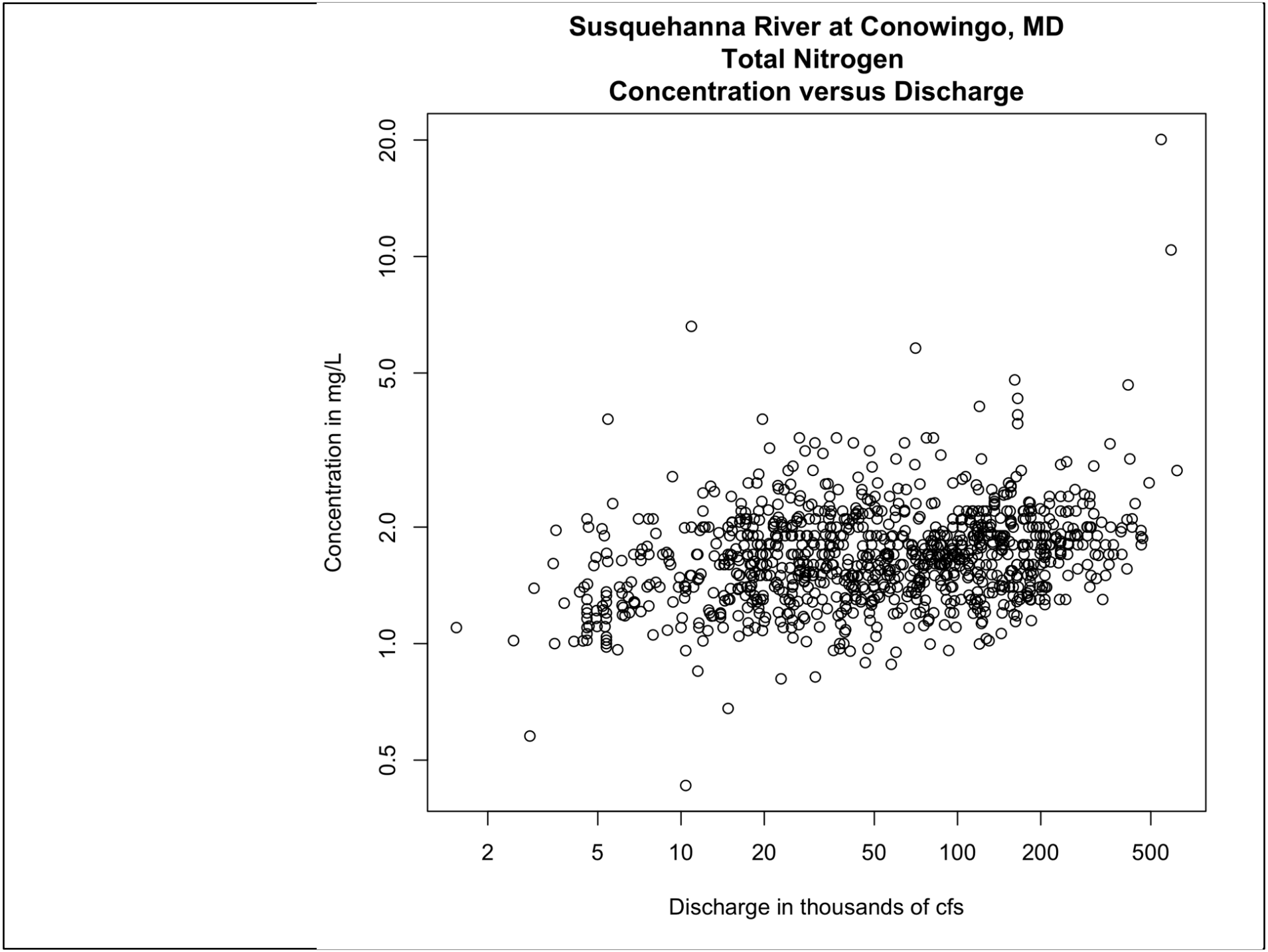
- T.S. Lee 1.7% OrthoP
- The 2011 5% OrthoP
- The past decade 11% OrthoP
- The past 34 year 14% OrthoP

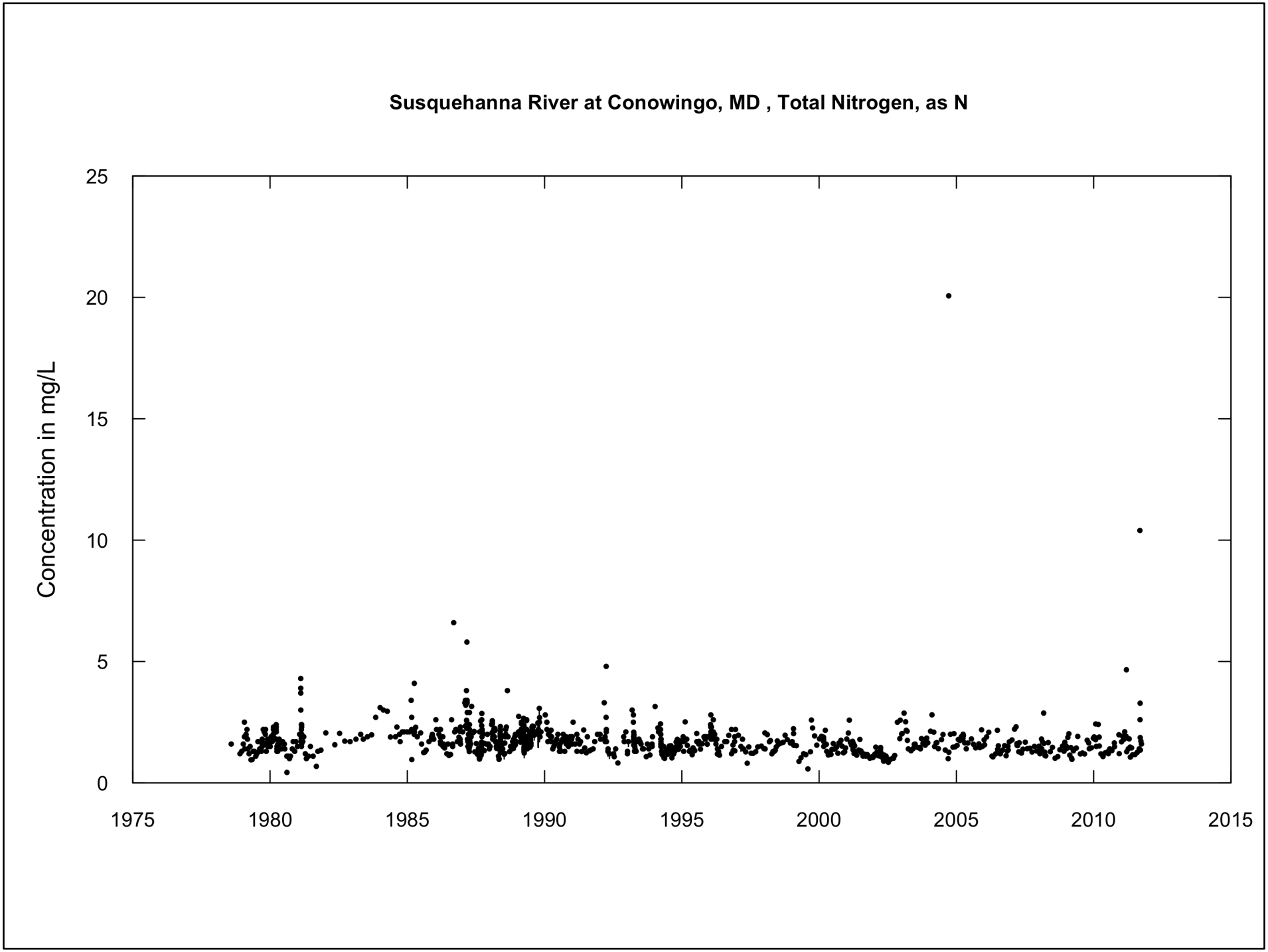
USGS

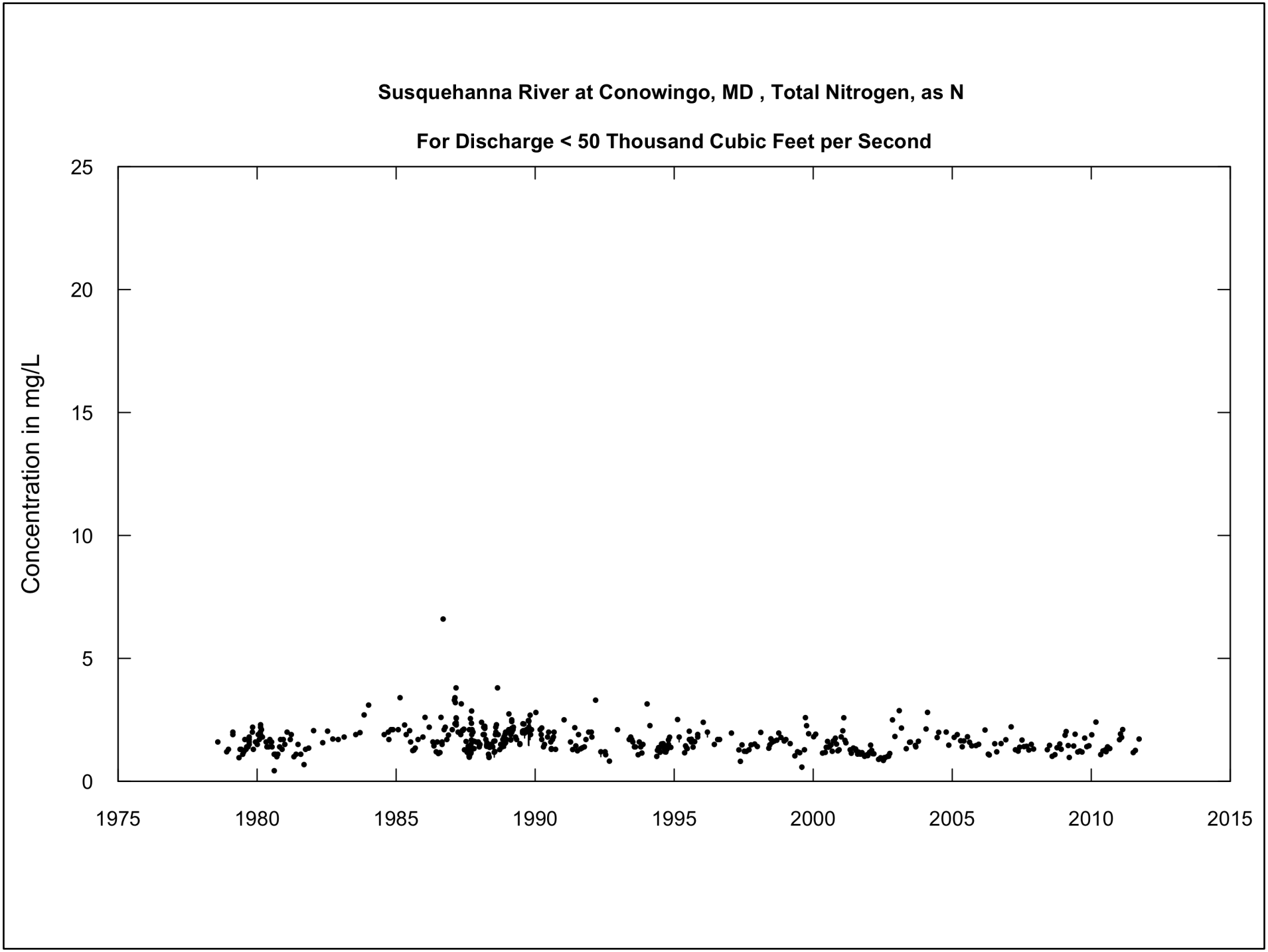
Ratio of Orthophosphate to Total Phosphorus Flow Normalized Flux

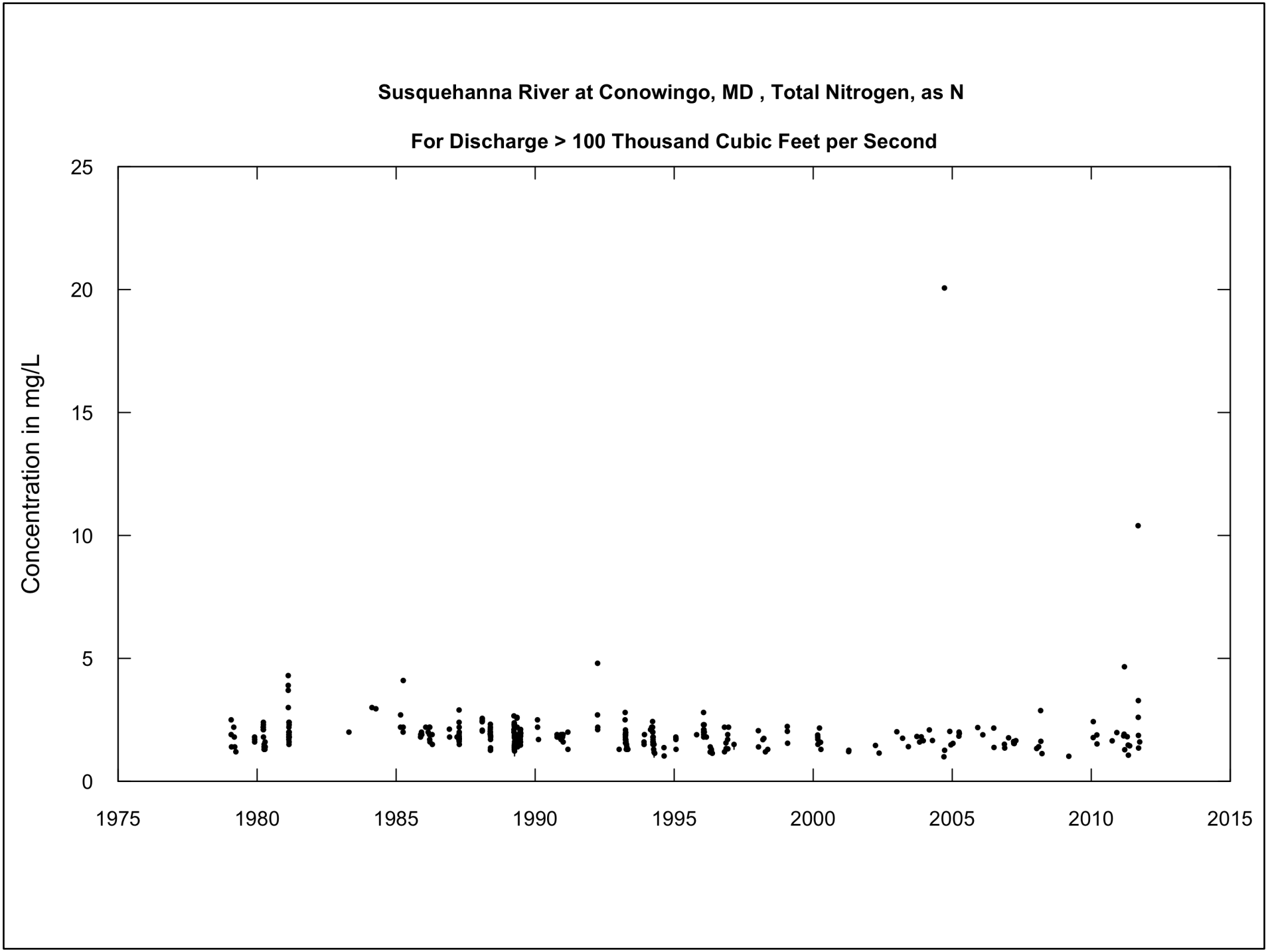
- As of 2011 it is about 12%
- As of 1996 it was about 16%
- As of 1980 it was about 24%
- In other words, OrthoPhosphorus is becoming a smaller fraction of Total P

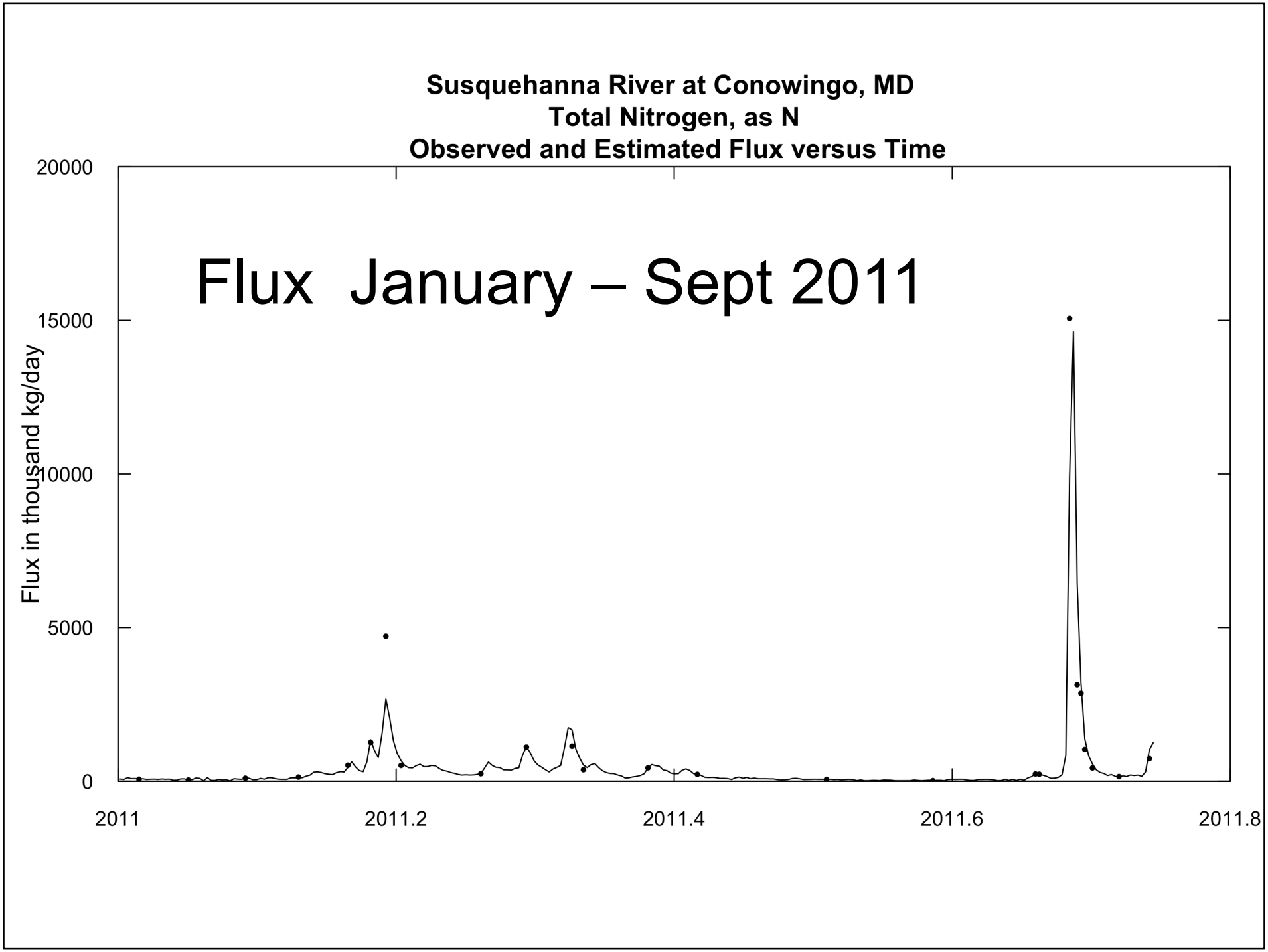
USGS

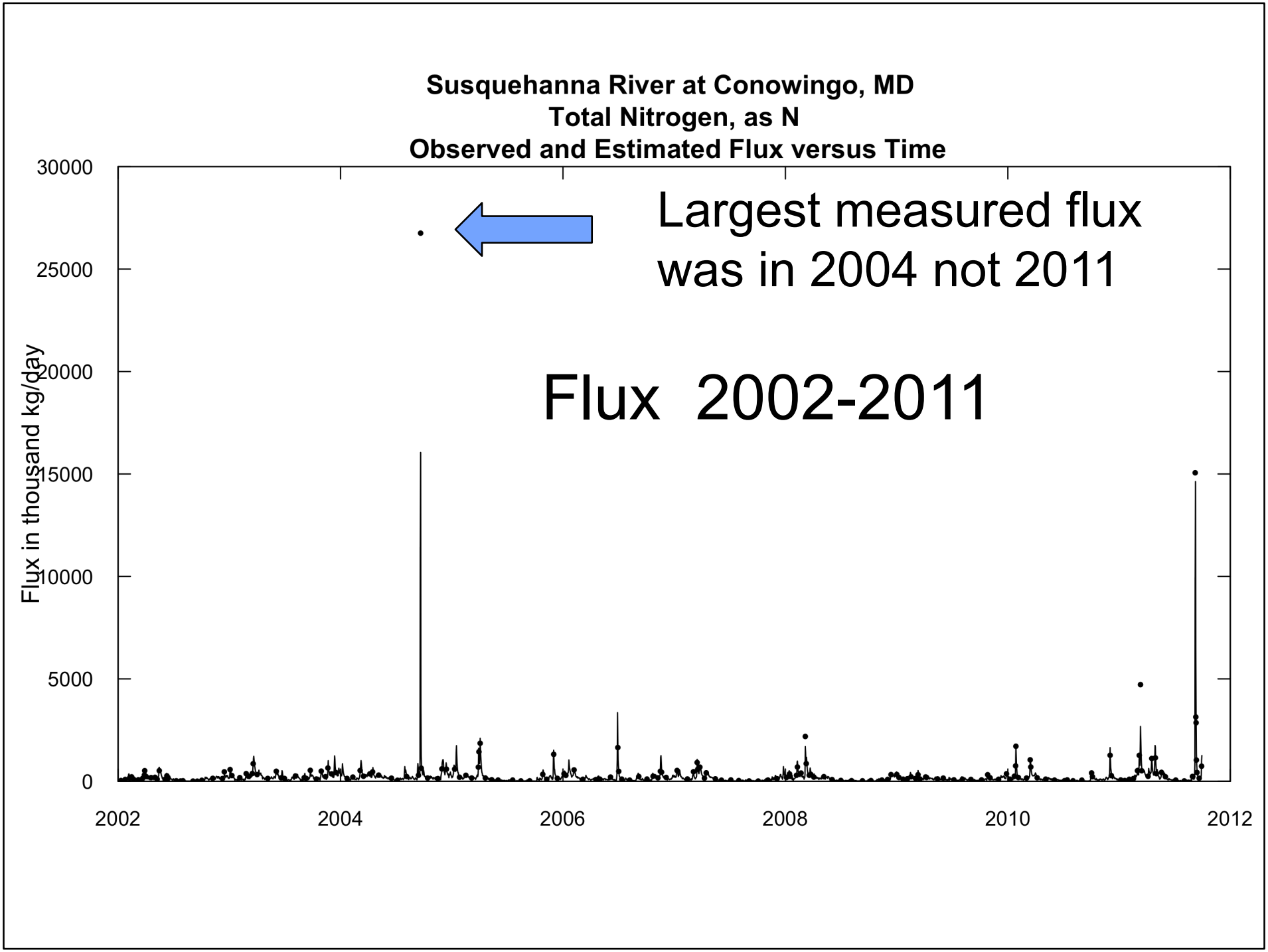

Susquehanna River at Conowingo, MD
Total Nitrogen
Concentration versus Discharge
Concentration in mg/L
0.5
1.0
2.0
5.0
10.0
20.0
2
5
10
20
50
100
200
500
Discharge in thousands of cfs


Susquehanna River at Conowingo, MD , Total Nitrogen, as N
Concentration in mg/L
25
20
15
10
5
0
1975
1980
1985
1990
1995
2000
2005
2010
2015


Susquehanna River at Conowingo, MD , Total Nitrogen, as N
For Discharge < 50 Thousand Cubic Feet per Second
Concentration in mg/L
25
20
15
10
5
0
1975
1980
1985
1990
1995
2000
2005
2010
2015


Susquehanna River at Conowingo, MD , Total Nitrogen, as N
For Discharge > 100 Thousand Cubic Feet per Second
Concentration in mg/L
25
20
15
10
5
0
1975
1980
1985
1990
1995
2000
2005
2010
2015

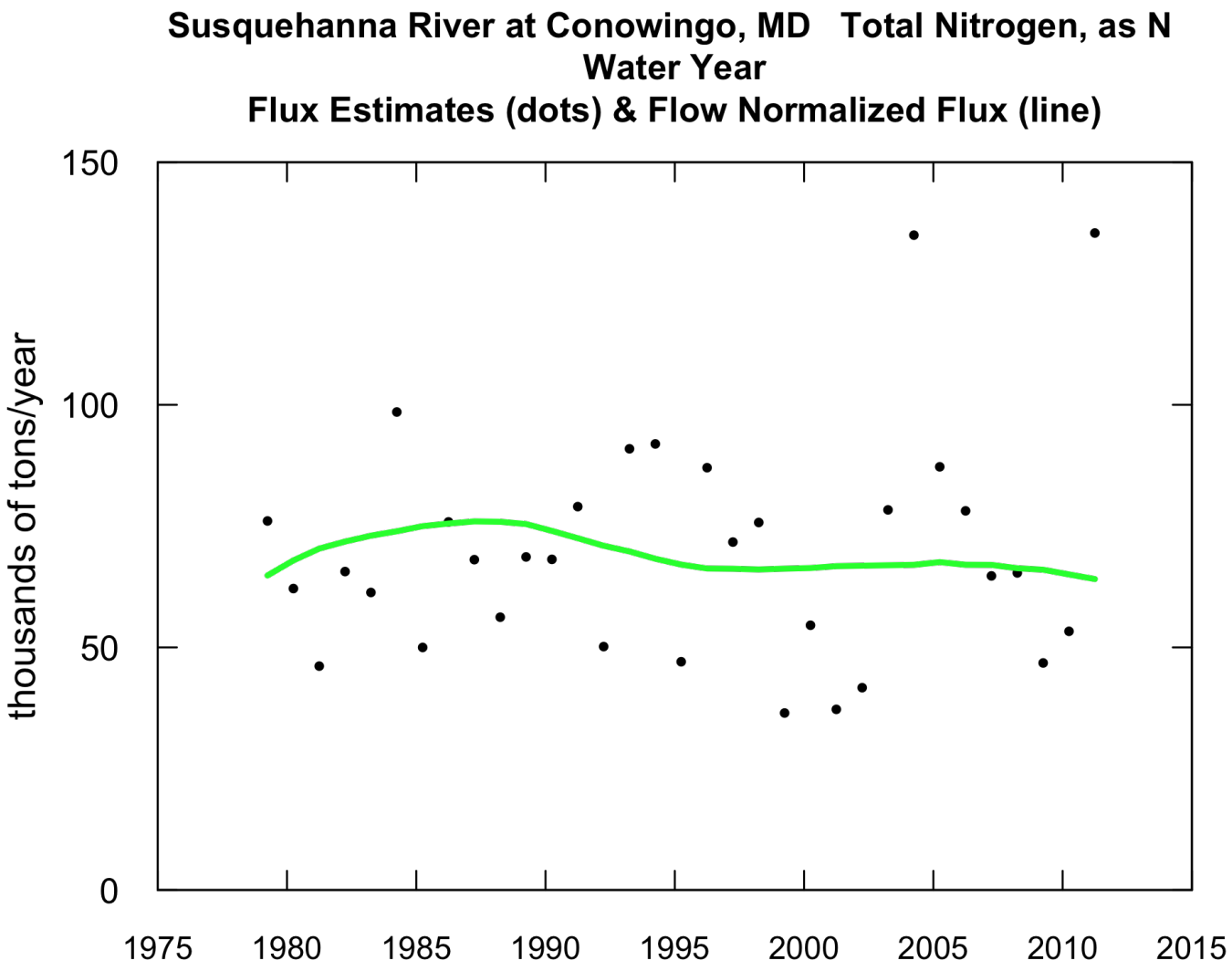

Susquehanna River at Conowingo, MD
Total Nitrogen, as N
Observed and Estimated Flux versus Time
Flux January – Sept 2011
Flux in thousand kg/day
20000
15000
10000
5000
0
2011
2011.2
2011.4
2011.6
2011.8


Susquehanna River at Conowingo, MD
Total Nitrogen, as N
Observed and Estimated Flux versus Time
Largest measured flux was in 2004 not 2011
Flux 2002-2011
Flux in thousand kg/day
30000
25000
20000
15000
10000
5000
0
2002
2004
2006
2008
2010
2012

Annual Flux
In 10^3 tons/yr

2011 = 135
2010 = 50
2004 = 135

Flow Normalized Flux Change Since 1995
-5%



Total Nitrogen flux estimates using WRTDS

- T.S. Lee flux about 42,000 tons
- The 2011 water year 135,000 tons
- The past decade average was 78,600 tons/yr
- The past 34 year average was 69,800 tons/yr

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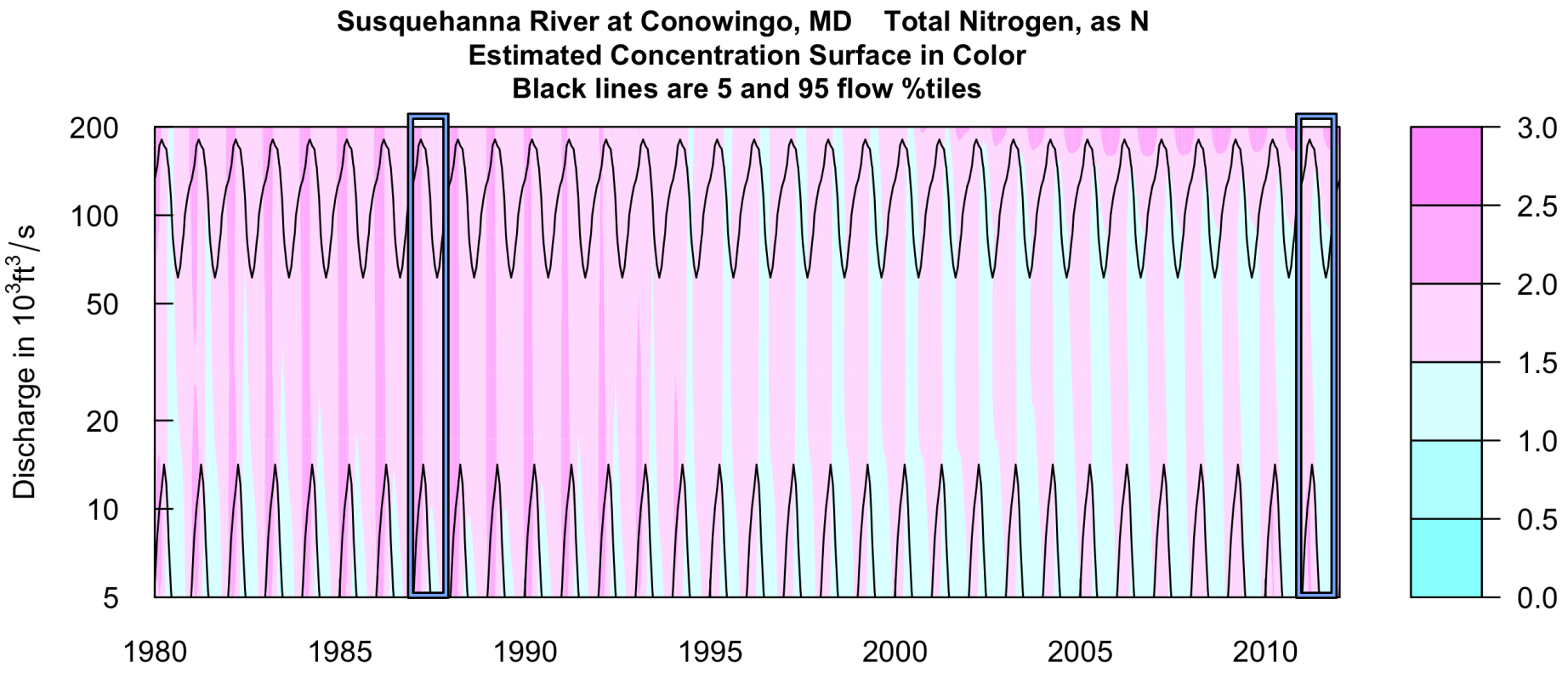
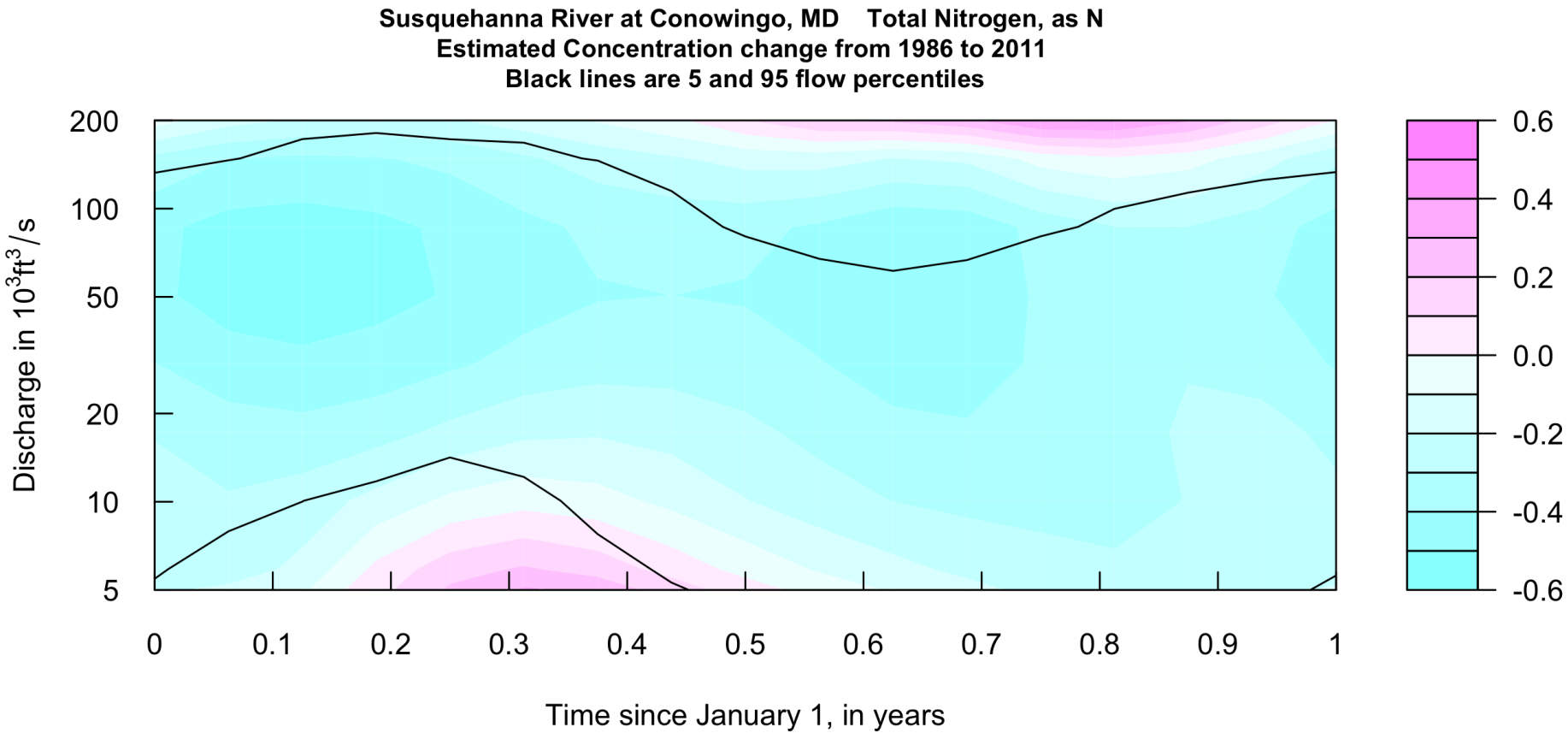
Evolving behavior of TN



Compute the difference between two years

- Decreased concentrations at almost all flows and seasons
- Biggest decrease between about 40,000 and 100,000 cfs
- Biggest decreases in Winter and early Summer
- Slight indication of increase at very low flow in Spring
- and at very high flow in Tropical Storm season



Take home messages: TN

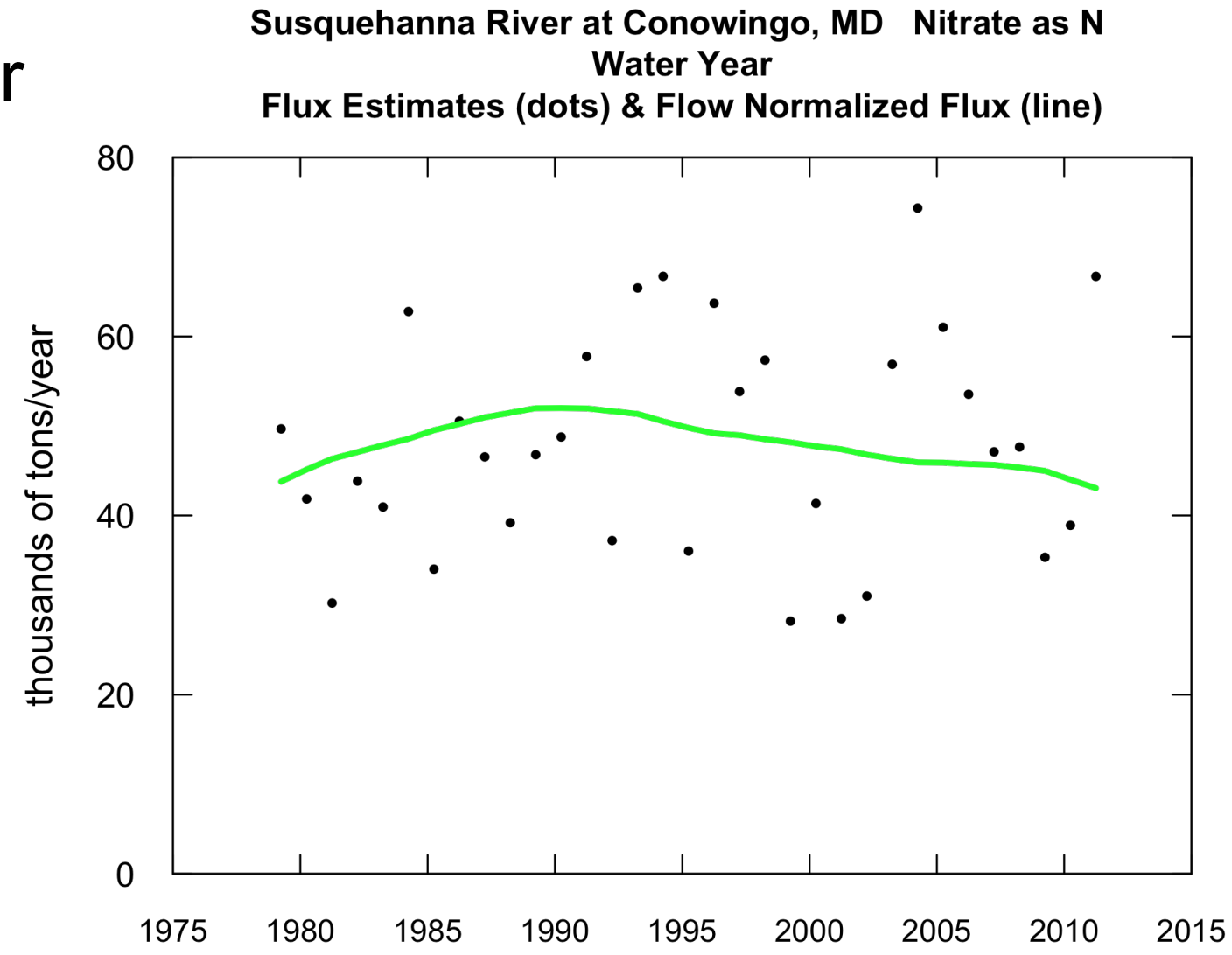
- Total Nitrogen concentrations are continuing to decline at most discharges.
- But at very high flows they are showing some increase.
- TN flow-normalized flux continues to fall. Down about 16% since its high in 1987.
- Year to year variability in actual TN flux is increasing (standard deviation about double for 2002-2011 what it was for 1979-2001).

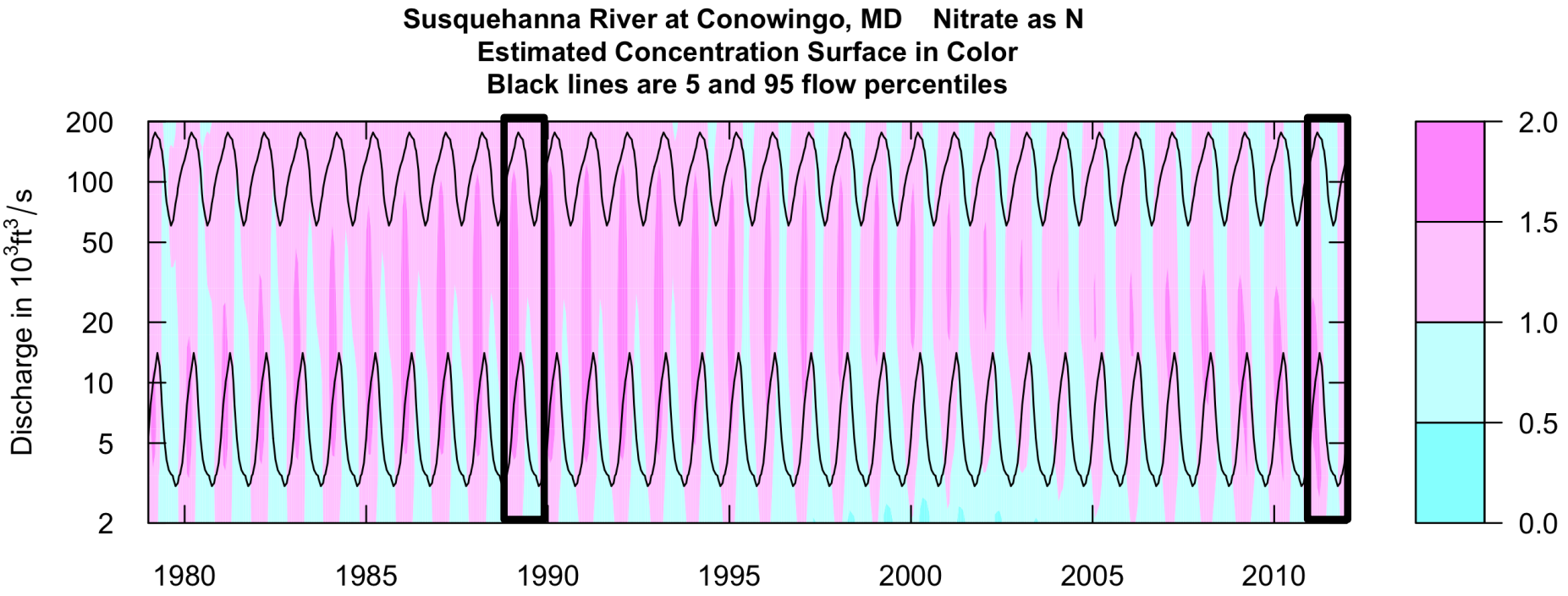
USGS

Annual
Flux
In 10^3 tons/yr

2011= 67
2010= 39
2004= 74

Flow
Normalized
Flux down
17%
Since 1990

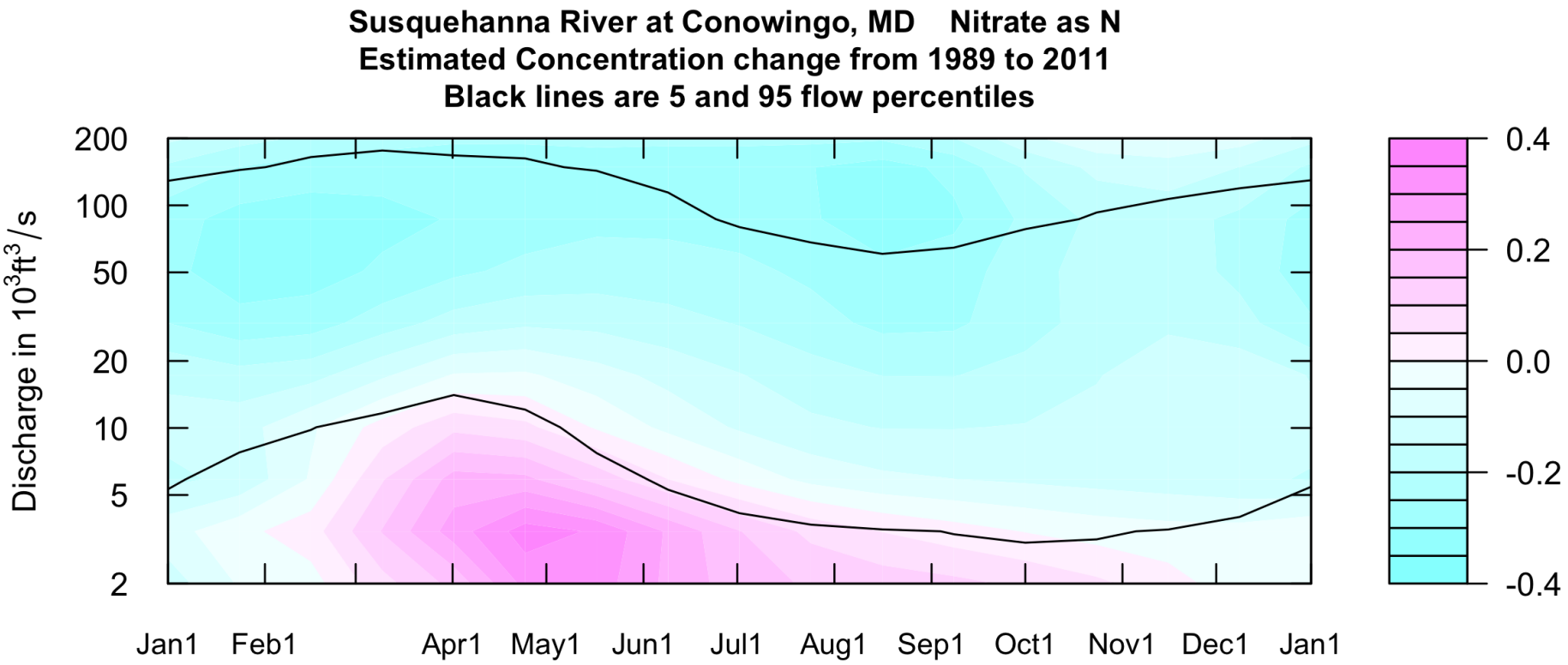




Let's compare 1989 and 2011

Changes in Nitrate behavior 1989 - 2011

- **Nitrate has been decreasing across all seasons and almost all flows, particularly high flows**
- **Only increases are at very low flows in the Spring**



Ratio of Nitrate to Total N

- T.S. Lee 19% Nitrate
- The 2011 49% Nitrate
- The past decade 65% Nitrate
- The past 34 year 69% Nitrate

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Ratio of Nitrate to Total Nitrogen in the Flow Normalized Flux

- As of 2011 it is about 67%
- As of 1996 it was about 74%
- As of 1980 it was about 67%
- Nitrate may be becoming a slightly smaller fraction of the total as scour events increase the suspended N flux

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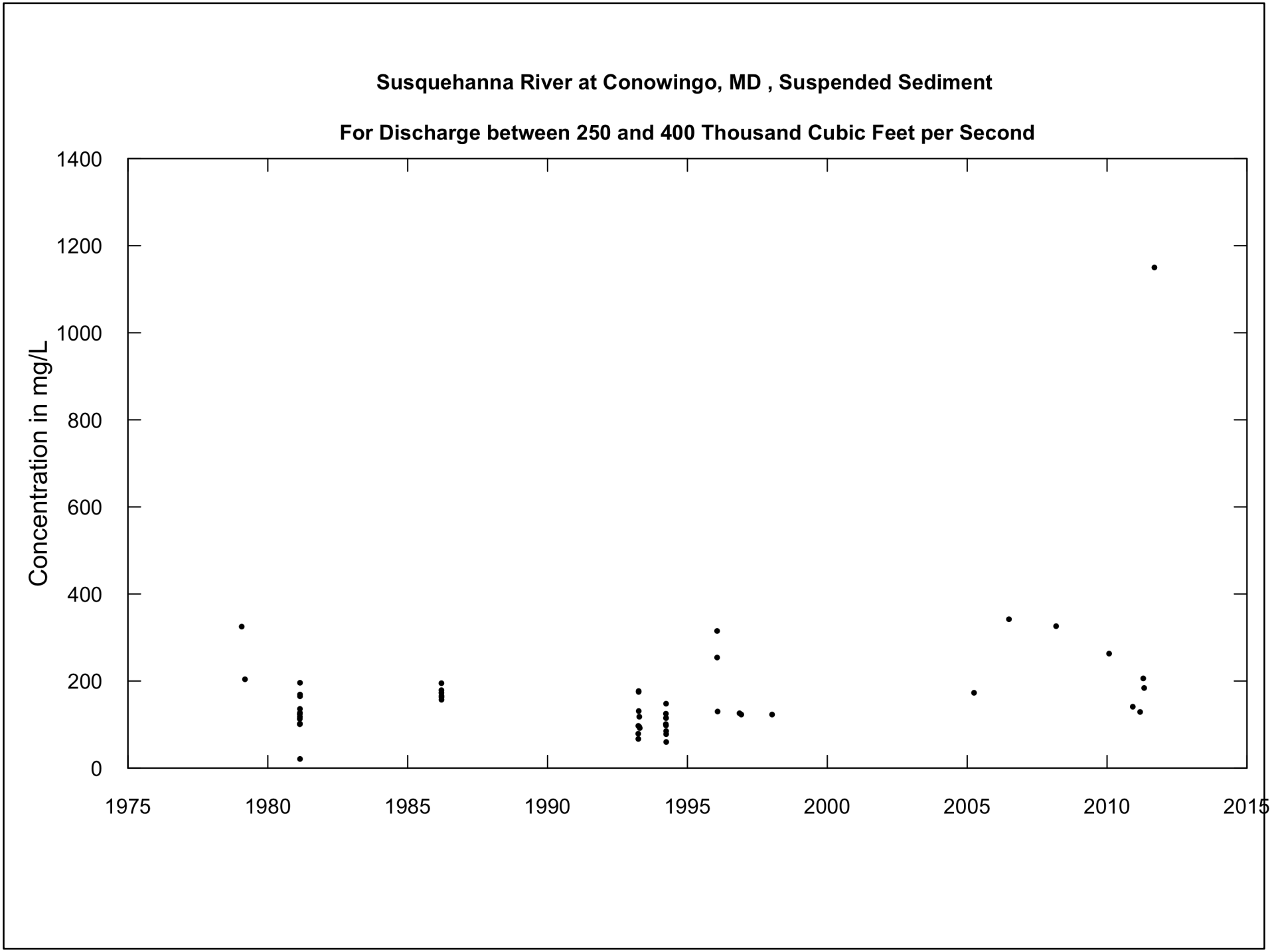
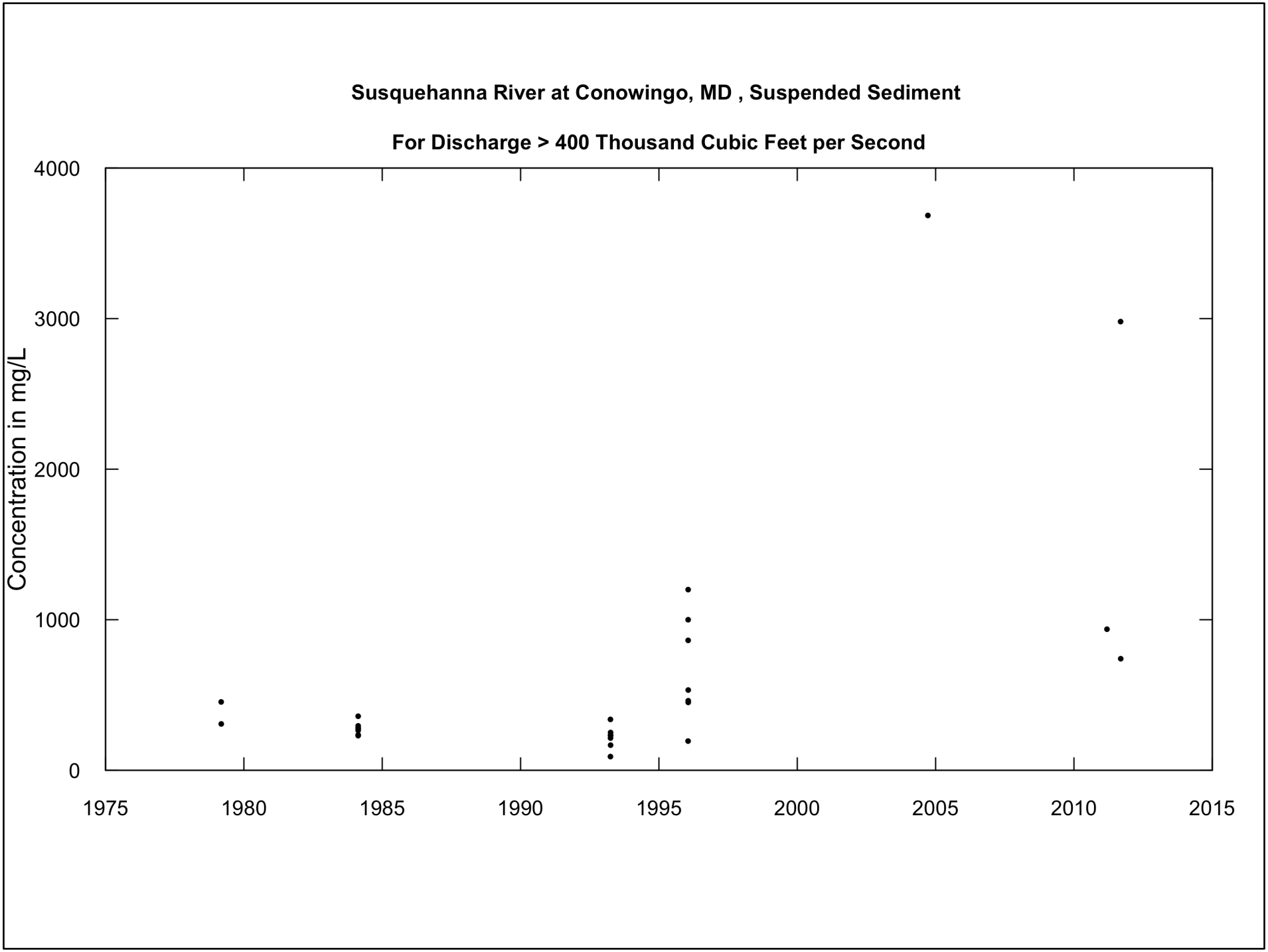
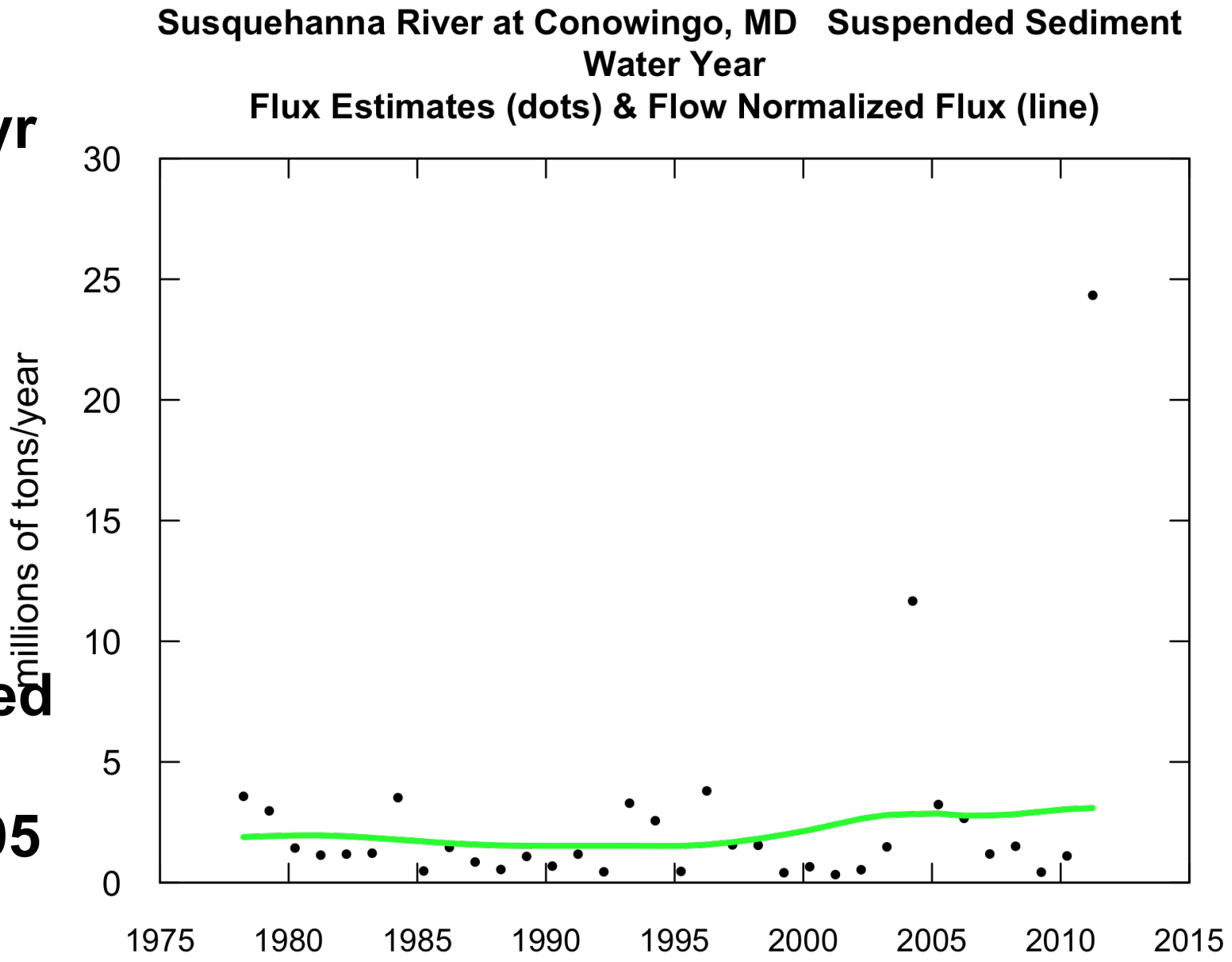

Susquehanna River at Conowingo, MD , Suspended Sediment
For Discharge between 250 and 400 Thousand Cubic Feet per Second
Concentration in mg/L
1400
1200
1000
800
600
400
200
0
1975
1980
1985
1990
1995
2000
2005
2010
2015


Susquehanna River at Conowingo, MD , Suspended Sediment
For Discharge > 400 Thousand Cubic Feet per Second
Concentration in mg/L
4000
3000
2000
1000
0
1975
1980
1985
1990
1995
2000
2005
2010
2015

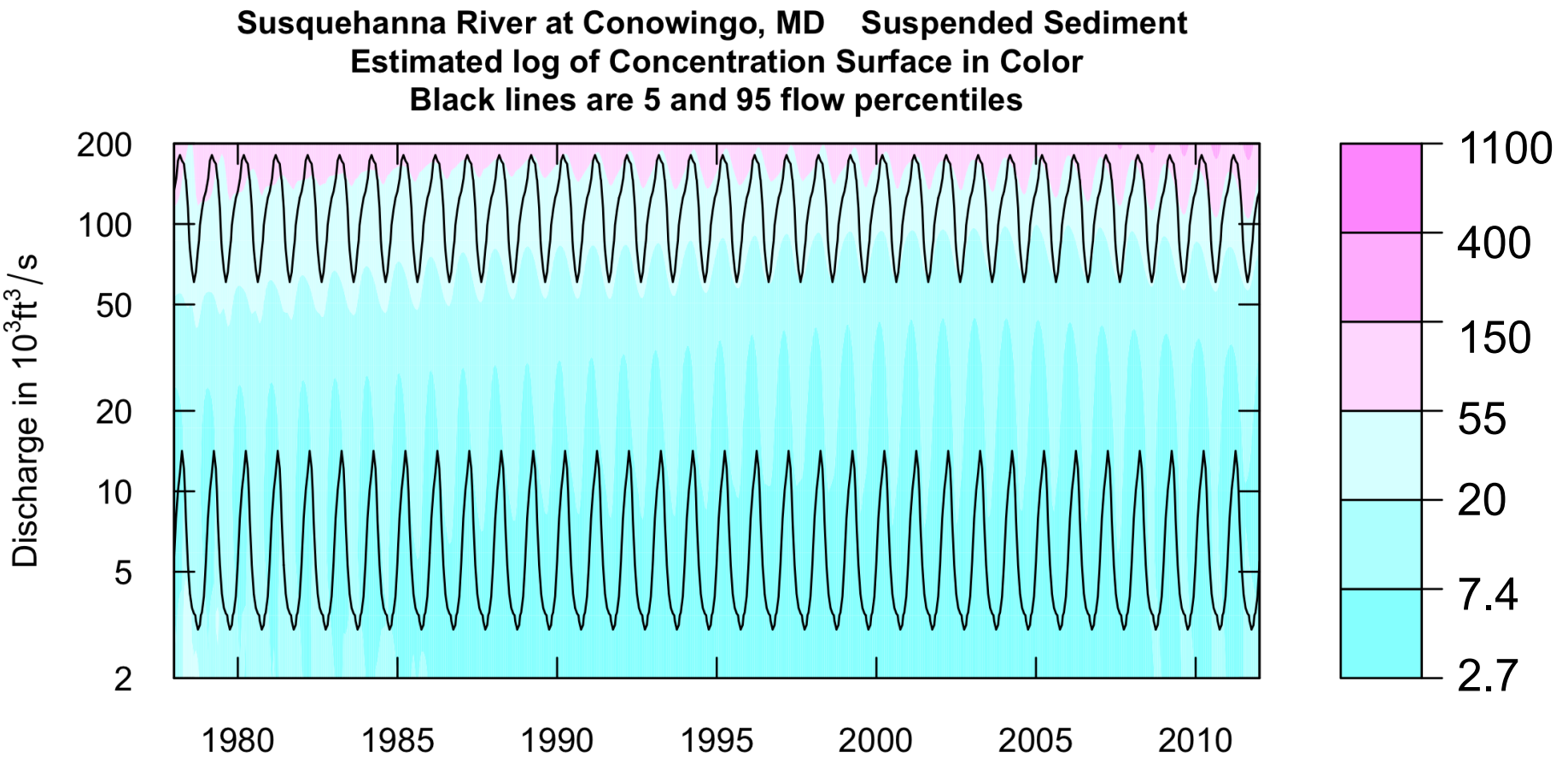
Annual Flux in 10^6 tons/yr

2011=24
2010= 1
2004=12

Flow Normalized Up 103% Since 1995



Evolving behavior of Suspended Sediment



Very difficult to define:

So much depends on a few rare events

Suspended sediment flux estimates using WRTDS

- T.S. Lee flux about 19 million tons
- The 2011 water year 24 million tons
- The past decade average was 4.8 million tons
- The past 34 year average was 2.5 million tons

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	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Nitrate			
Total Nitrogen			
Ortho Phosphate			
Total Phosphorus			
Suspended Sediment			

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Nitrate	11%	1.5%	0.5%
Total Nitrogen			
Ortho Phosphate			
Total Phosphorus			
Suspended Sediment			

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Nitrate	11%	1.5%	0.5%
Total Nitrogen	31%	5%	1.8%
Ortho Phosphate			
Total Phosphorus			
Suspended Sediment			

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Nitrate	11%	1.5%	0.5%
Total Nitrogen	31%	5%	1.8%
Ortho Phosphate	20%	3%	1.1%
Total Phosphorus			
Suspended Sediment			

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Nitrate	11%	1.5%	0.5%
Total Nitrogen	31%	5%	1.8%
Ortho Phosphate	20%	3%	1.1%
Total Phosphorus	61%	22%	9%
Suspended Sediment			

	T.S. Lee as a % of 2011	T.S. Lee as a % of last decade	T.S. Lee as a % of full record
Time	2%	0.2%	0.06%
Flow	12%	1.8%	0.6%
Nitrate	11%	1.5%	0.5%
Total Nitrogen	31%	5%	1.8%
Ortho Phosphate	20%	3%	1.1%
Total Phosphorus	61%	22%	9%
Suspended Sediment	78%	39%	22%

Future role of sensor data (turbidity and nitrate):

- More accurate assessments of actual concentrations and fluxes
- Improve process understanding (e.g. hysteresis, roles of different tributaries, long-term antecedent conditions)
- Provide a basis for improved understanding of estimation error

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What does this all mean for the Bay?

- The ability of the dams to trap materials is diminishing and the extent and frequency of scour is increasing.
- We are on a trajectory of having high flow events play a more and more important role in delivering sediment and total phosphorus to the Bay.
- The inputs of nitrogen continue to fall but phosphorous (both suspended and dissolved) and sediment continue to rise.

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