Long-term trends and mass-balance of nutrient and sediment loadings in the Lower Susquehanna River Watershed

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Johns Hopkins University

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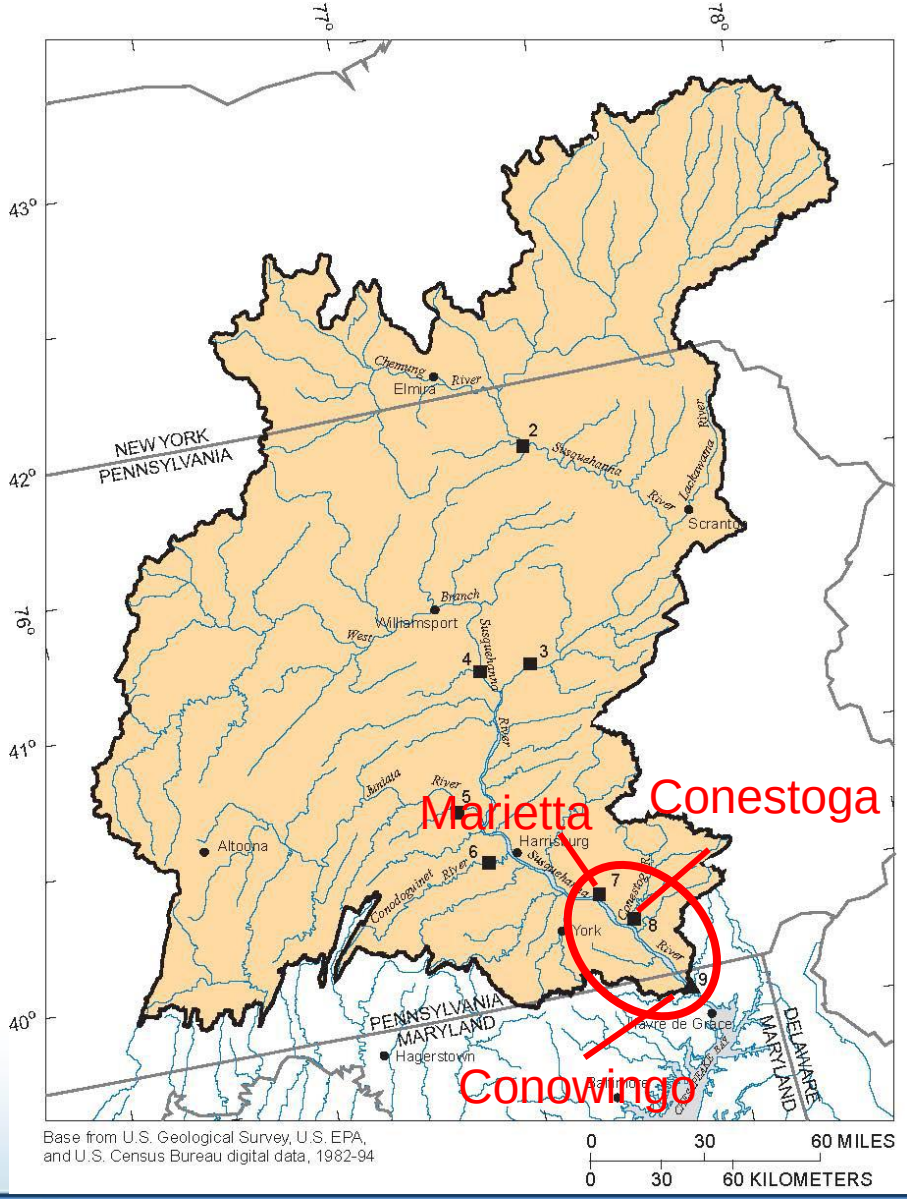
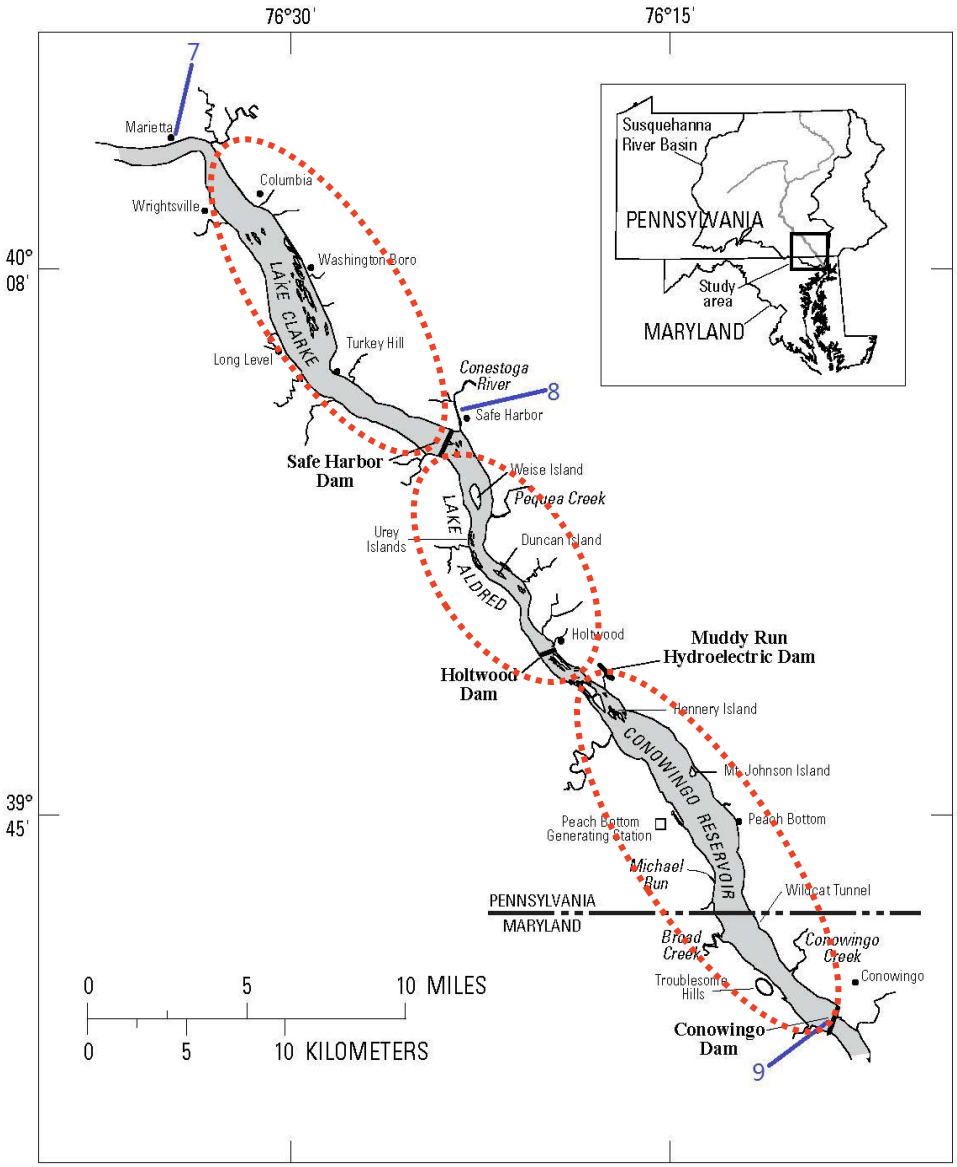
Topics


NEW YORK
PENNSYLVANIA
Elmira
Williamsport
Scranton
Harrisburg
Altoona
York
Lancaster
Hagerstown
Havre de Grace
PENNSYLVANIA
MARYLAND
DELAWARE
Marietta
Conestoga
Conowingo
Base from U.S. Geological Survey, U.S. EPA, and U.S. Census Bureau digital data, 1982-94
0 30 60 MILES
0 30 60 KILOMETERS


76°30'
76°15'
40° 08'
39° 45'
Marietta
Columbia
Wrightsville
Washington Boro
Turkey Hill
Long Level
LAKE CLARKE
Conestoga River
Safe Harbor
Safe Harbor Dam
Weise Island
Pequea Creek
Urey Islands
Duncan Island
LAKE ALDRED
Holtwood
Holtwood Dam
Muddy Run Hydroelectric Dam
Hennery Island
Mt. Johnson Island
CONOWINGO RESERVOIR
Peach Bottom Generating Station
Peach Bottom
Michael Run
Wildcat Tunnel
PENNSYLVANIA
MARYLAND
Broad Creek
Conowingo Creek
Conowingo
Troublesome Hills
Conowingo Dam
0 5 10 MILES
0 5 10 KILOMETERS
Susquehanna River Basin
PENNSYLVANIA
Study area
MARYLAND

Topics

1. What are the long-term seasonal trends of nutrient and sediment loads at the reservoir outlet?

2. What are the long-term seasonal trends of nutrient and sediment loads at the reservoir inlets?

3. What is the extent of sediment deposition or scour in the reservoir on a daily basis (1987-2012)?

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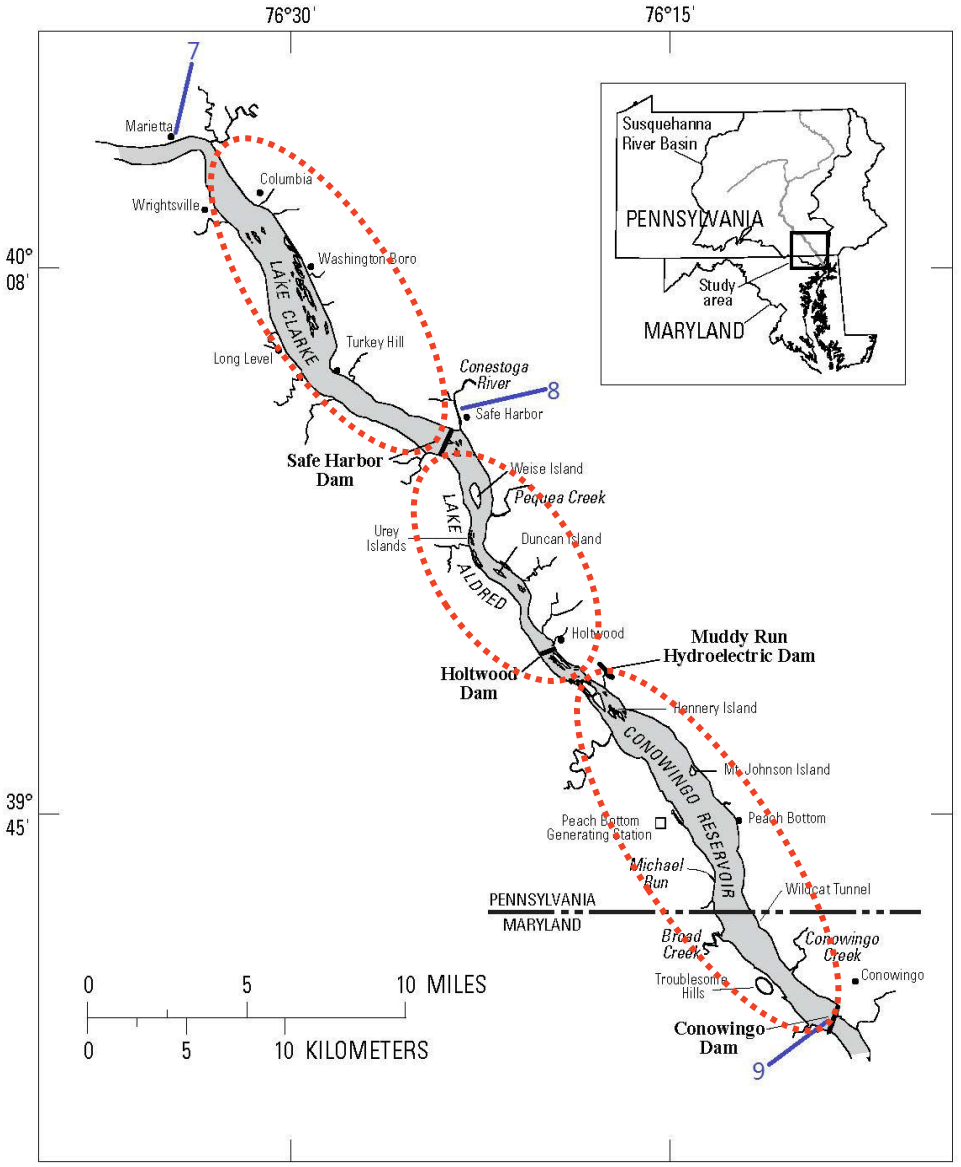
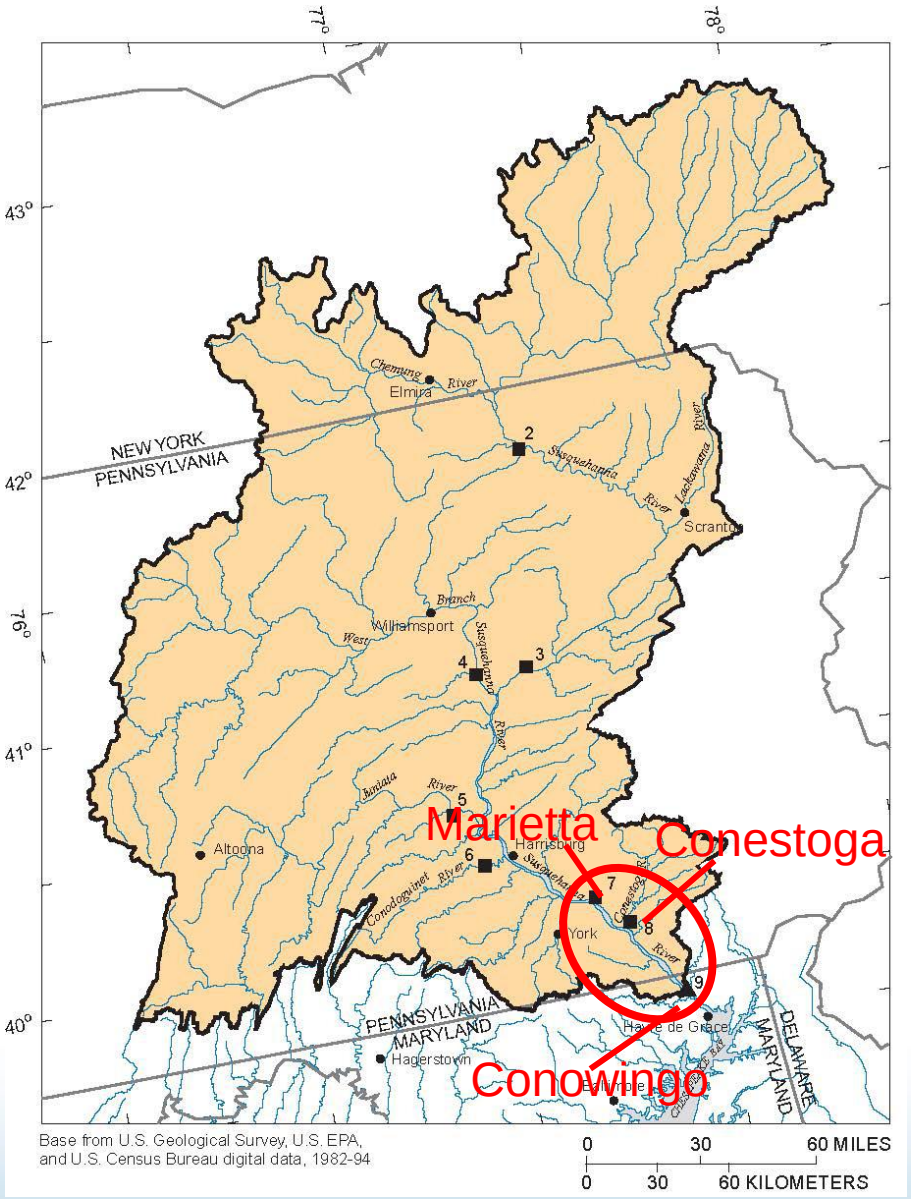


Study Area and Data



- Study sites: 3 stations around the reservoirs;
- Below the reservoir system: 1 USGS station on the river fall-line at **Conowingo** Dam, MD **(~99%** freshwater in SRB);
- Above the reservoir system: 2 SRBC stations at **Marietta** and **Conestoga**, PA **(~97.6%** of watershed monitored by Conowingo);
- Data:
  - Discharge data (**daily**);
  - Concentration data (**semi-monthly**);
    - ✓ N (TN, DN),
    - ✓ P (TP, DP),
    - ✓ SS;
- Method: WRTDS **flow-normalization** method (Hirsch et al. 2010).

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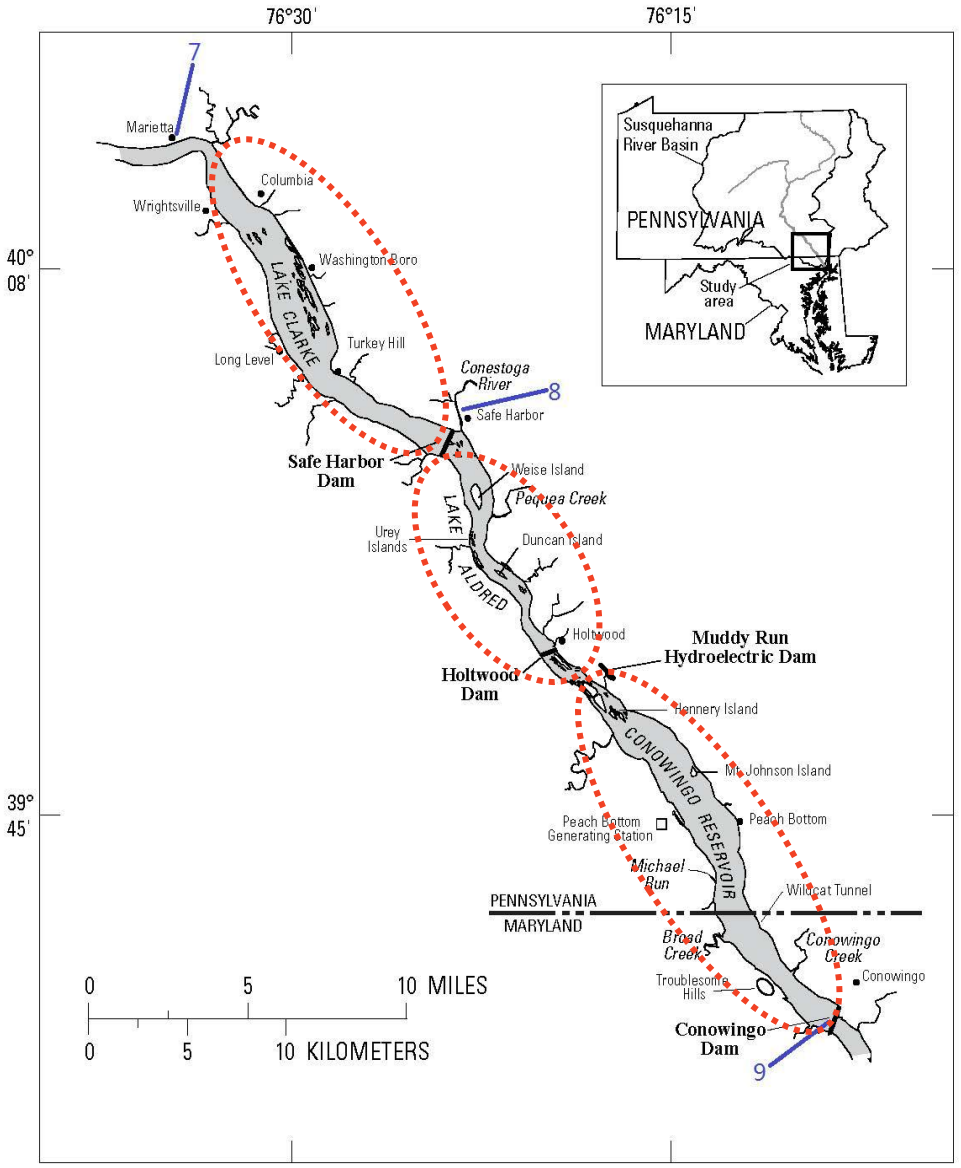
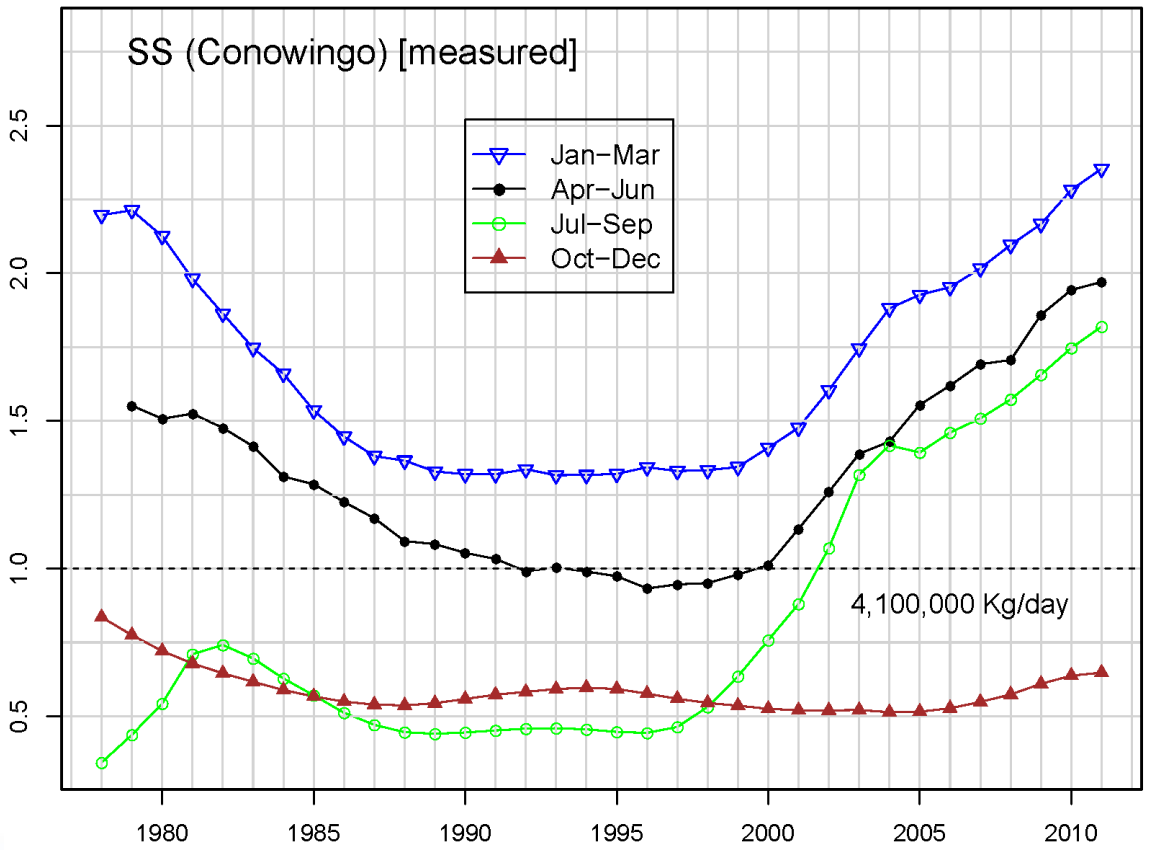


SS load at the reservoir outlet (1978-2011)

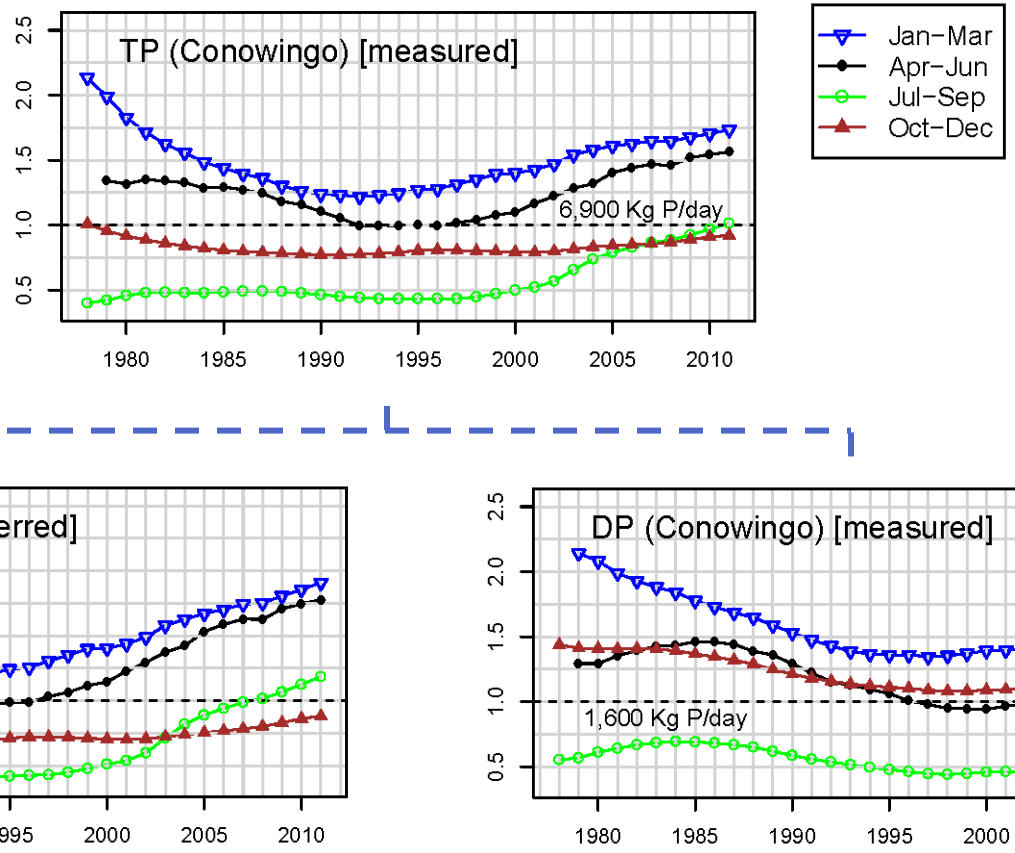
Marietta + Conestoga

Reservoirs

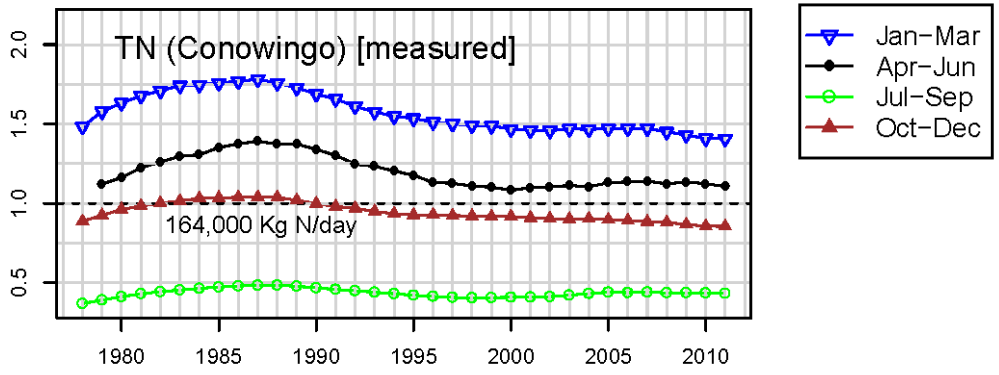
Conowingo?

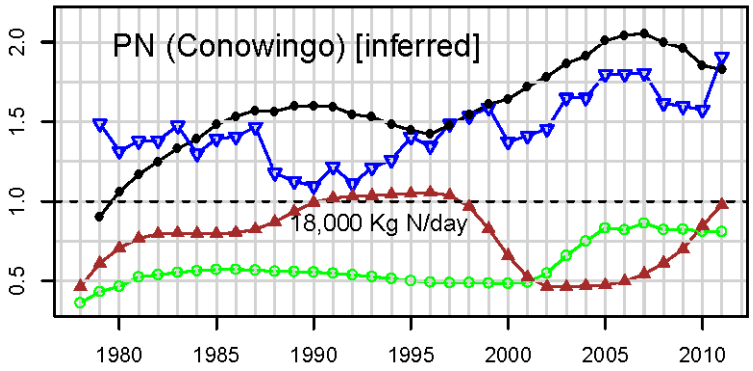


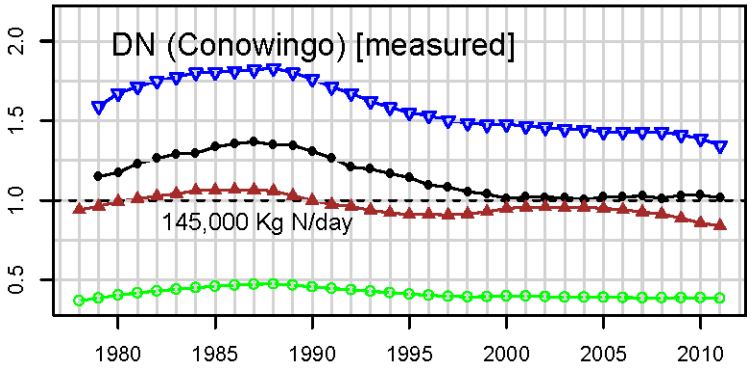
P load at the reservoir outlet (1978-2011)



N load at the reservoir outlet (1978-2011)







N, P, and SS loads at the reservoir outlet

Marietta + Conestoga

↓

Reservoirs

↓

Conowingo?

→

Summary (below-reservoir):

- Downward trends of DP and DN loads;
- Upward trends of SS, PP, and PN loads at Conowingo.

Dissolved vs. Particulate:

- DN&DP reduction: temporary benefits;
- PN&PP increase: potential challenges (decomposition in summer).

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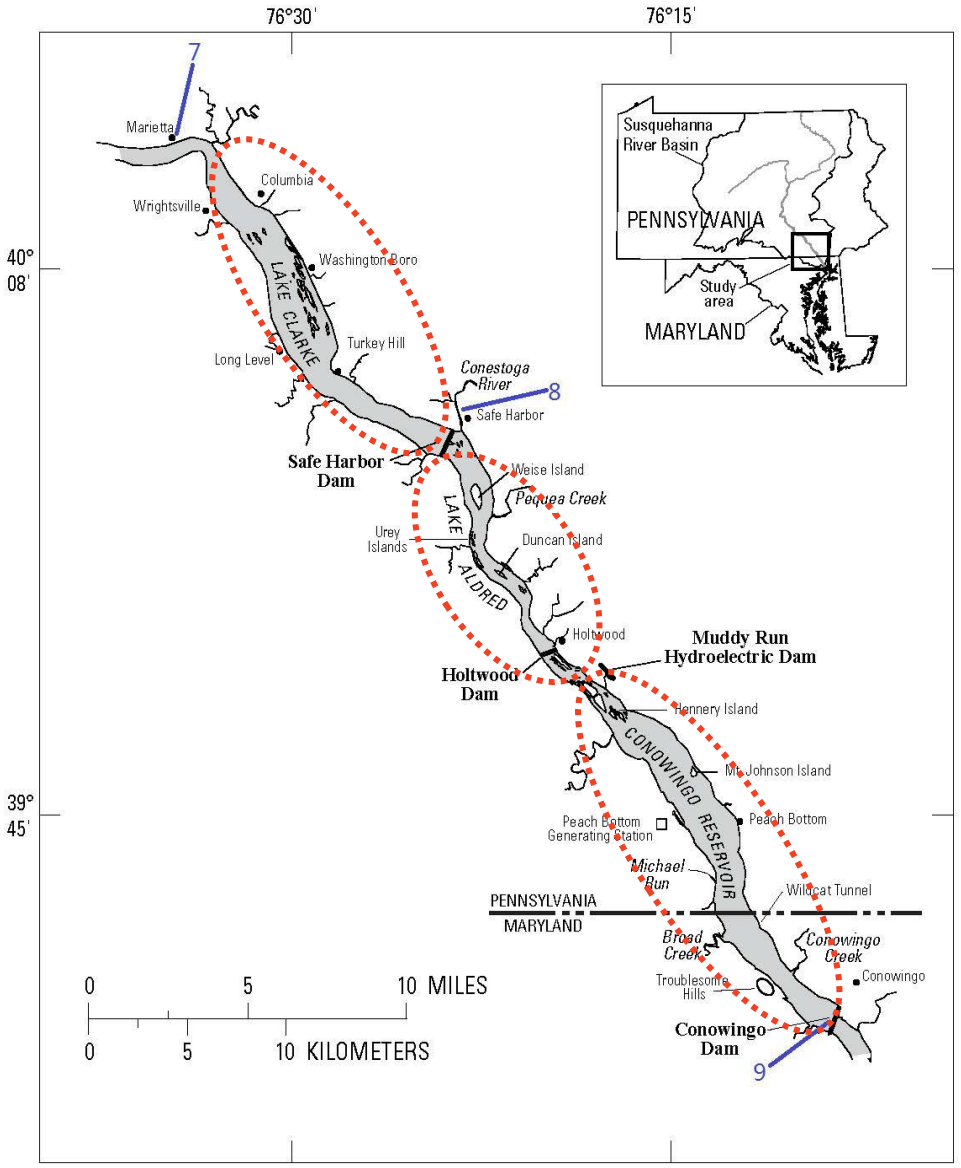
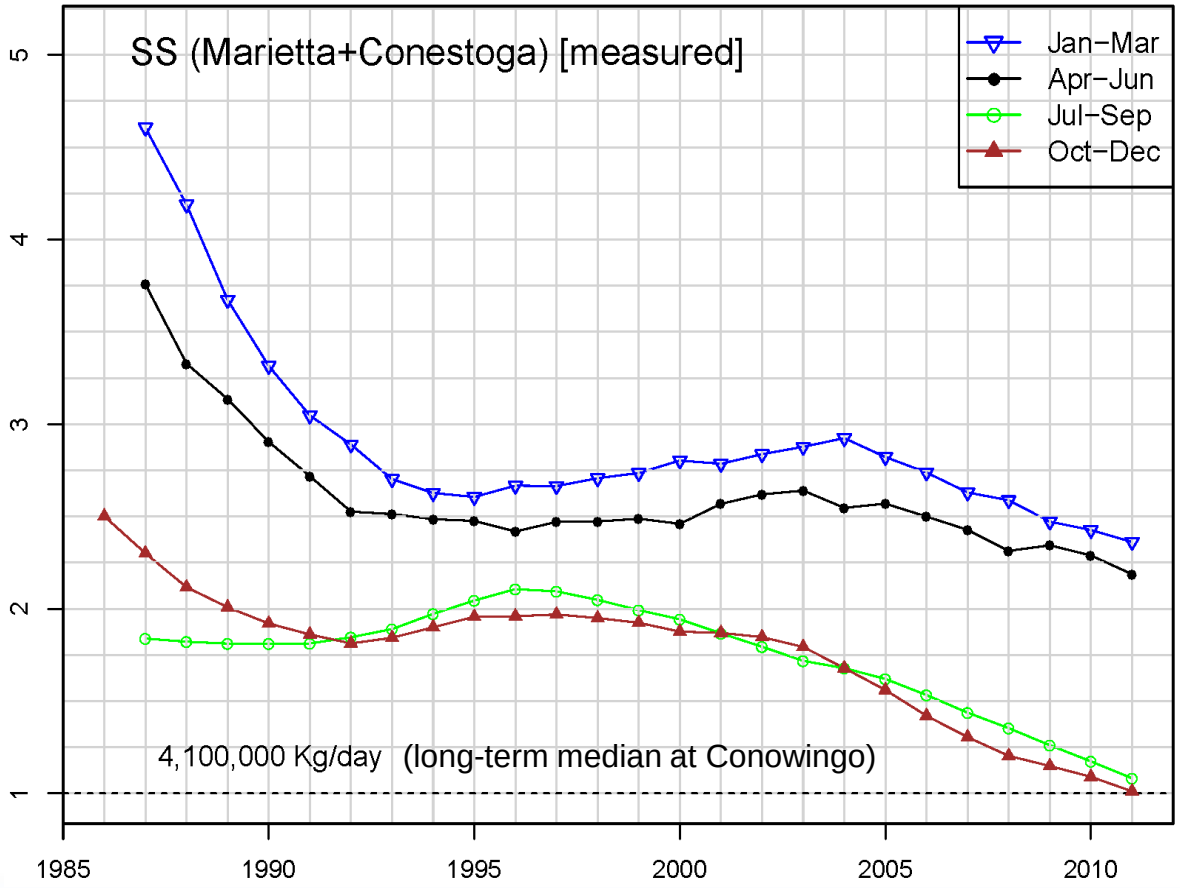


SS load at the reservoir inlets (1986-2011)

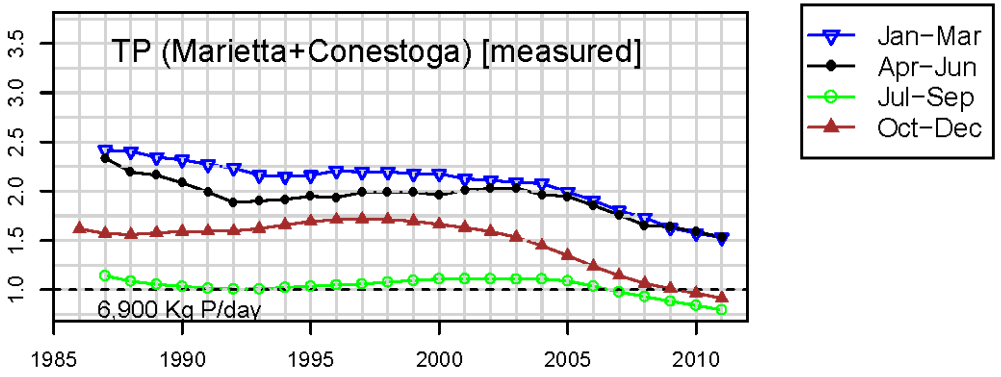
Marietta + Conestoga?

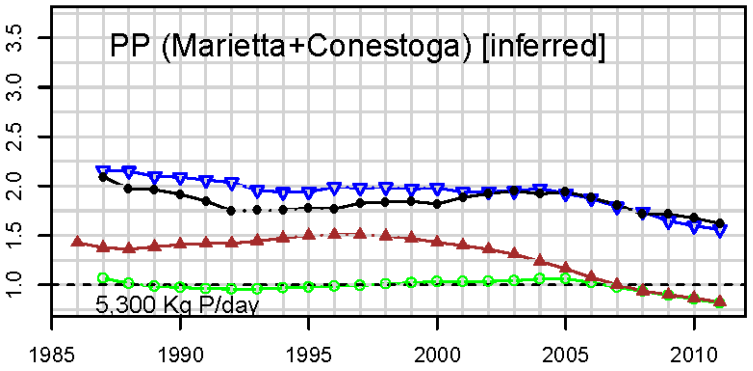
Reservoirs

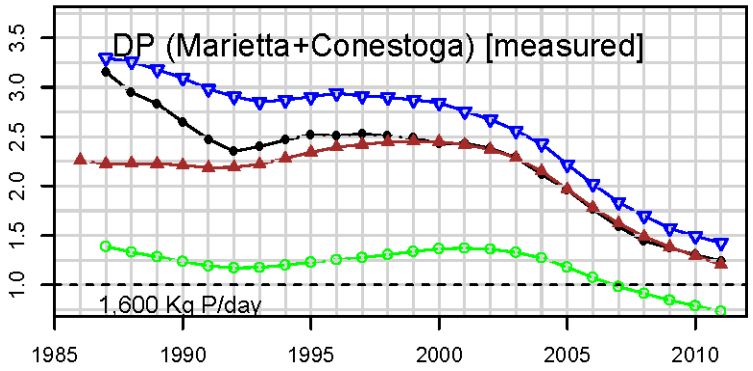
Conowingo



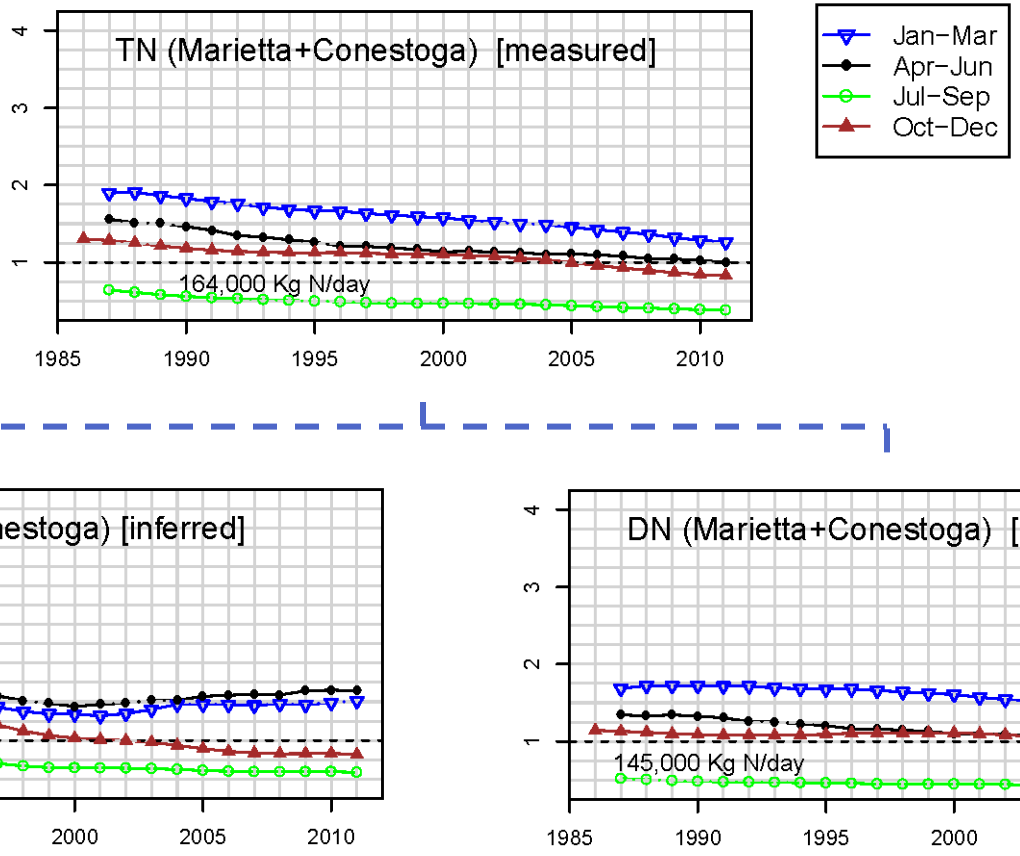
P load at the reservoir inlets (1986-2011)



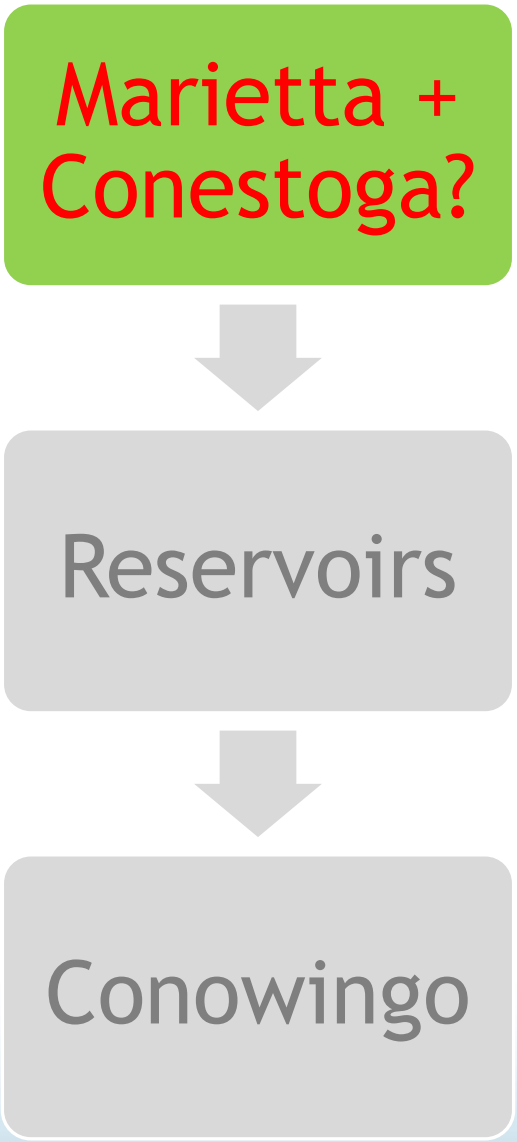




N load at the reservoir inlets (1986-2011)



SS, N, and P loads at the reservoir inlets (1986-2011)



Summary (above-reservoir):

- Downward trends of SS, P (TP, PP, DP), and N (TN, PN, DN) loads from Marietta and Conestoga in all seasons;
- Effective management controls in the non-tidal SRB above the reservoir;
- However, identification of relative contribution of different management actions is unclear.

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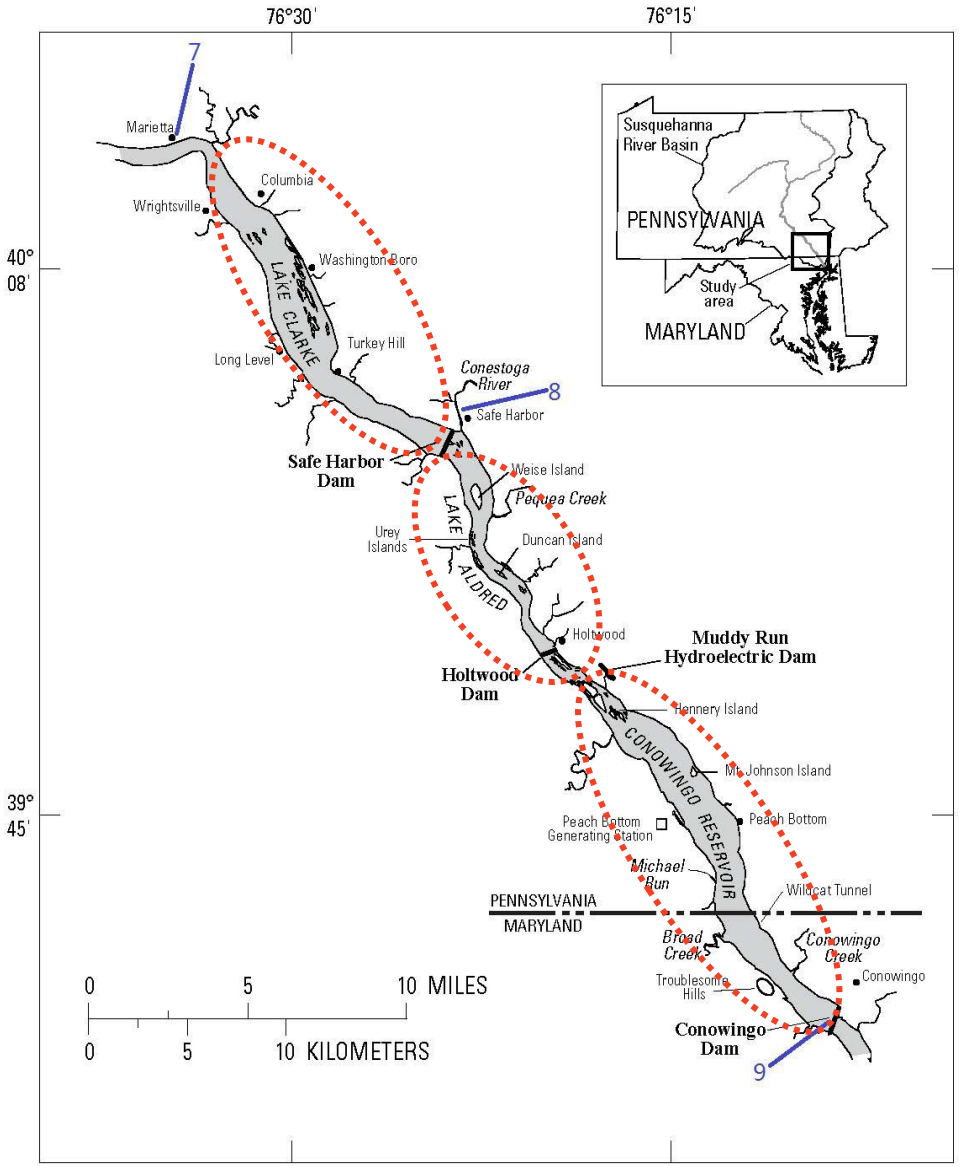
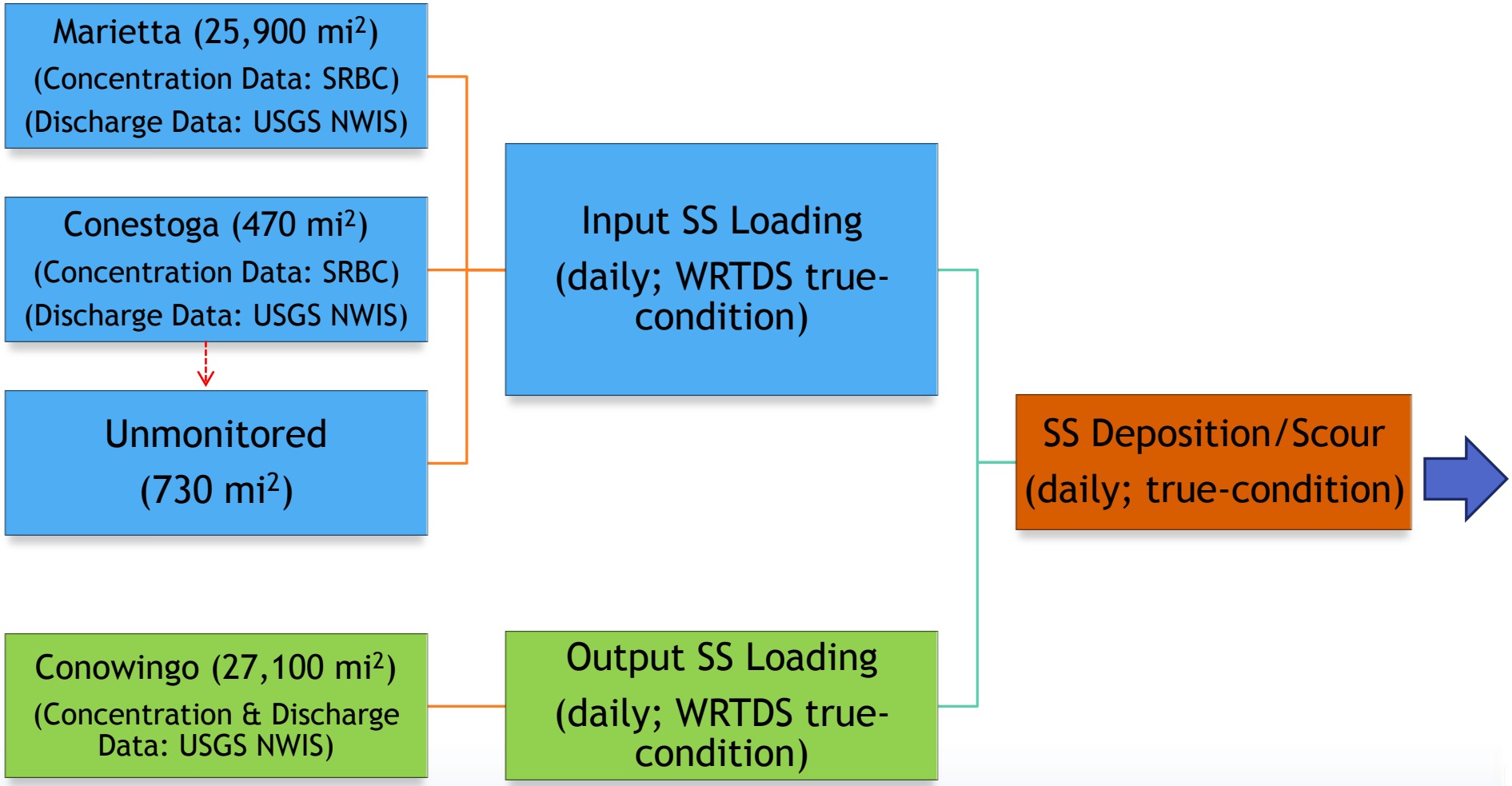
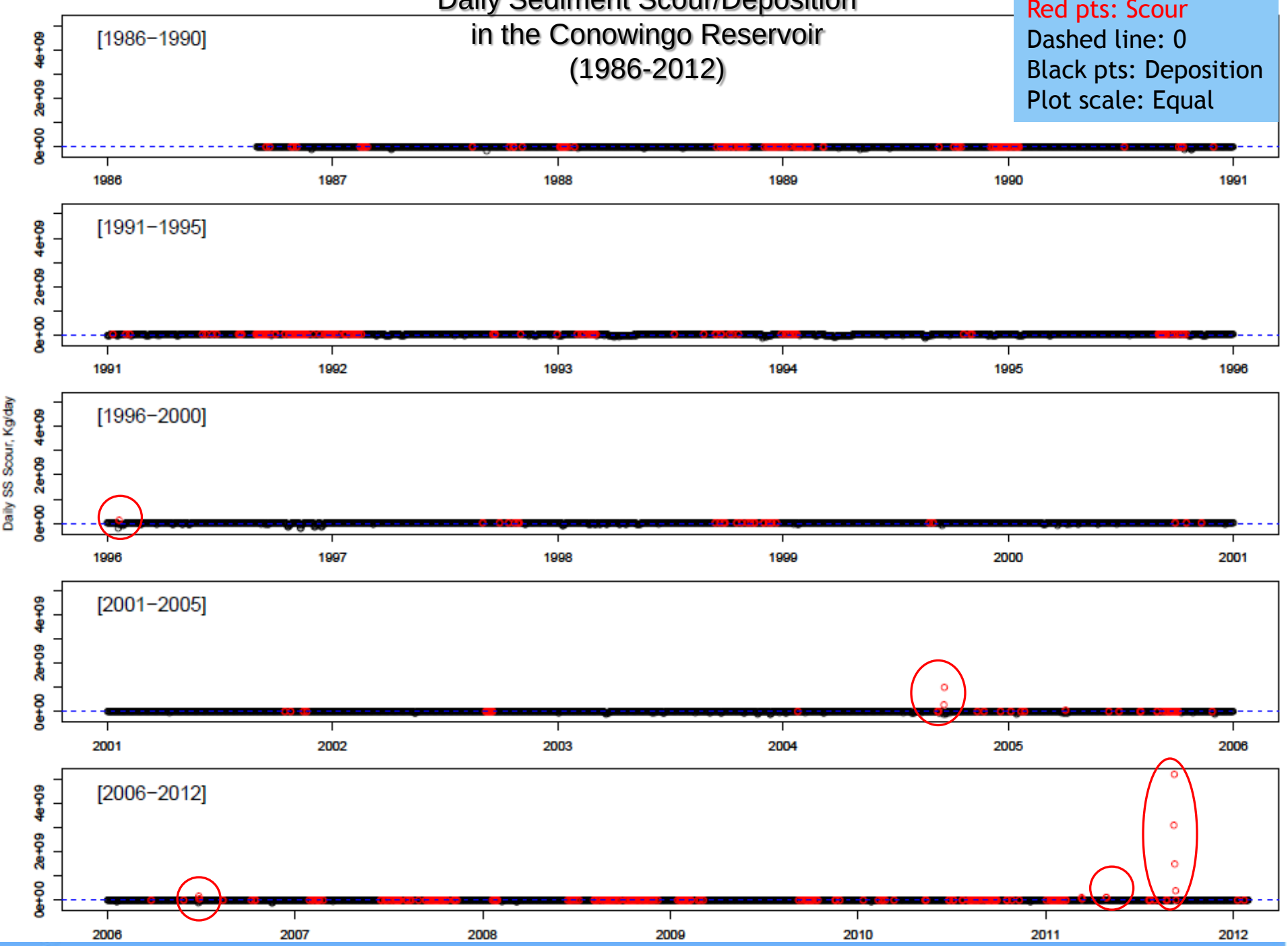


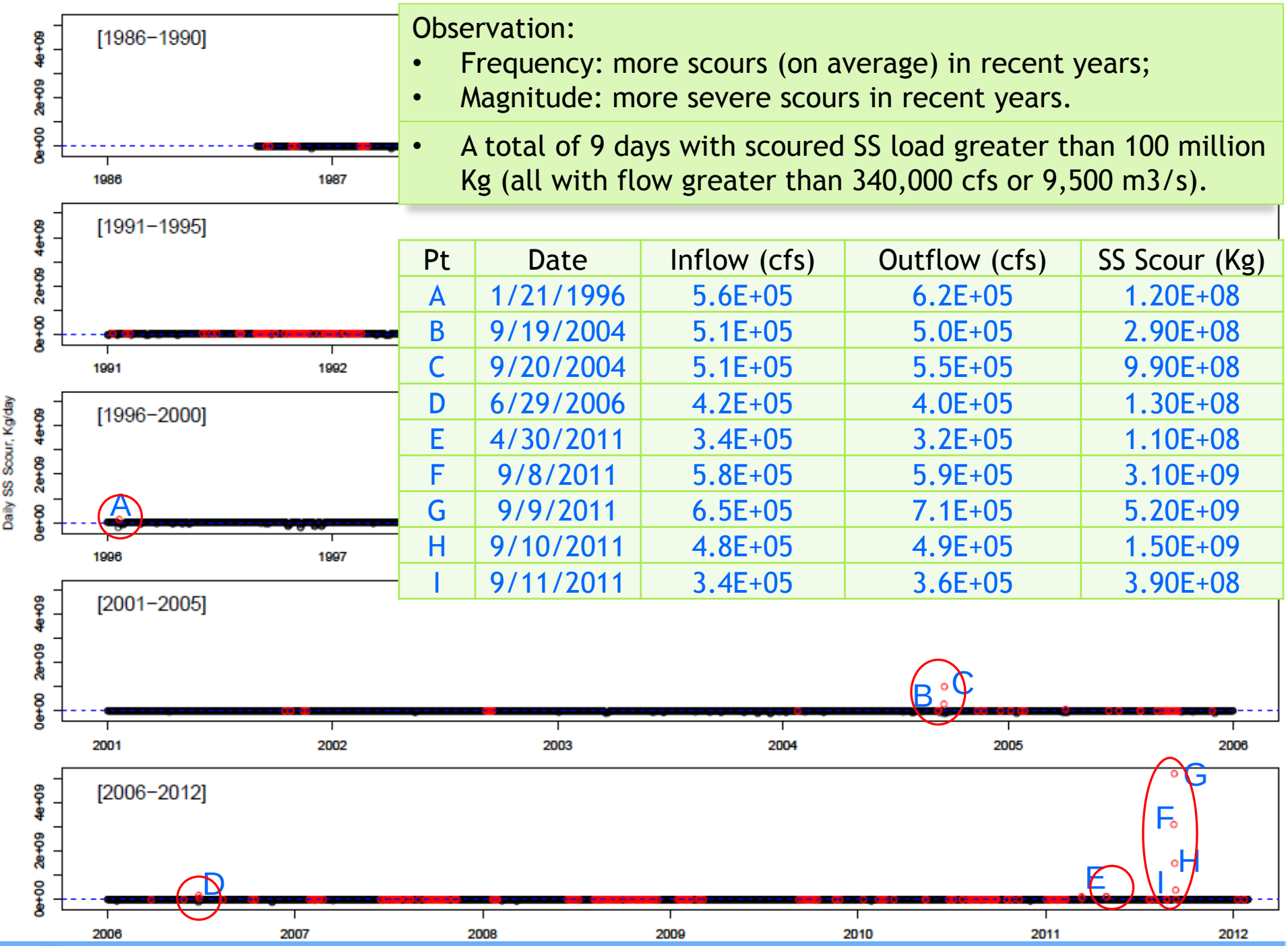
Mass Balance Analysis



Daily Sediment Scour/Deposition in the Conowingo Reservoir (1986-2012)

Red pts: Scour
Dashed line: 0
Black pts: Deposition
Plot scale: Equal





Observation:

- Frequency: more scours (on average) in recent years;
- Magnitude: more severe scours in recent years.

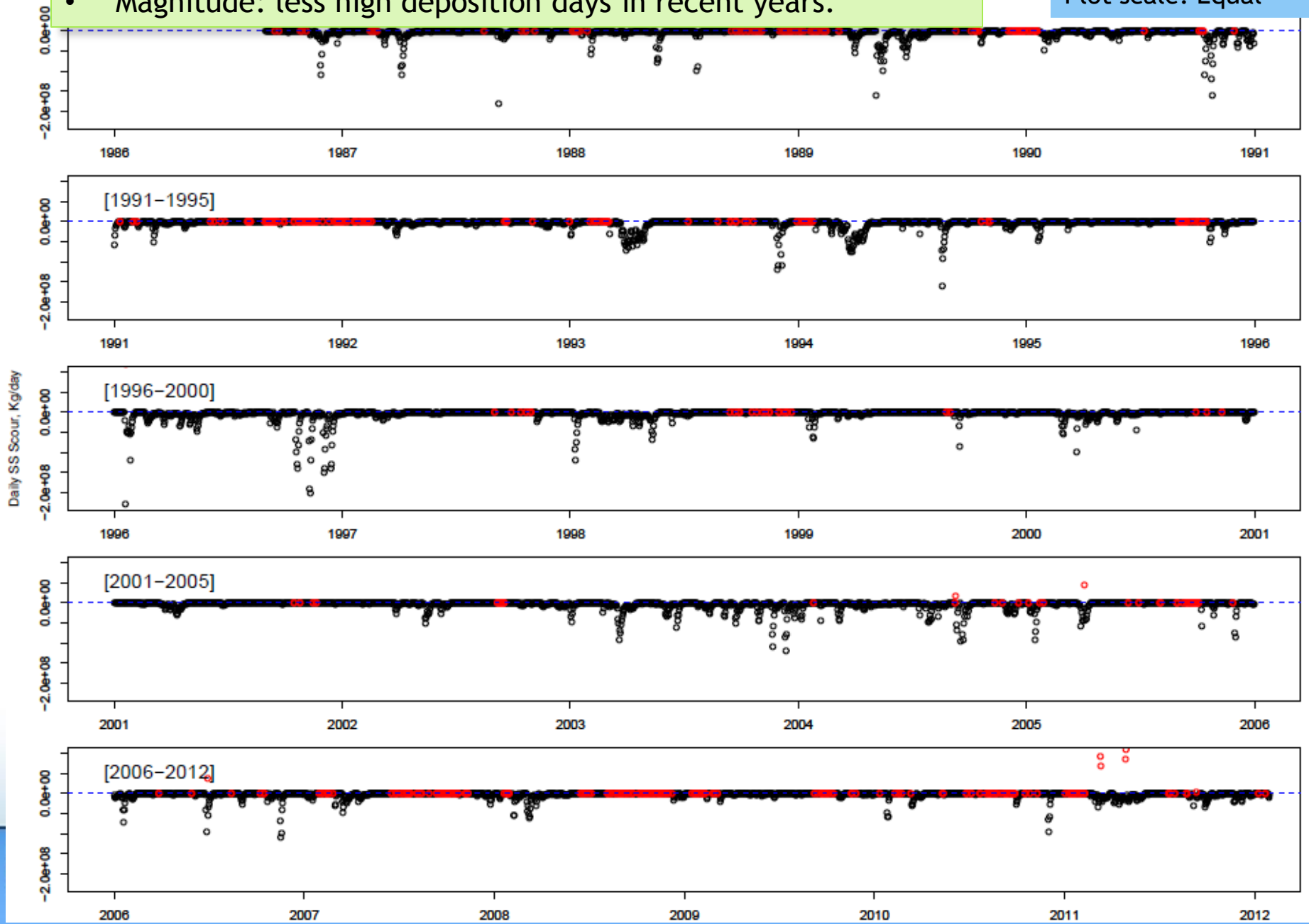
- A total of 9 days with scoured SS load greater than 100 million Kg (all with flow greater than 340,000 cfs or 9,500 m3/s).

Pt	Date	Inflow (cfs)	Outflow (cfs)	SS Scour (Kg)
A	1/21/1996	5.6E+05	6.2E+05	1.20E+08
B	9/19/2004	5.1E+05	5.0E+05	2.90E+08
C	9/20/2004	5.1E+05	5.5E+05	9.90E+08
D	6/29/2006	4.2E+05	4.0E+05	1.30E+08
E	4/30/2011	3.4E+05	3.2E+05	1.10E+08
F	9/8/2011	5.8E+05	5.9E+05	3.10E+09
G	9/9/2011	6.5E+05	7.1E+05	5.20E+09
H	9/10/2011	4.8E+05	4.9E+05	1.50E+09
I	9/11/2011	3.4E+05	3.6E+05	3.90E+08

Observation:

- Frequency: less depositions (on average) in recent years;
- Magnitude: less high deposition days in recent years.

Red pts: Scour
Black pts: Deposition
Plot scale: Equal



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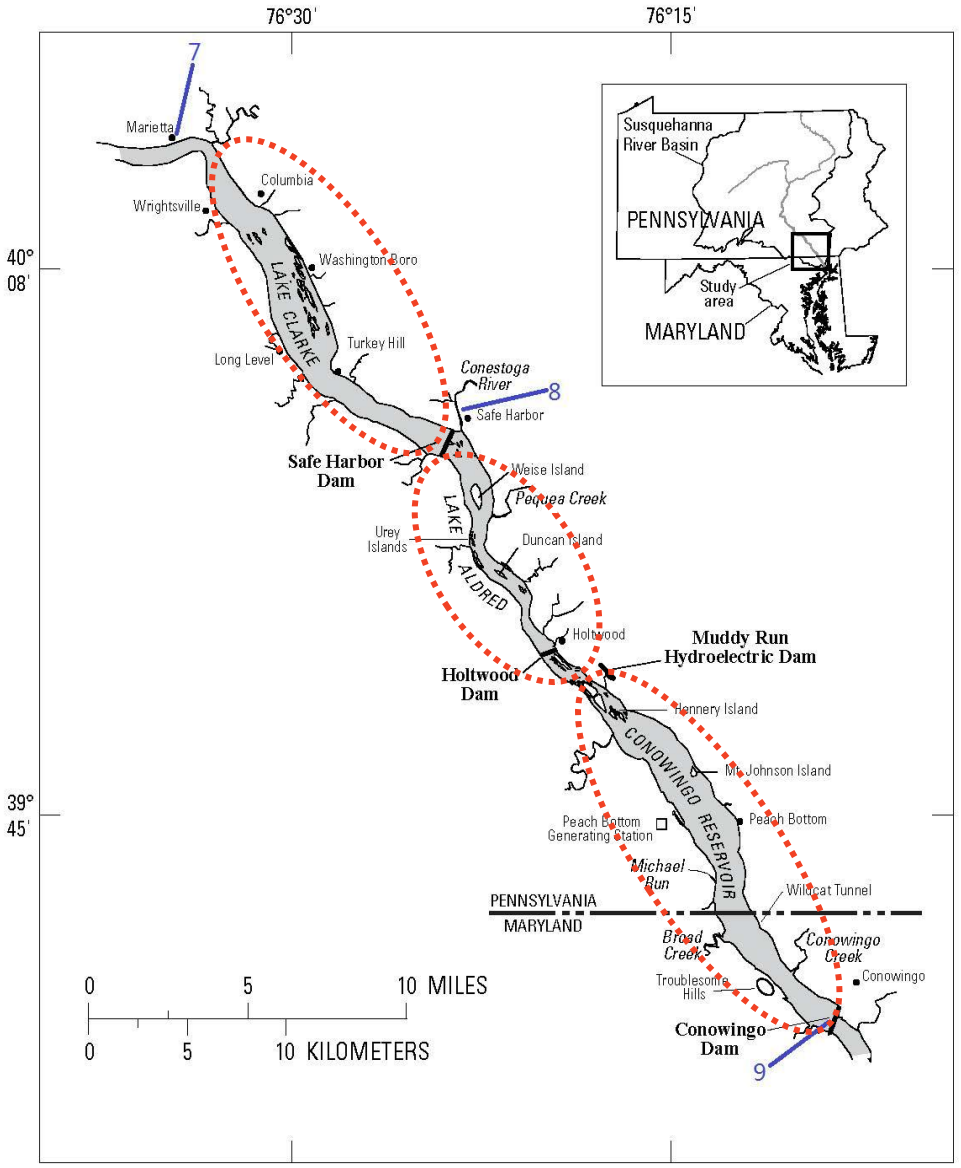
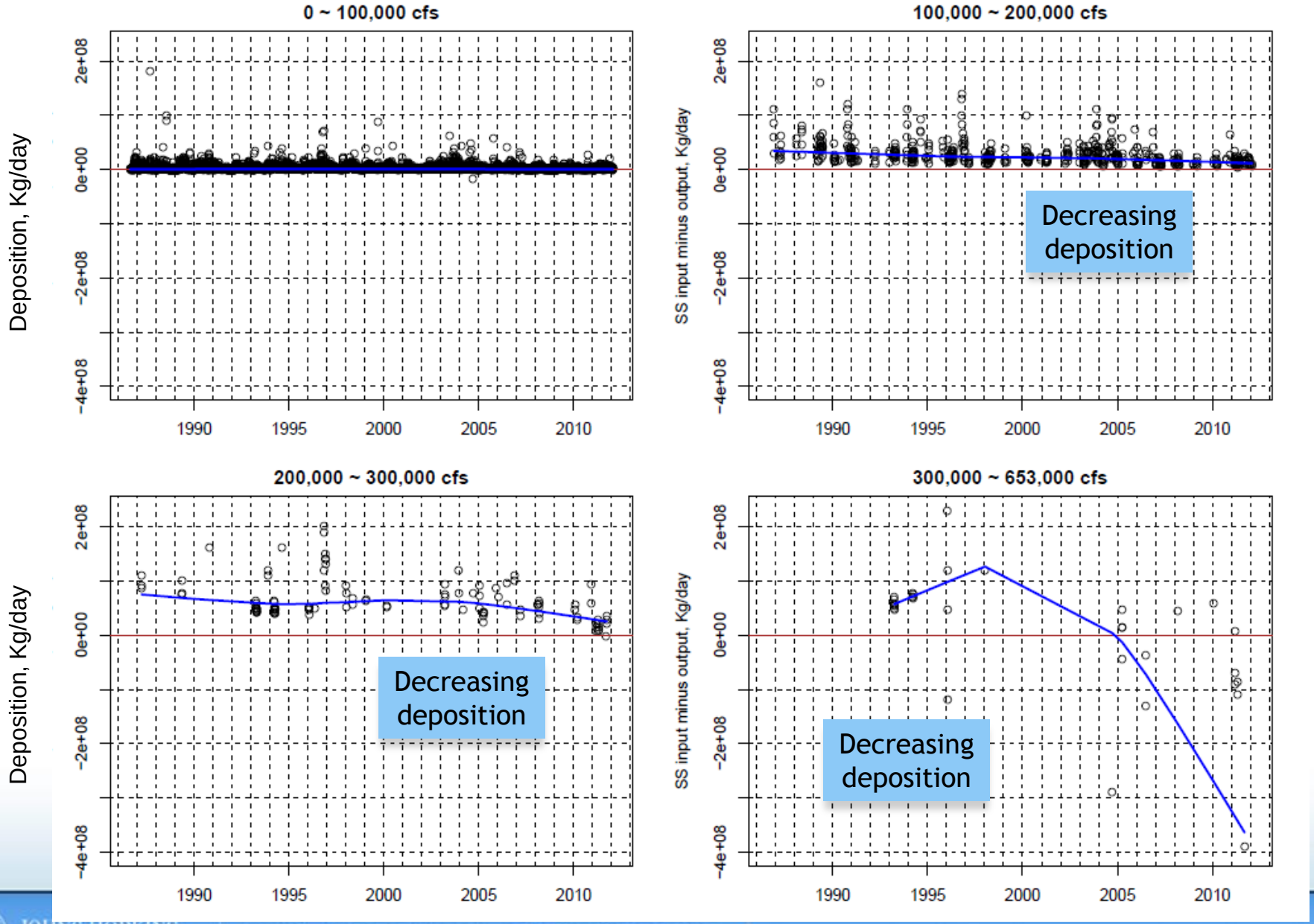


Sediment Deposition by Flow Classes (only deposition days)



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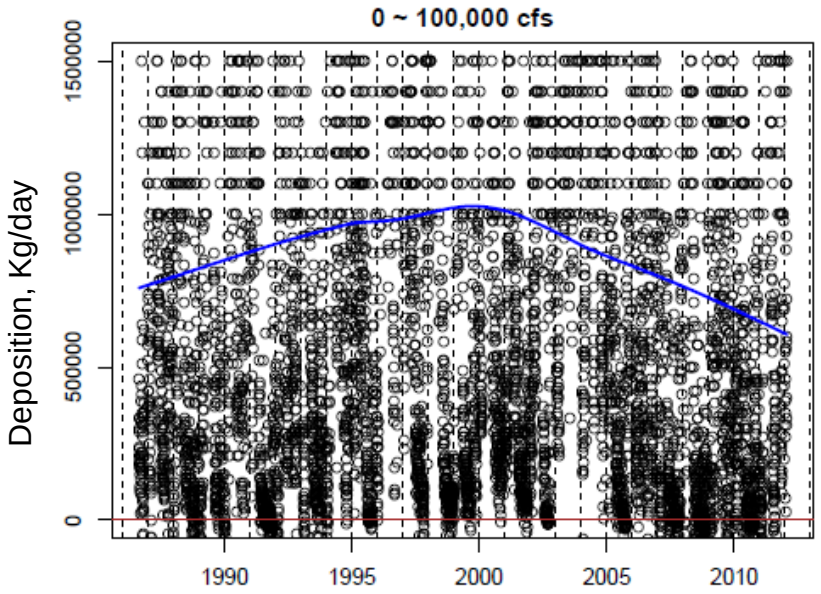
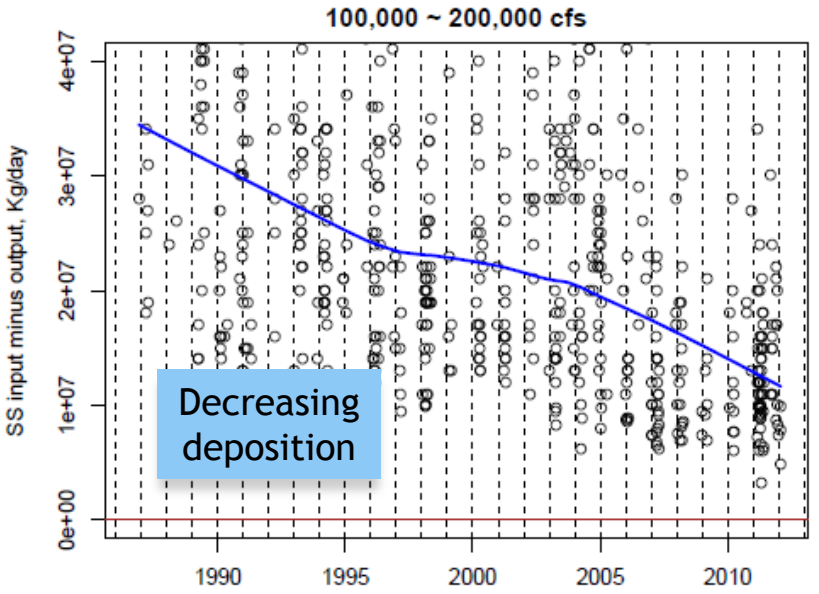
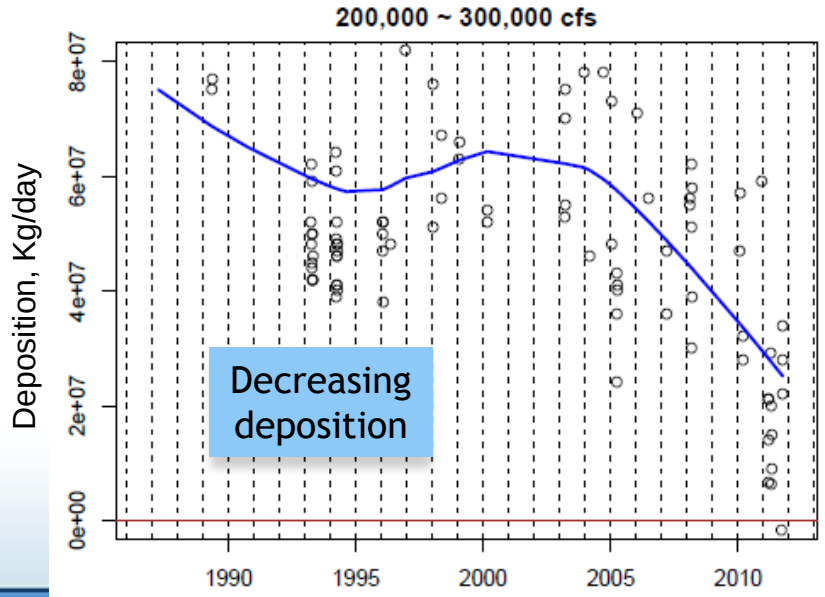
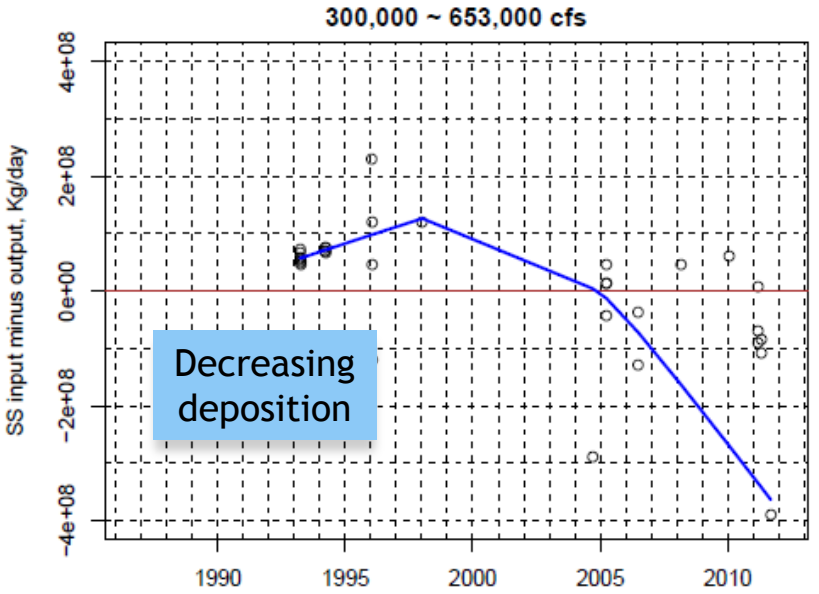
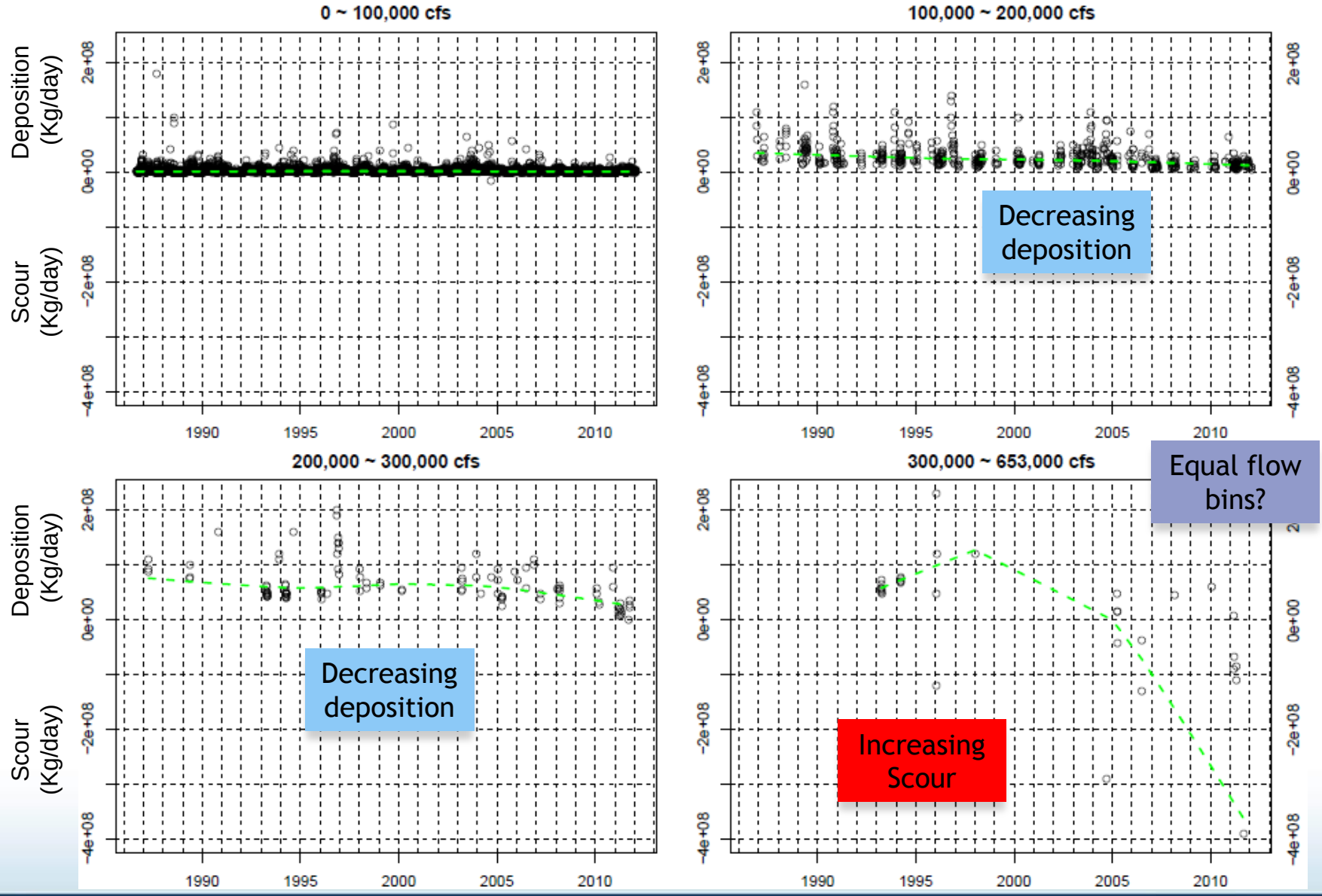




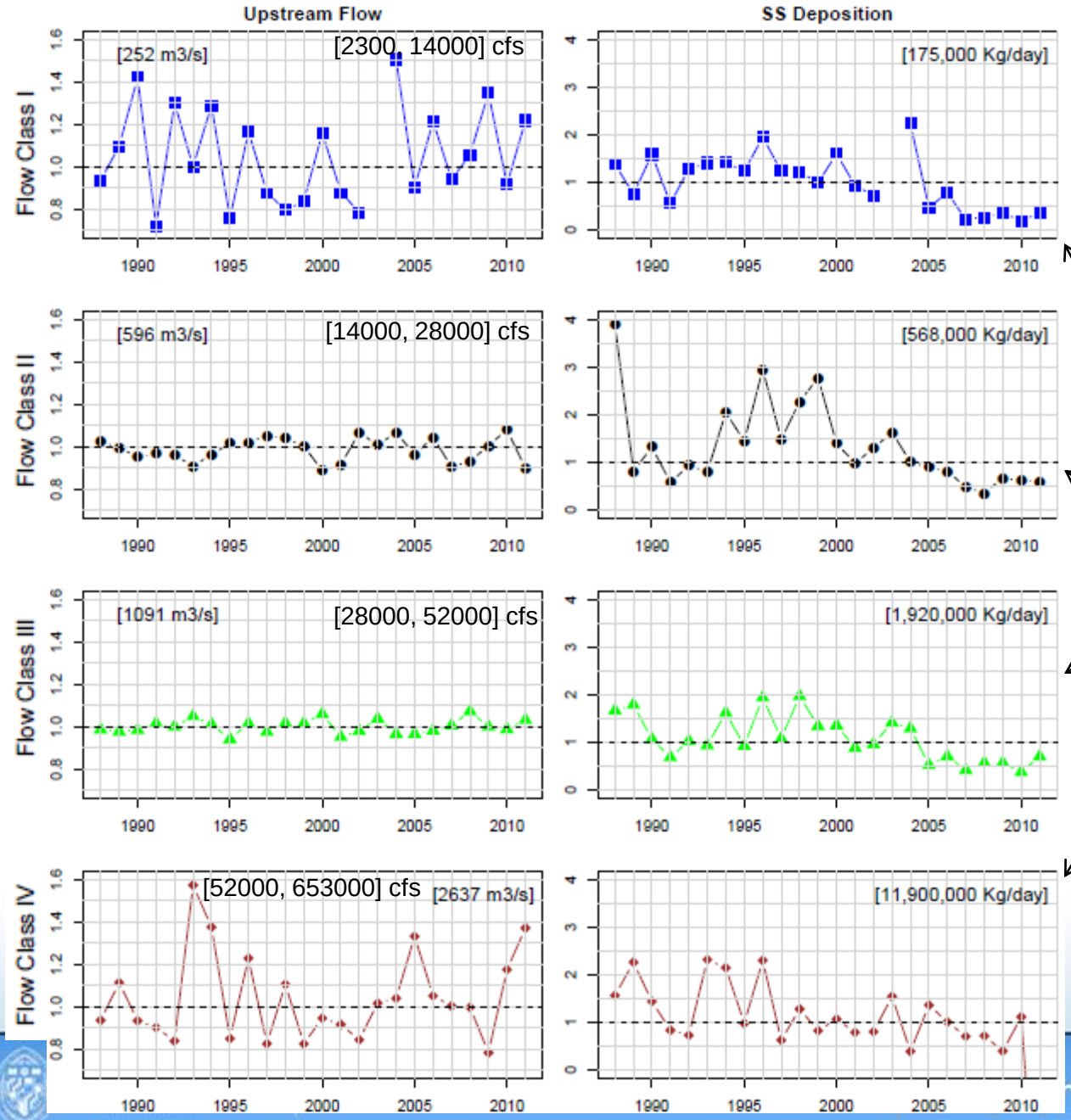




Sediment Deposition by Flow Classes (all days)



SS Deposition by Equal-sized Flow Bins



Less deposition in all flow classes in recent years

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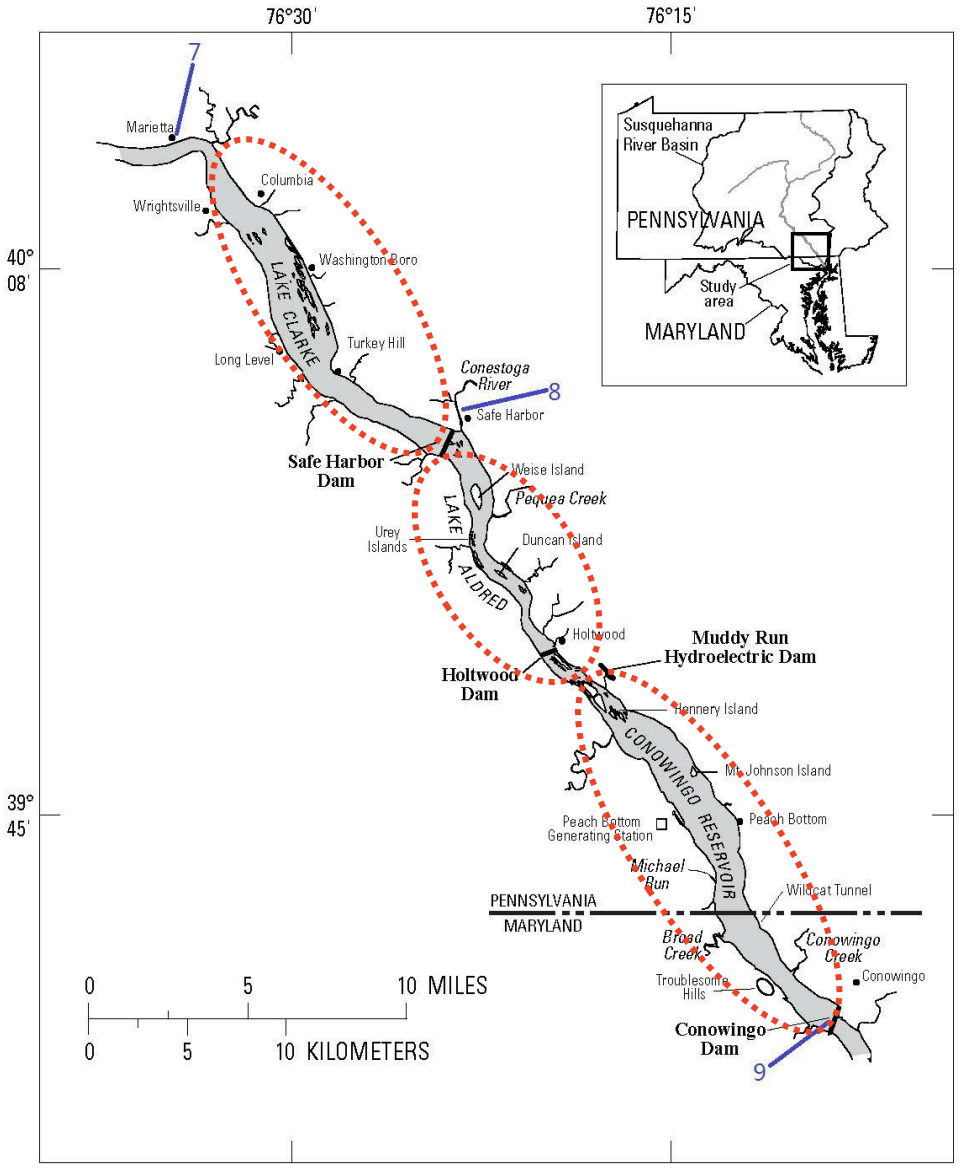
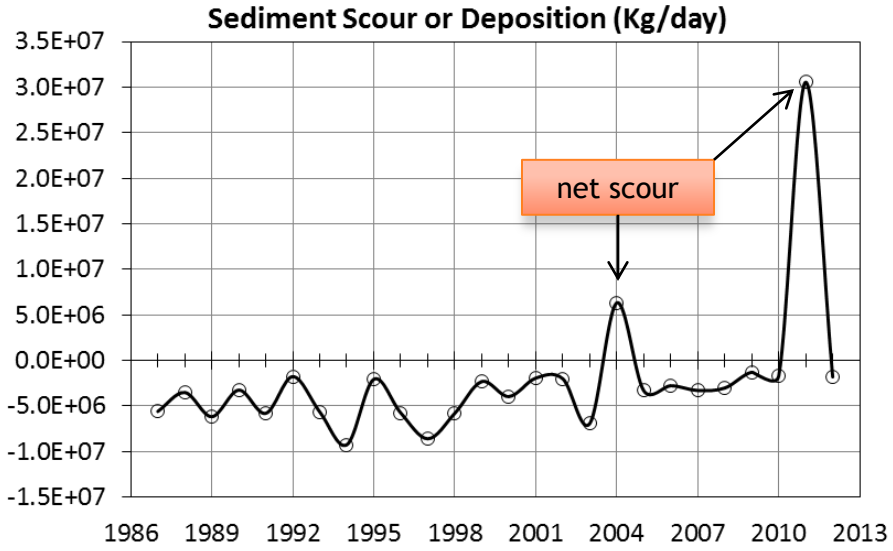
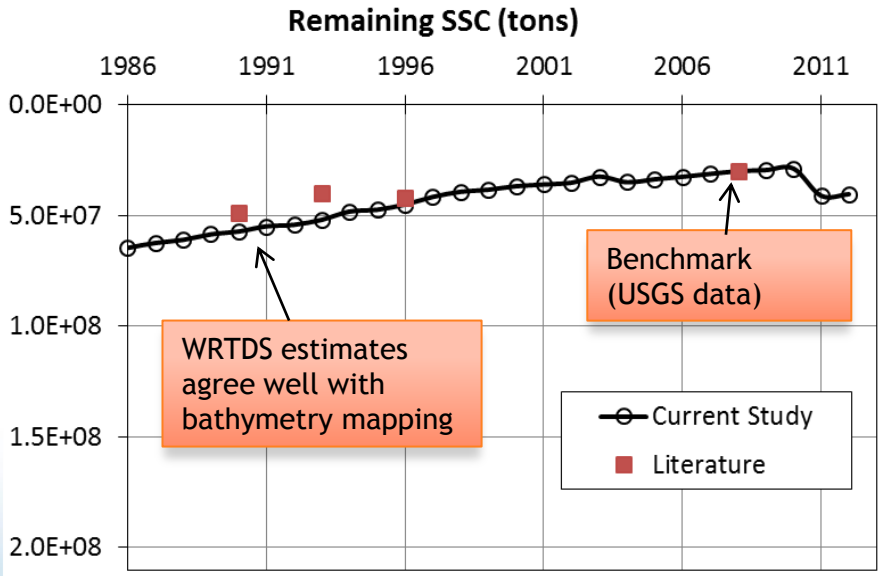
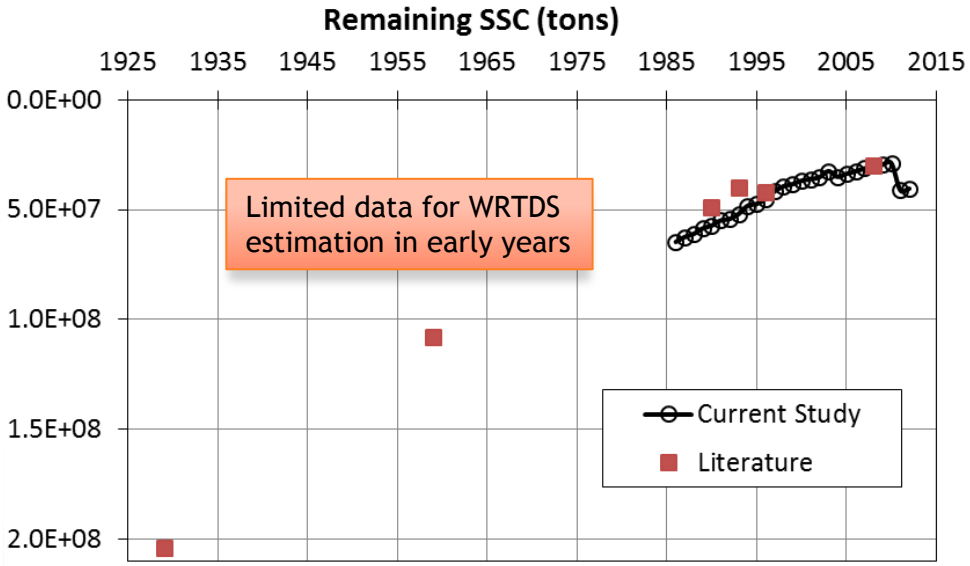


Annual Changes in Storage







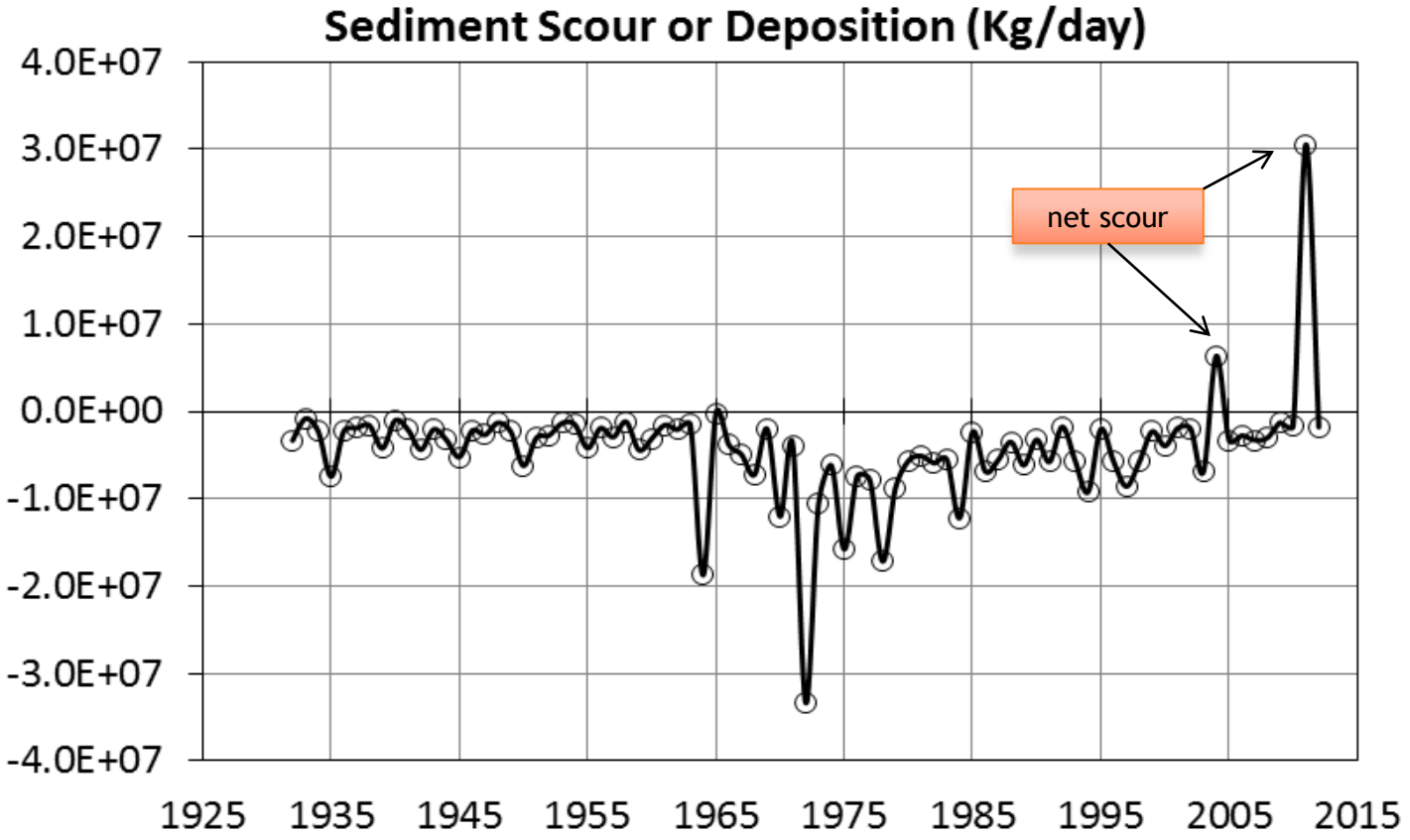
Summary

- Sediment and nutrient loading trends were reconstructed at Marietta, Conestoga, and Conowingo using the WRTDS method.
- Downward trends of SS, P (TP, PP, DP), and N (TN, PN, DN) loads were observed for the Susquehanna watershed above the reservoir system, indicating effective management controls in the watershed.
- Increasing amounts of SS, PP, and PN are entering the Bay as the result of major loss in reservoir performance, which will pose significant challenges to attainment of TMDL goals for the SRB.
- Scour events have become more frequent, and the extreme scours have become more severe in recent years.
- As the reservoir fills up, deposition has been generally decreasing during not only the highflow events, but also the moderate-flow events.
- WRTDS-derived deposition trajectory seems to match with Conowingo bathymetry results reasonably well (1987-2012).

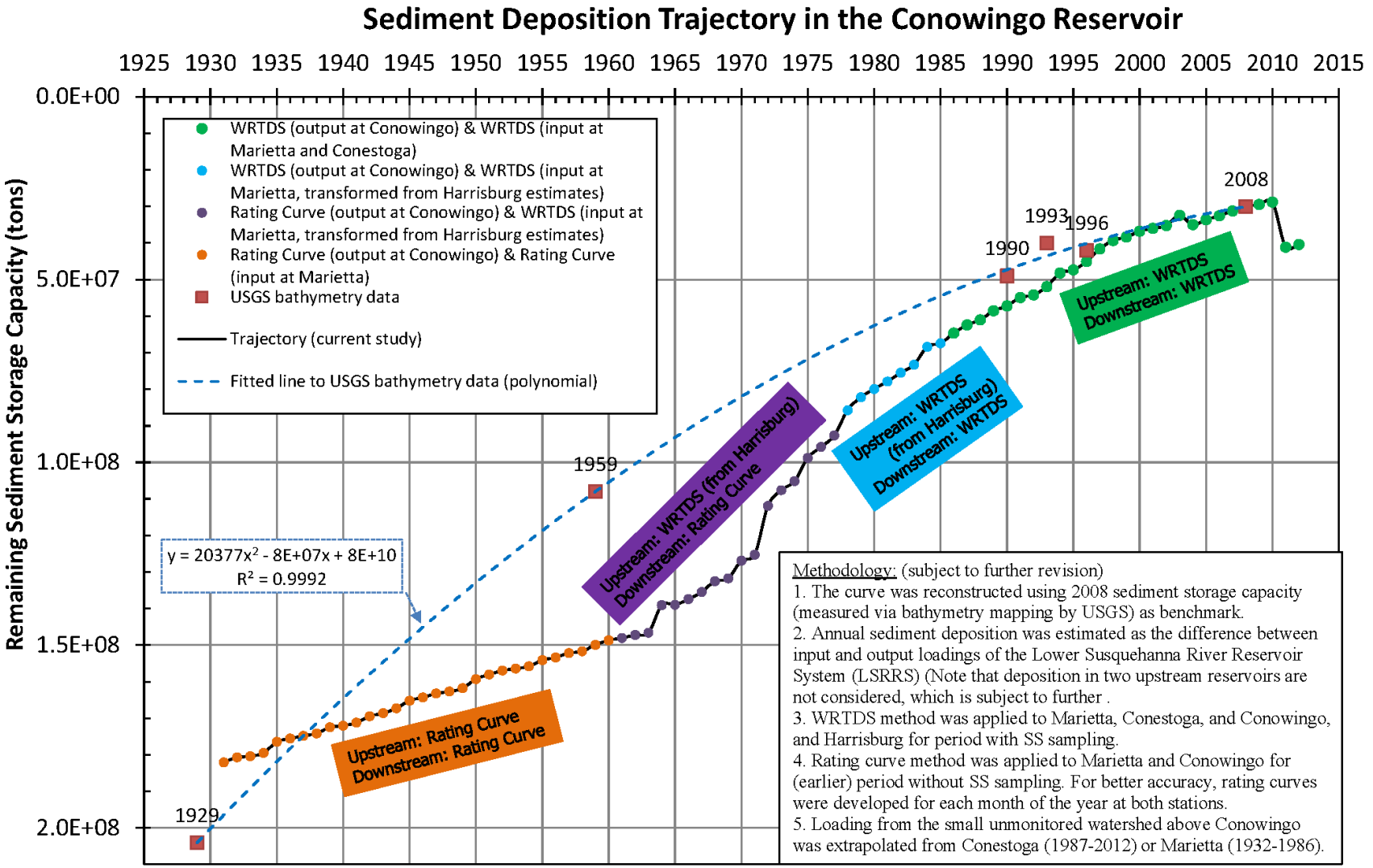
Acknowledgement

- Bob Hirsch (USGS)
- Damian Brady (U. Maine)
- Kevin McGonigal (SRBC)
- U.S. Water Environment Research Federation
- U.S. National Science Foundation
- Maryland Sea Grant

Annual Changes in Storage (preliminary)



Conowingo Sediment Storage since 1929 (preliminary)



Method: WRTDS*

Output A: "true-condition" daily concentration and load

- using daily streamflow data and roughly semi-monthly concentration data, the method generates complete time series of *daily* loading and concentration estimates;
- weighted regression was implemented using selected samples that are proximate to the estimation day to make estimation;
- helpful to understand the impact of nutrient and sediment on the Bay ecosystem.

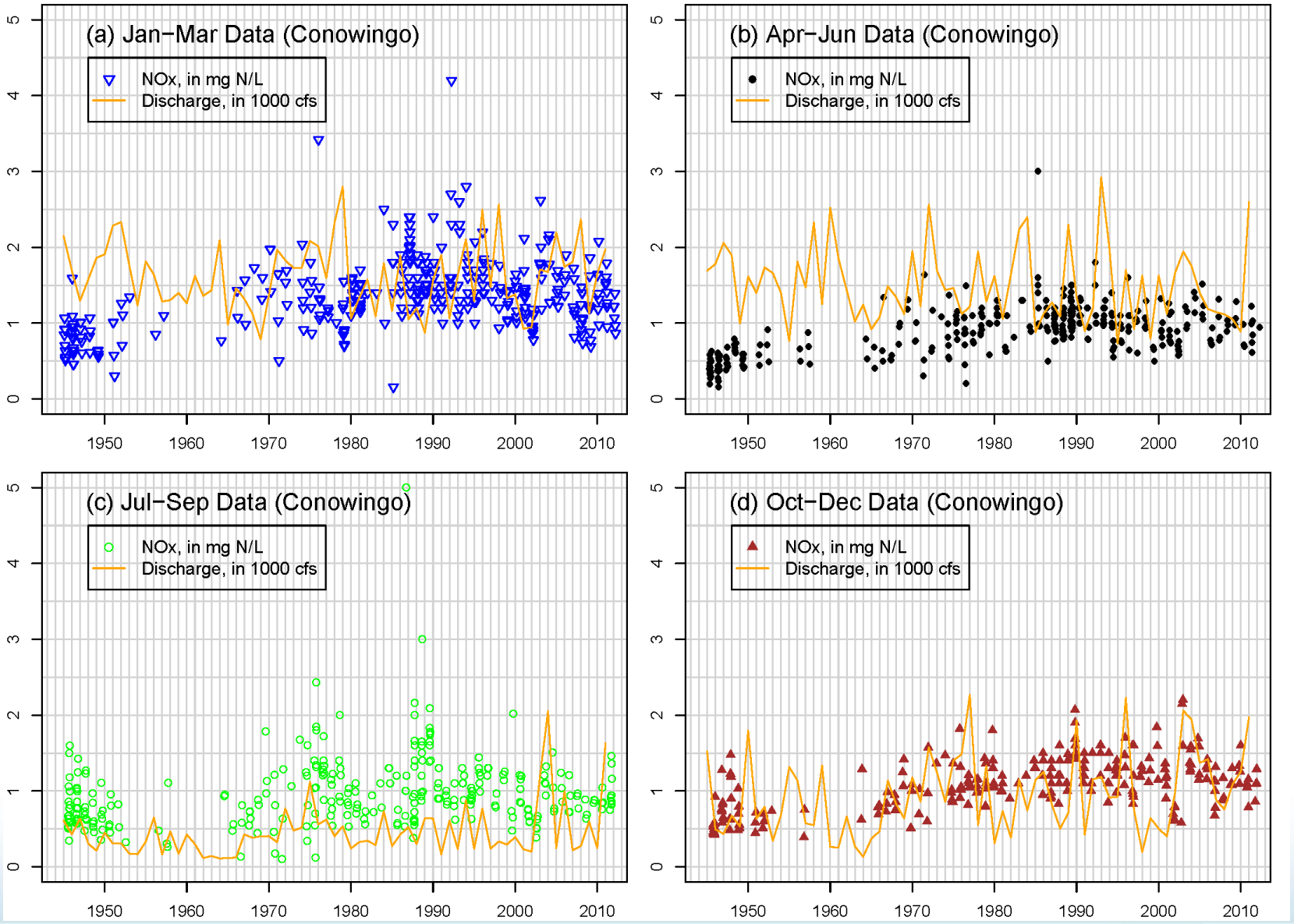
Output B: "flow-normalized" daily concentration and load

- the method generates complete times series of *daily* loading and concentration estimates;
- link the estimation to full hydrological cycle associated with the estimation day;
- helpful to assess progress of management actions by largely removing impacts induced by variability in streamflow.

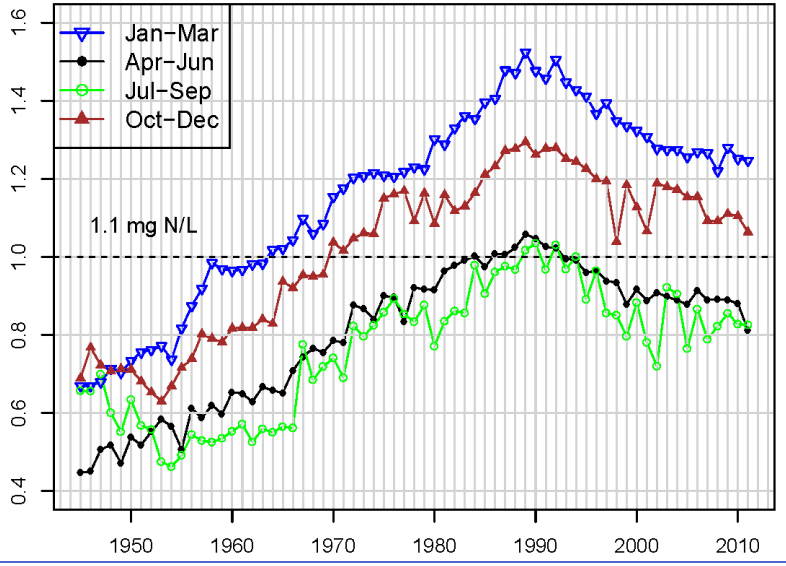
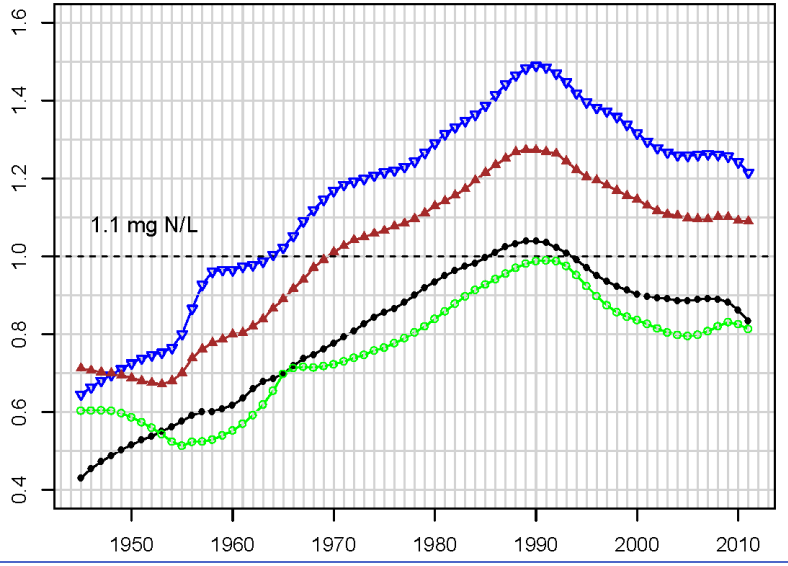
Daily estimates → monthly average, seasonal average, annual average, etc

* WRTDS = weighted regressions on time, discharge, and season (Hirsch et al. 2010)

Example: NO_x observational data at Conowingo (1945-2011)



Example: NO_x seasonal estimates at Conowingo (1945-2011)

Seasonal Ave.	True-condition	Flow-normalized
Concentration		
Load