Lower Susquehanna River Watershed Assessment

“Sediment Behind the Dams”

Parallel Studies

- Baltimore District USACE
  - 2008 – 2011 application period.
  - ADH hydrodynamic and sediment transport model for Conowingo Reservoir and Susquehanna Flats
  - HEC-RAS hydrodynamic and sediment transport model for Lakes Clarke and Aldred.
  - CBEMP for Chesapeake Bay.

Parallel Studies

- Objectives
  - Evaluate strategies that will maintain or decrease sediment and associated nutrient delivery to Chesapeake Bay.
  - Prioritize strategies that will reduce the volume of sediment and associated nutrients available for transport during high-flow storm events.
  - Determine the impacts of the loss of sediment and nutrient storage capacity behind Conowingo Dam to the Chesapeake Bay.

Parallel Studies

- USEPA Chesapeake Bay Program
  - 1991 – 2000 application period.
  - HSPF model for Conowingo Reservoir.
  - CBP Watershed Model for remainder of watershed.
  - CBEMP for Chesapeake Bay.
  - Objective
    - Assess impact of reservoir filling and scouring on Chesapeake Bay following implementation of TMDL's.

CBP Three-Step Program

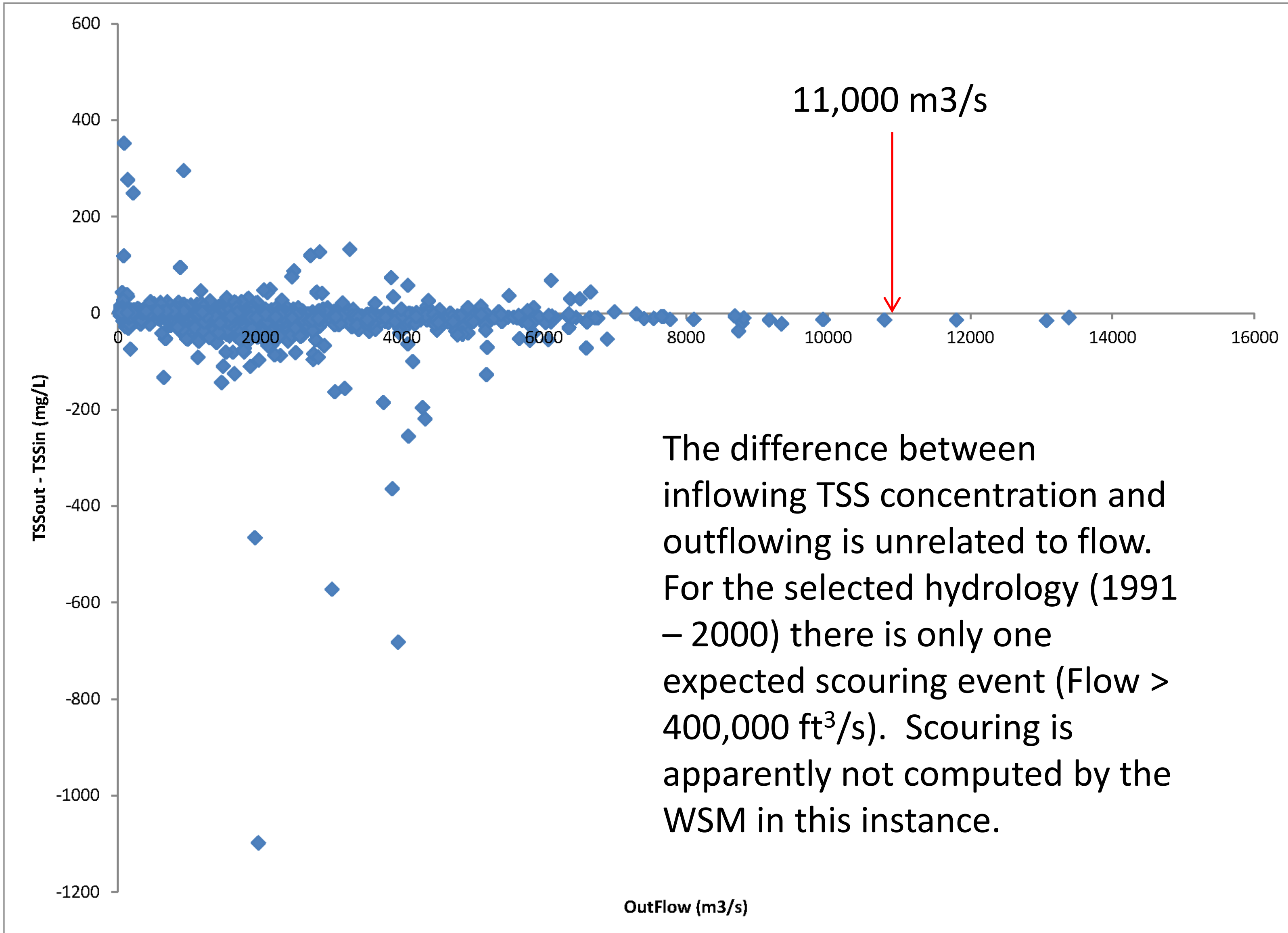
- Step 1 – Eliminate Conowingo Reservoir
  - The reservoir is full, residence time is short, settling is negligible.
  - Simulates a period with no erosion.
  - Simulations for 2010 Progress Run (existing conditions) and TMDL (future conditions).

CBP Three-Step Program

- Step 2 – Scour in Conowingo Reservoir
  - Try to match two reported outcomes.
    - 0% N, 50% P, 100% TSS increase in annual loads (Hirsch estimate of change from 1996 – 2001).
    - 0% N, 70% P, 250% TSS increase in annual loads (Hirsch citation of Langland and Hainly 1997 report).
  - Erosion implemented in Conowingo section of CBP Watershed Model.
  - Settling remains implemented between scour events.
  - Simulations for 2010 Progress Run (existing conditions) and TMDL (future conditions).

CBP Three-Step Program

- Step 3 – Evaluate Impact of Major Events
  - Move the January 1996 "Big Melt" to spring/summer.
  - Requires new CH3D hydrodynamic runs based on new storm periods.
    - 1996 without flood.
    - 1996 with flood in January.
    - 1996 with flood in June.
  - Six runs planned. TMDL loads with and without reservoir filled for the three hydrodynamic conditions. We need to review what we mean by "reservoir filled." 100% TSS increase or 250% TSS increase?



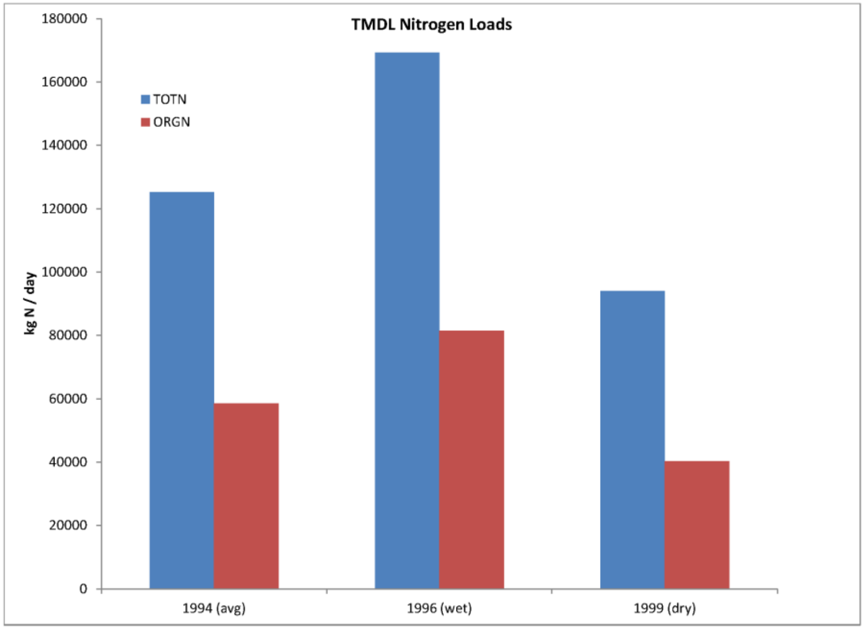
The difference between inflowing TSS concentration and outflowing is unrelated to flow. For the selected hydrology (1991 – 2000) there is only one expected scouring event (Flow > 400,000 ft^3/s). Scouring is apparently not computed by the WSM in this instance.

Step 1 - Basis for Scenarios

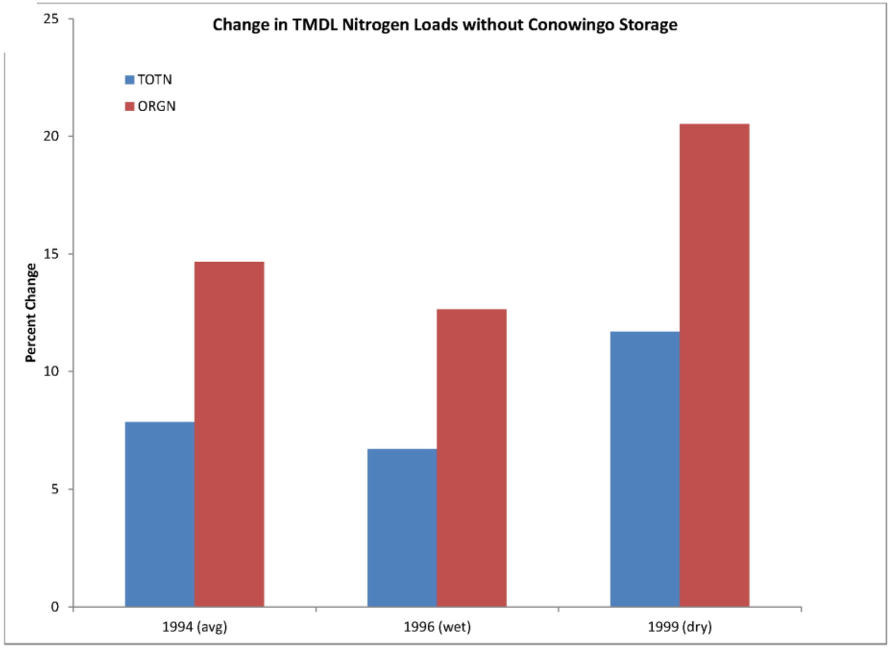
- No scouring occurs in the model. Limited scouring during the application period is expected in any event.
- The reservoir acts as a sink for solids (and nutrients in solid form).
- Our first approach to examining the effect of Conowingo infill is to eliminate it from the WSM system.
- The WQM receives loads directly from the Susquehanna River plus local loads to the Conowingo Reservoir.

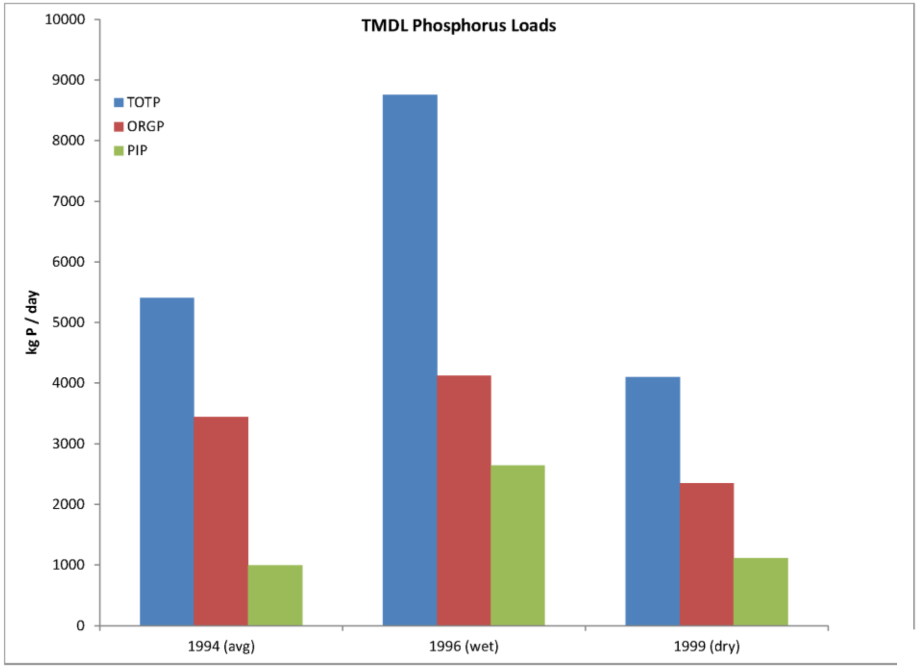
Step 1 - Scenario Conditions

- Ten years hydrology, 1991 – 2000.
- Base conditions from the 2010 TMDL (land use, point sources, atmospheric loads etc.).
- Phase 5.3.2 Watershed Model.
- The same phase of the WSM and same calibration status of the WQM as used for TMDL determination.
- Scenario conditions eliminate Conowingo Reservoir.

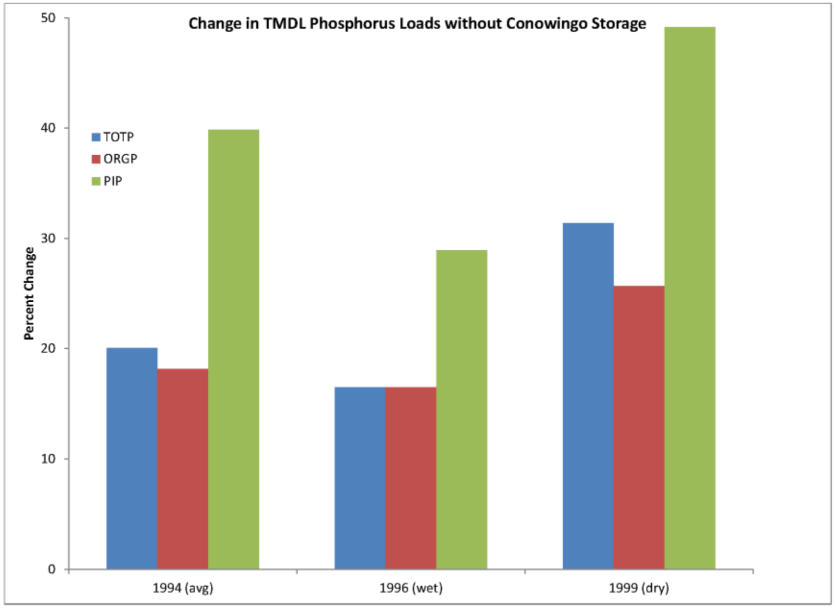


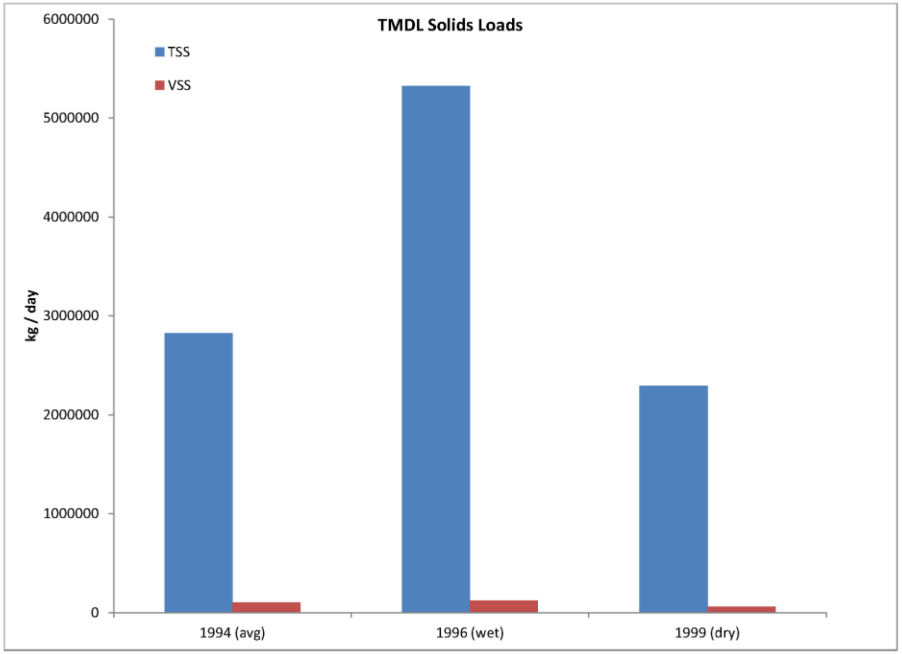
A large fraction of the nitrogen loads is as nitrate and is unaffected by settling or scour.



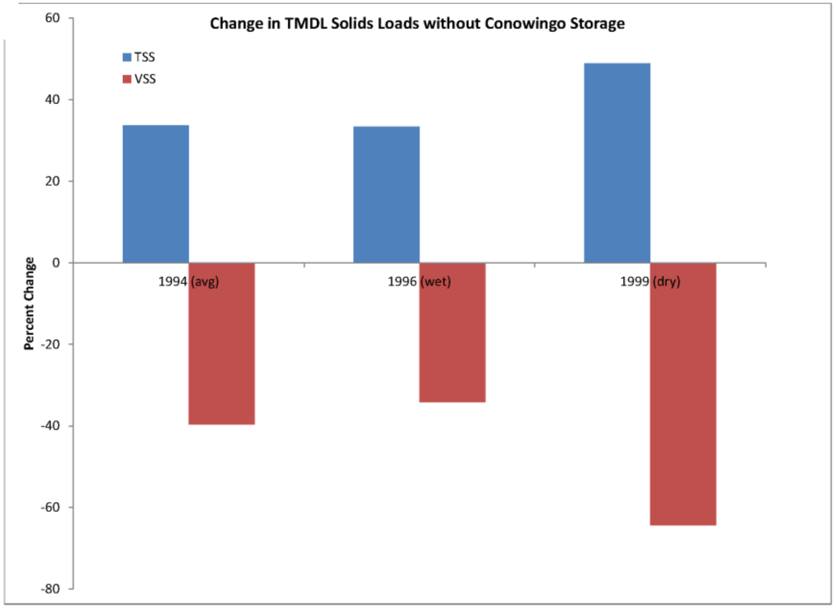


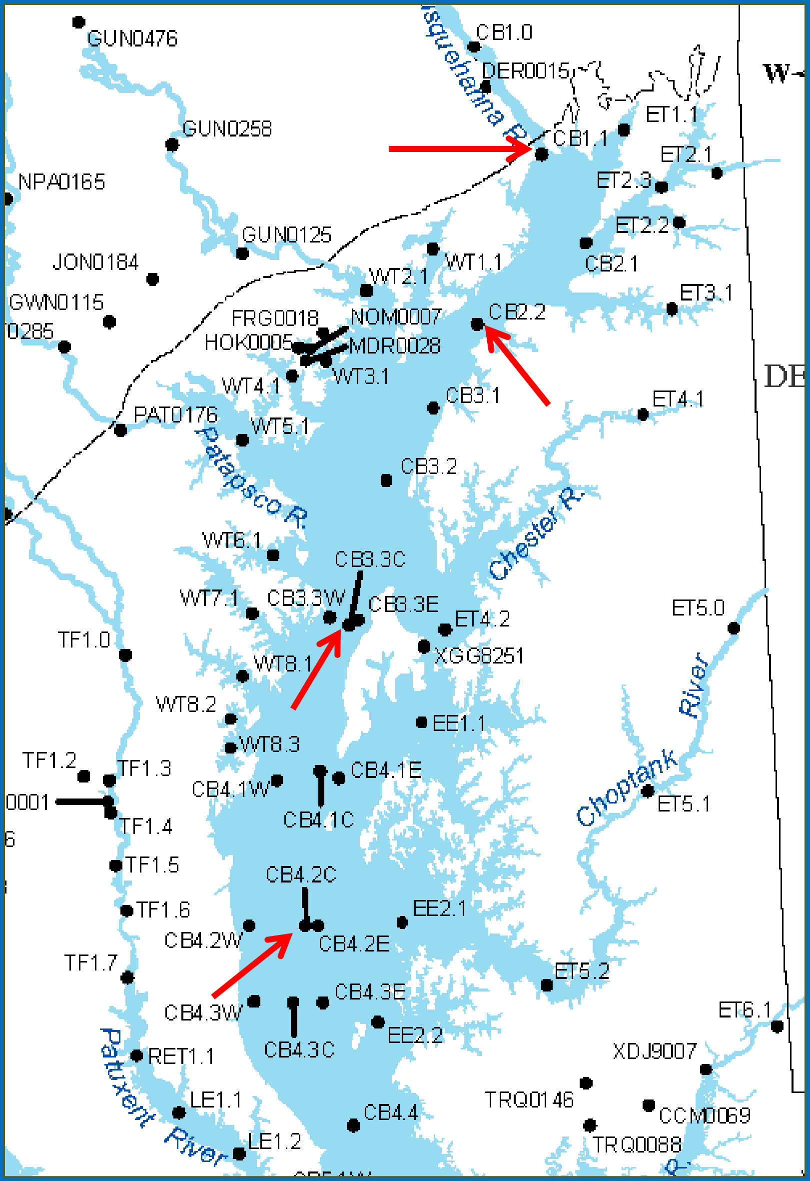
The majority of the phosphorus load is in particulate form. In our model, PIP is considered to be inert.





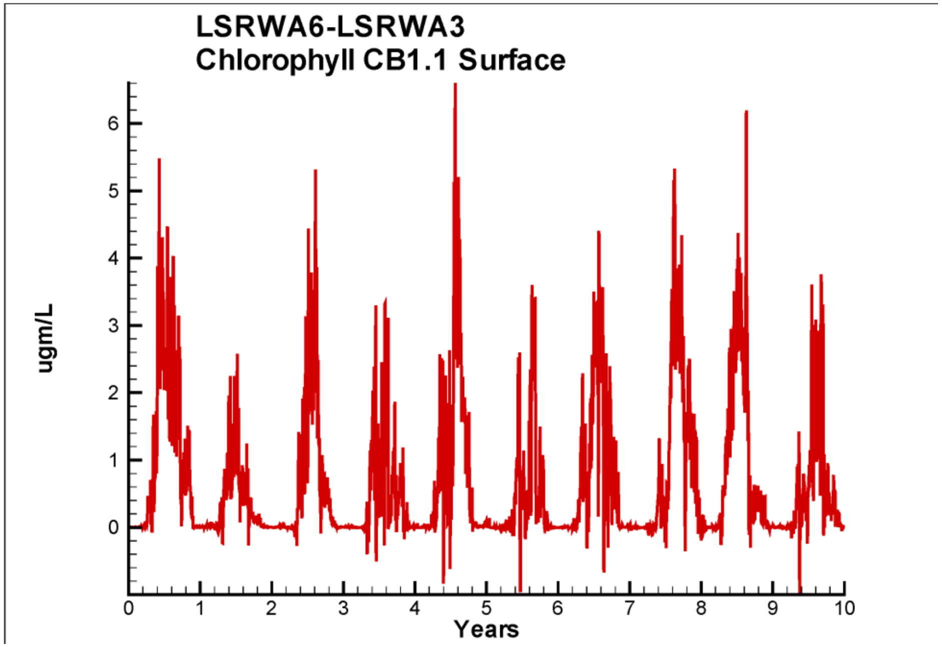
Volatile solids are largely formed by primary production in the reservoir. When we take out the reservoir, we eliminate primary production. Volatile solids are a negligible portion of the total solids, in any event.

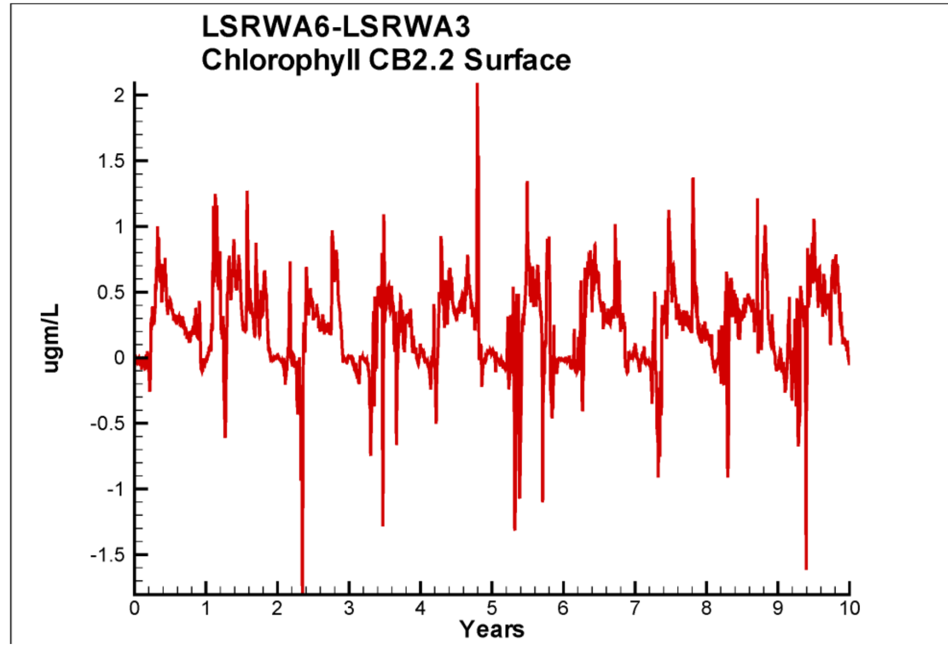


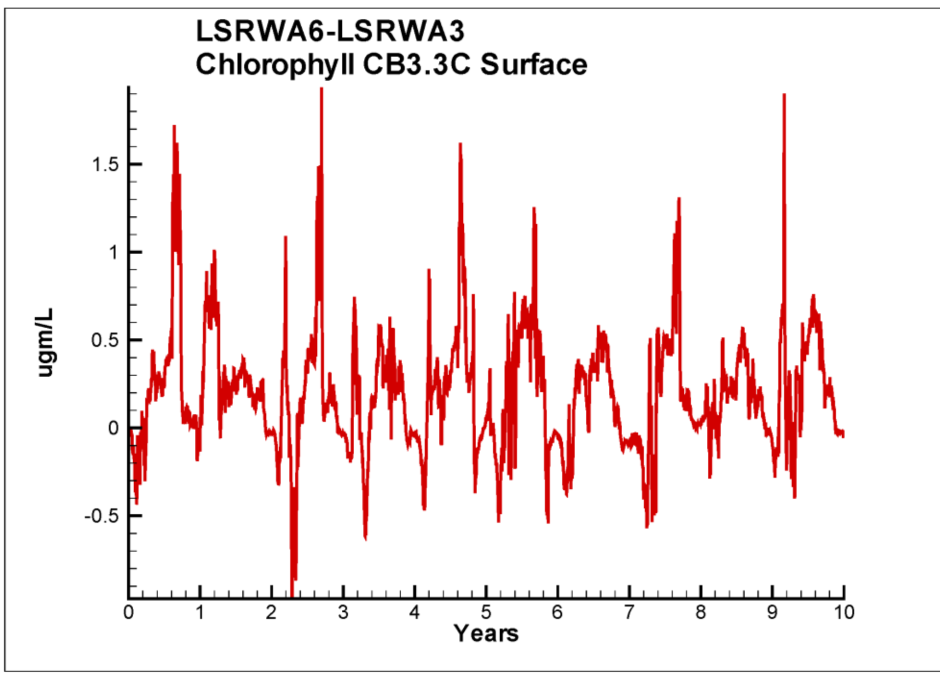


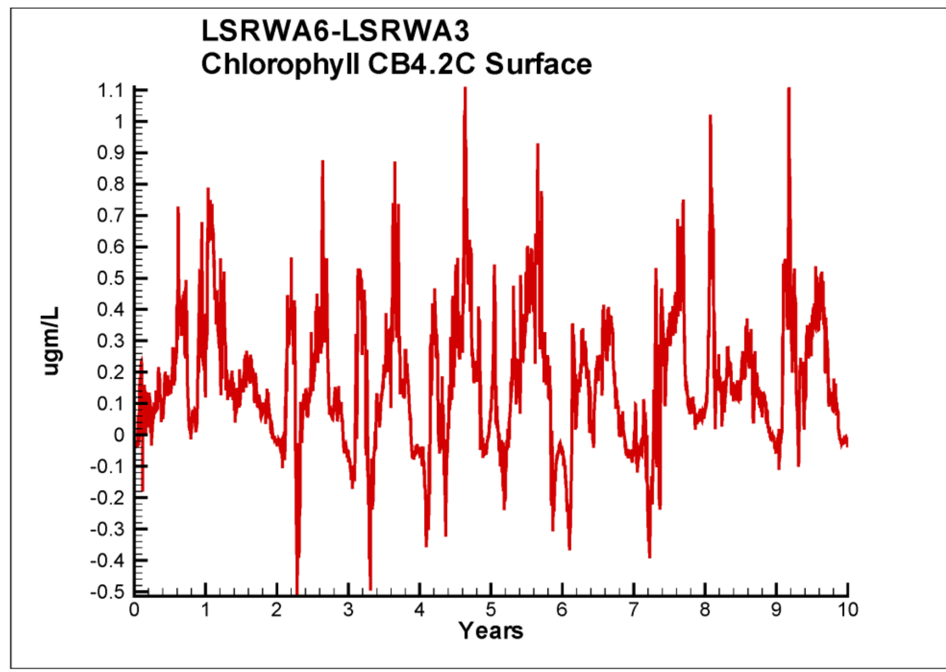
Examine key water quality constituents at four mainstem stations.

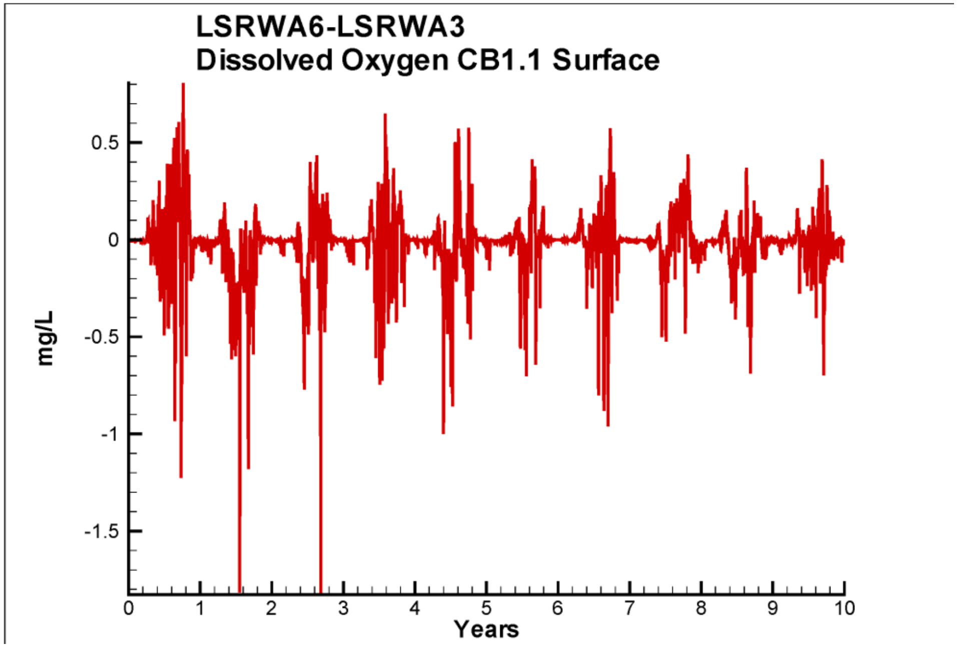
Focus on differences: Scenario – Base.

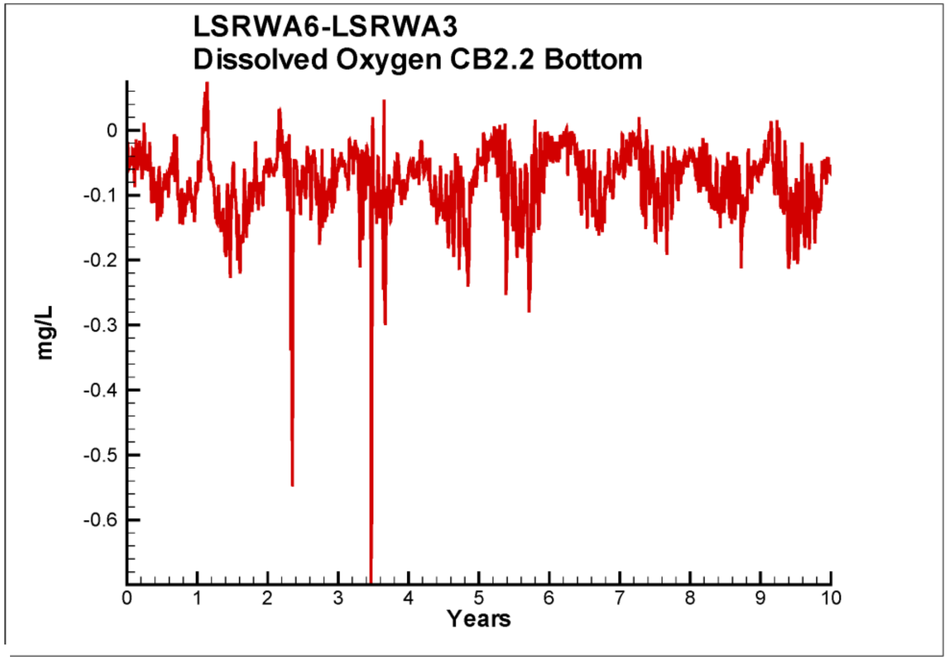

LSRWA6-LSRWA3
Chlorophyll CB1.1 Surface
ugm/L
0 1 2 3 4 5 6
Years
0 1 2 3 4 5 6 7 8 9 10

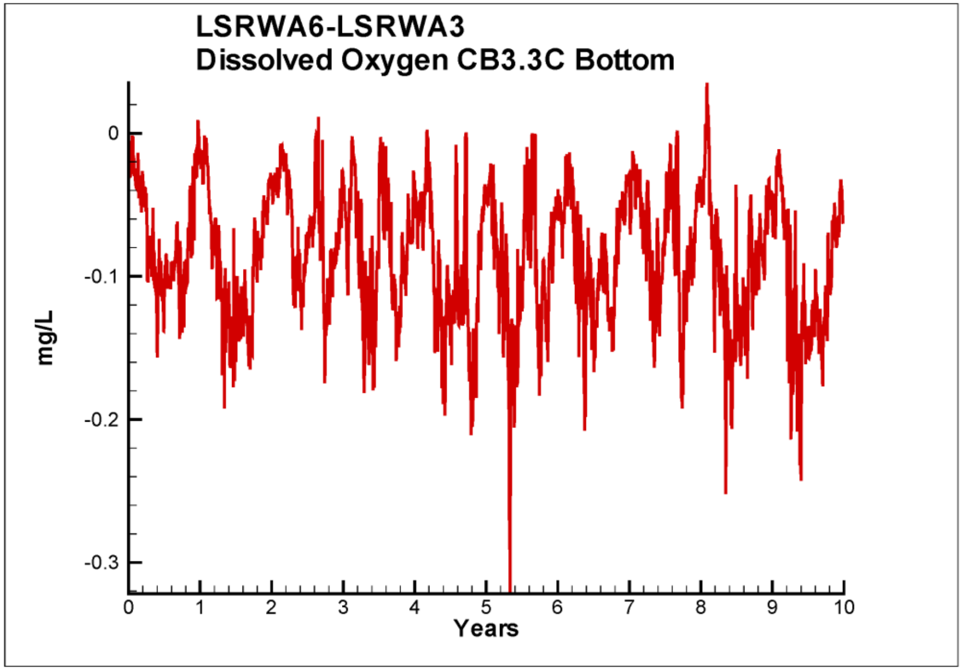

LSRWA6-LSRWA3
Chlorophyll CB2.2 Surface
ugm/L
-1.5 -1 -0.5 0 0.5 1 1.5 2
Years
0 1 2 3 4 5 6 7 8 9 10

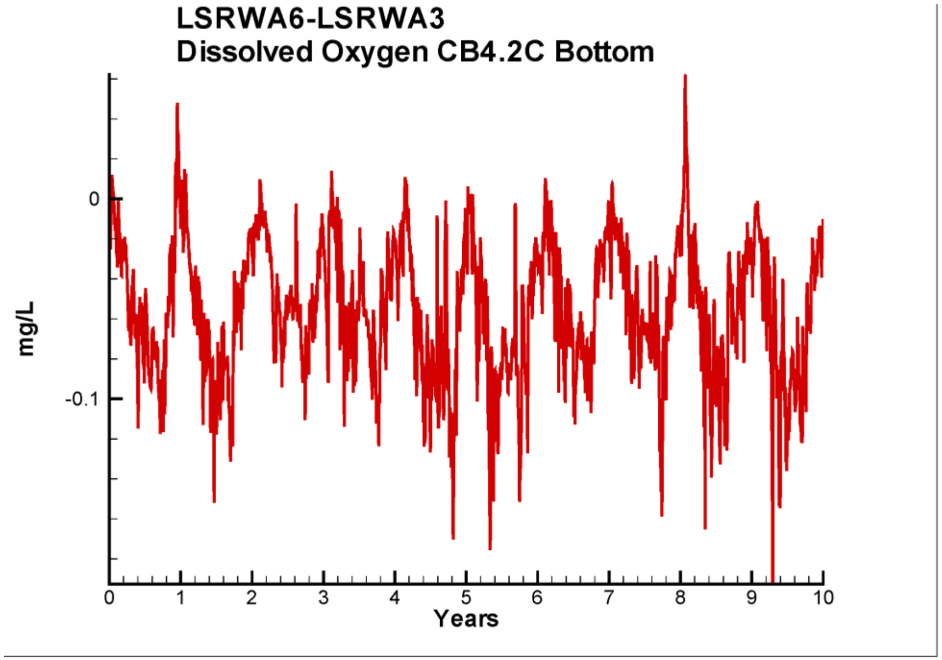

LSRWA6-LSRWA3
Chlorophyll CB3.3C Surface
ugm/L
-0.5 0 0.5 1 1.5
Years
0 1 2 3 4 5 6 7 8 9 10

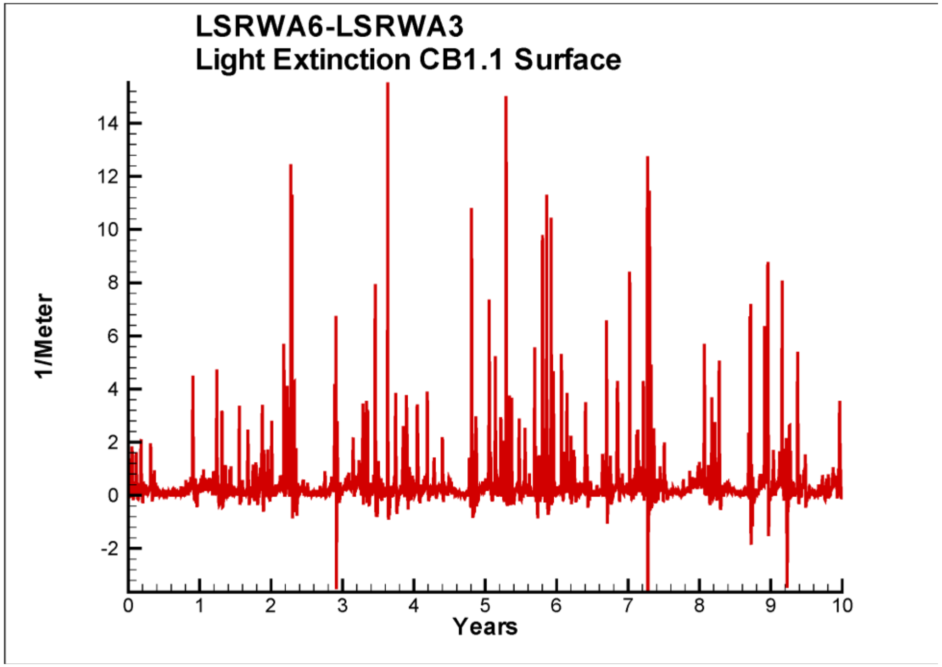

LSRWA6-LSRWA3
Chlorophyll CB4.2C Surface
ugm/L
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1
Years
0 1 2 3 4 5 6 7 8 9 10

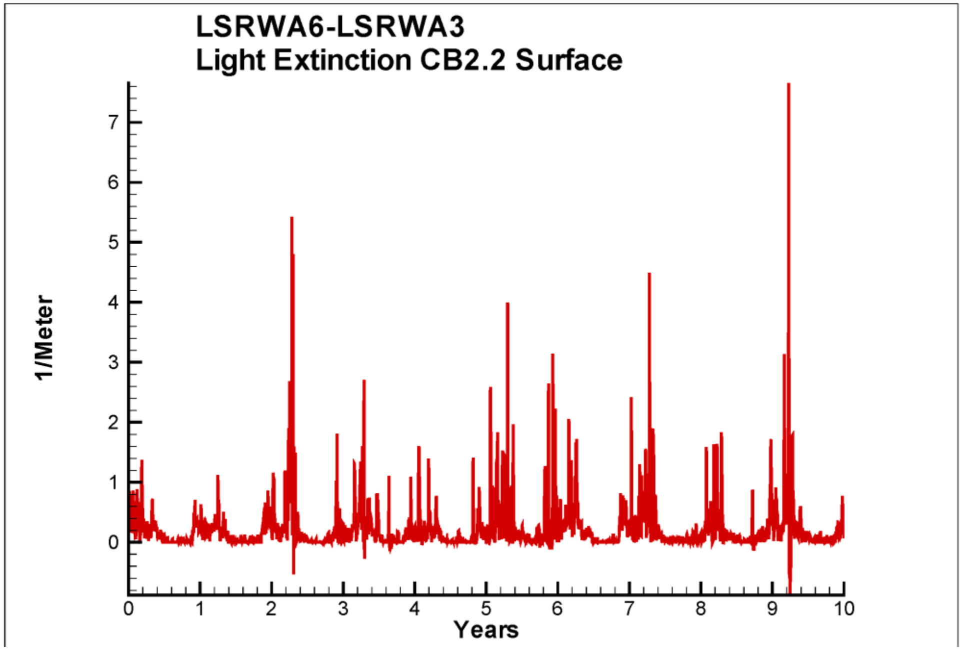

LSRWA6-LSRWA3
Dissolved Oxygen CB1.1 Surface
mg/L
Years

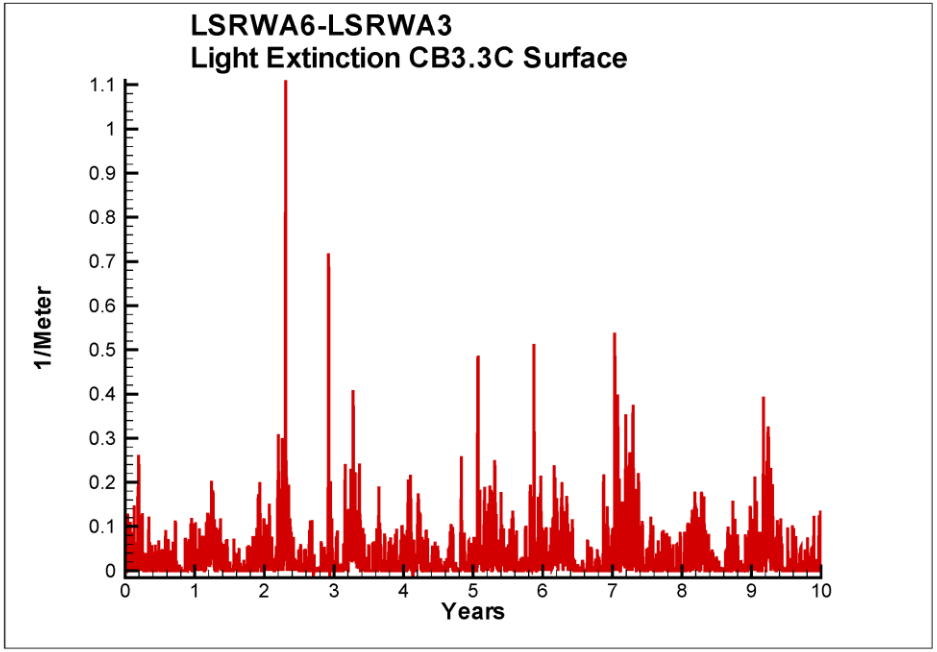

LSRWA6-LSRWA3
Dissolved Oxygen CB2.2 Bottom
mg/L
Years

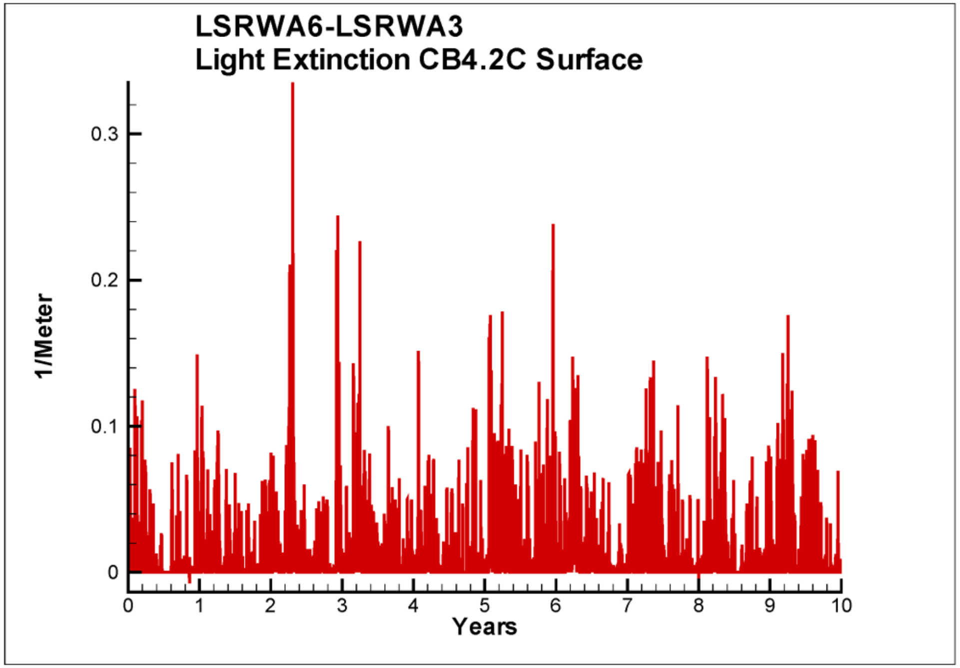

LSRWA6-LSRWA3
Dissolved Oxygen CB3.3C Bottom
mg/L
Years

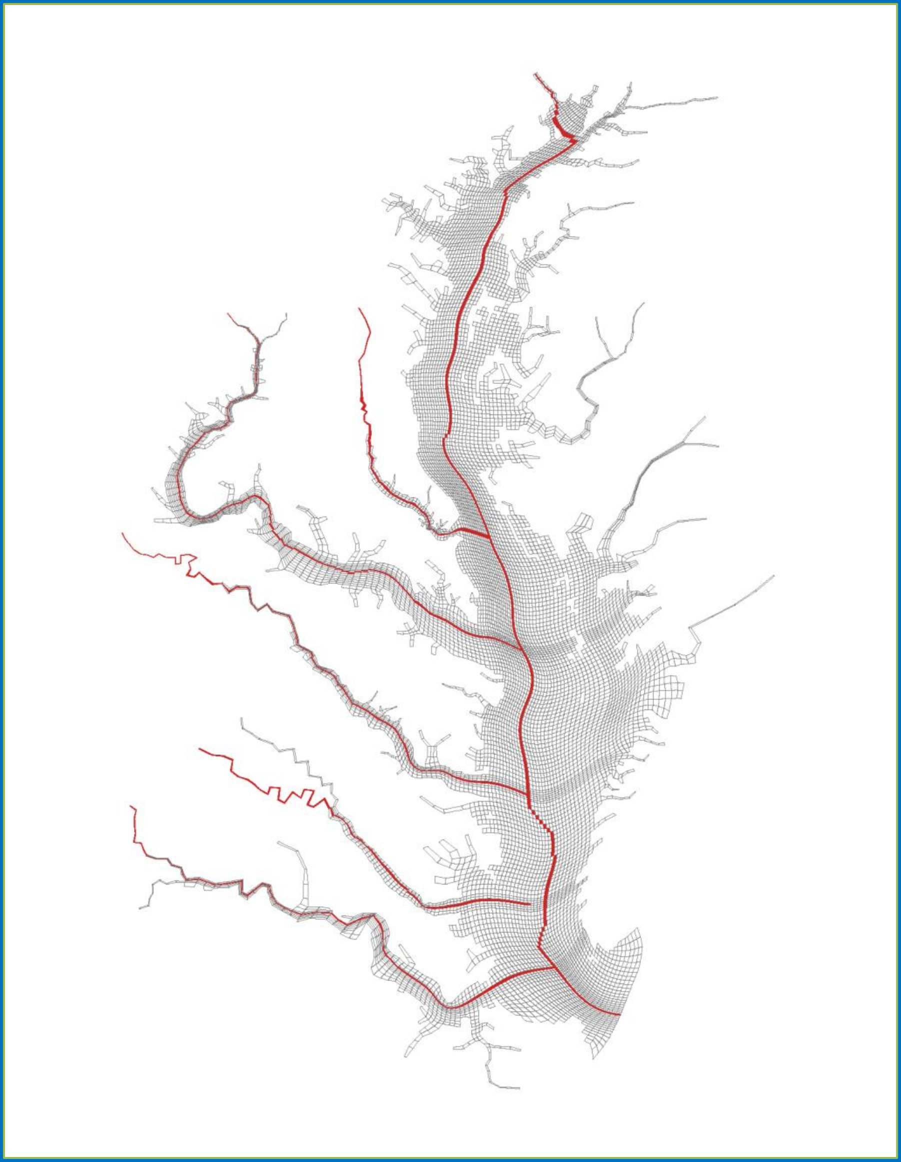

LSRWA6-LSRWA3
Dissolved Oxygen CB4.2C Bottom
mg/L
Years


LSRWA6-LSRWA3
Light Extinction CB1.1 Surface
1/Meter
Years
-2
0
2
4
6
8
10
12
14
0
1
2
3
4
5
6
7
8
9
10


LSRWA6-LSRWA3
Light Extinction CB2.2 Surface
1/Meter
Years
0
1
2
3
4
5
6
7
0
1
2
3
4
5
6
7
8
9
10


LSRWA6-LSRWA3
Light Extinction CB3.3C Surface
1/Meter
Years
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
0
1
2
3
4
5
6
7
8
9
10

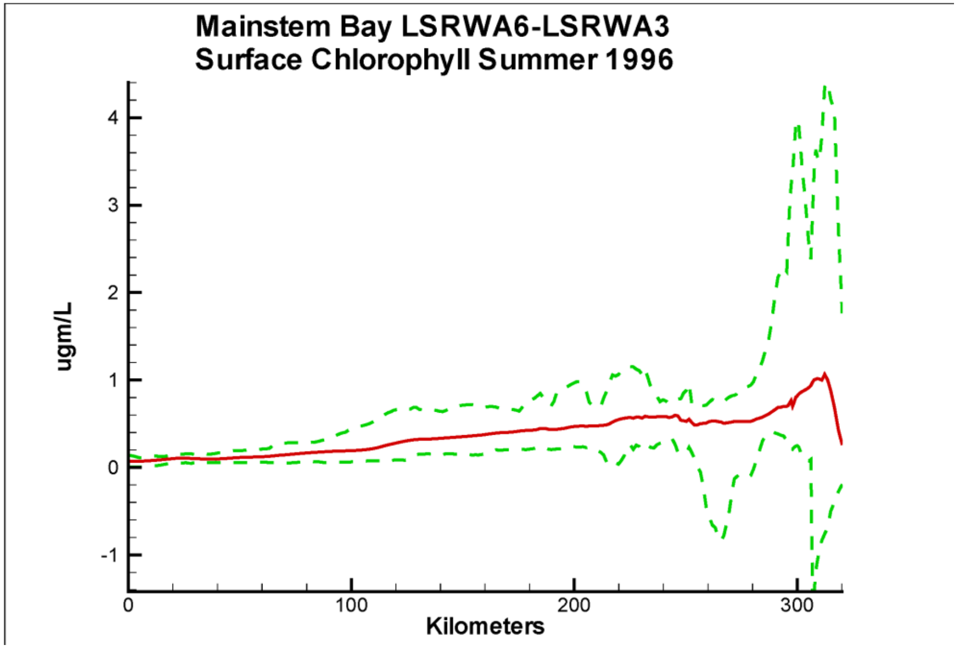

LSRWA6-LSRWA3
Light Extinction CB4.2C Surface
1/Meter
Years
0
0.1
0.2
0.3
0
1
2
3
4
5
6
7
8
9
10

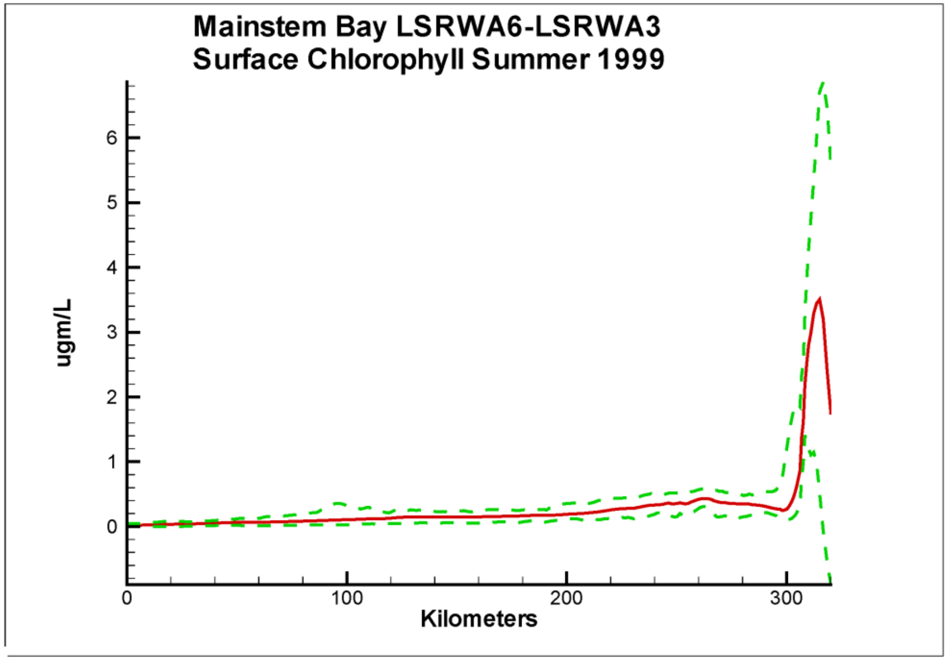


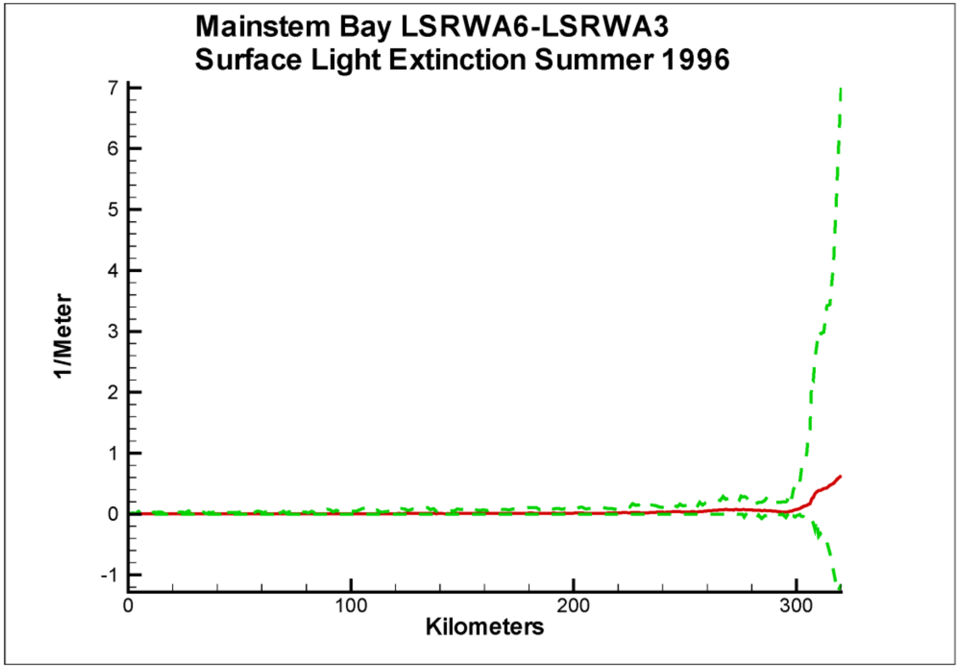
Examine summer-average (June – August) concentrations of key water quality constituents along the mainstem axis.

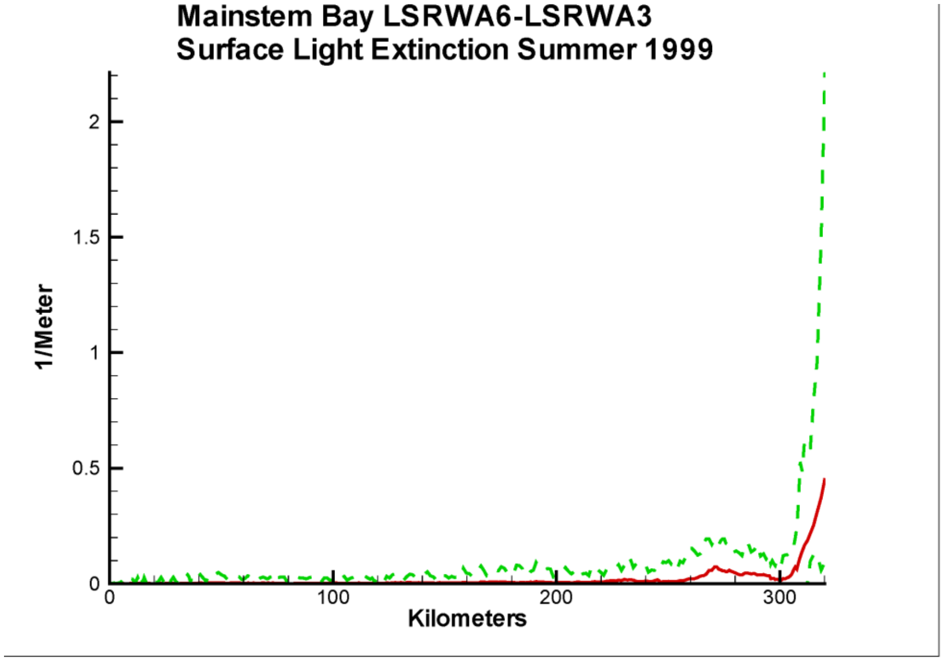
Focus on differences: Scenario – Base.

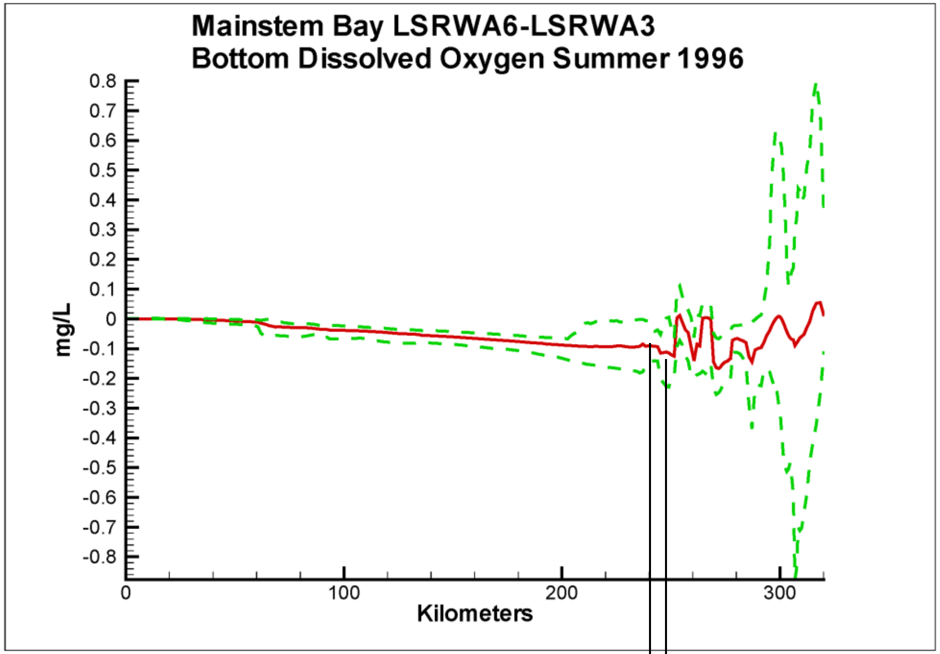
1996 is “wet” hydrology, 1999 is “dry” hydrology.


Mainstem Bay LSRWA6-LSRWA3
Surface Chlorophyll Summer 1996
ugm/L
Kilometers
0
100
200
300
-1
1
2
3
4

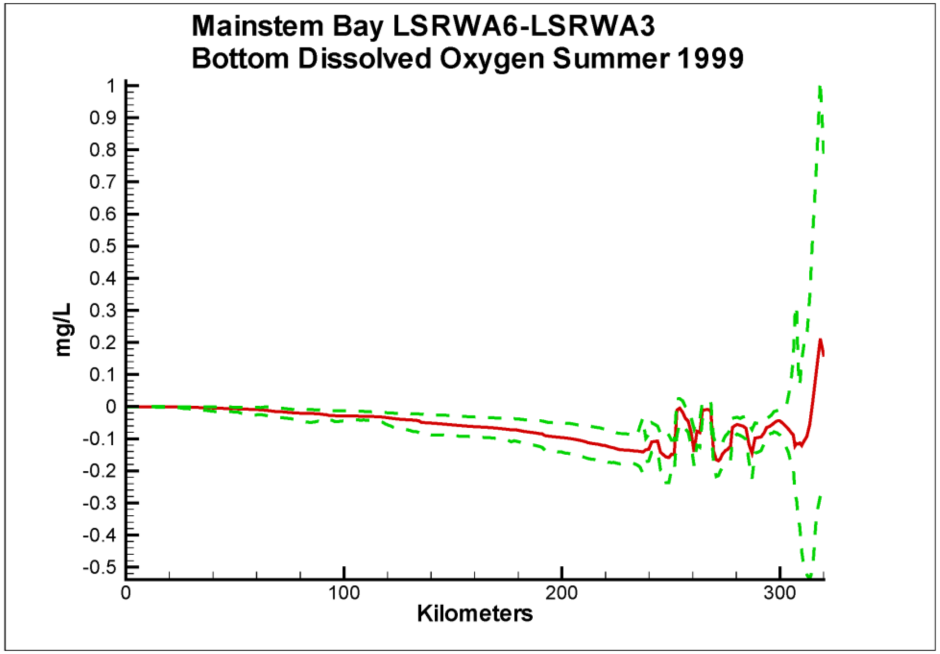

Mainstem Bay LSRWA6-LSRWA3
Surface Chlorophyll Summer 1999
ugm/L
Kilometers
0
100
200
300
1
2
3
4
5
6


Mainstem Bay LSRWA6-LSRWA3
Surface Light Extinction Summer 1996
1/Meter
Kilometers
0
100
200
300
-1
1
2
3
4
5
6
7

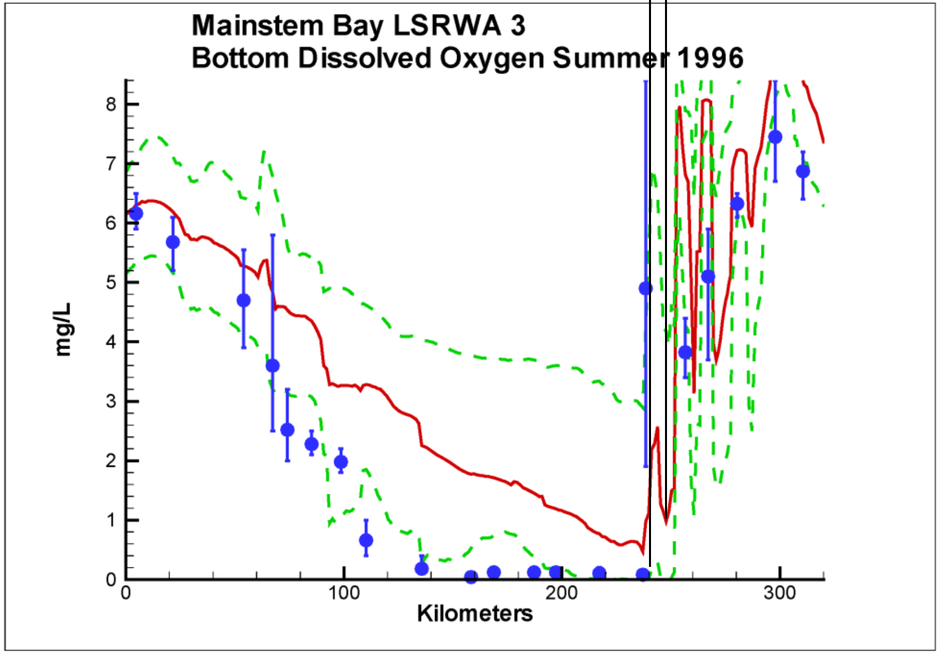

Mainstem Bay LSRWA6-LSRWA3
Surface Light Extinction Summer 1999
1/Meter
Kilometers
0
100
200
300
0.5
1
1.5
2



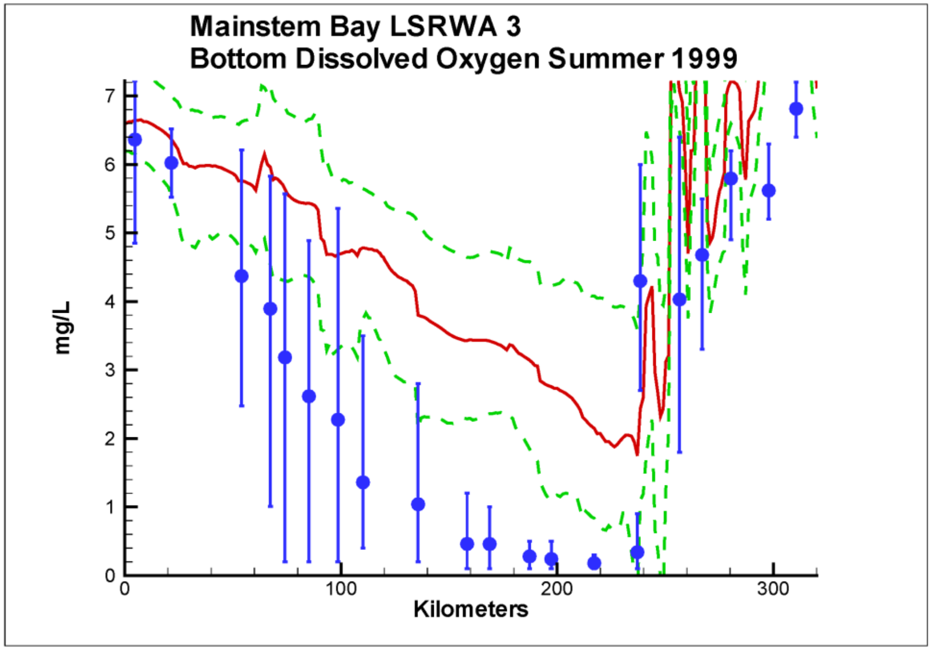
Mainstem Bay LSRWA6-LSRWA3
Bottom Dissolved Oxygen Summer 1996
mg/L
Kilometers



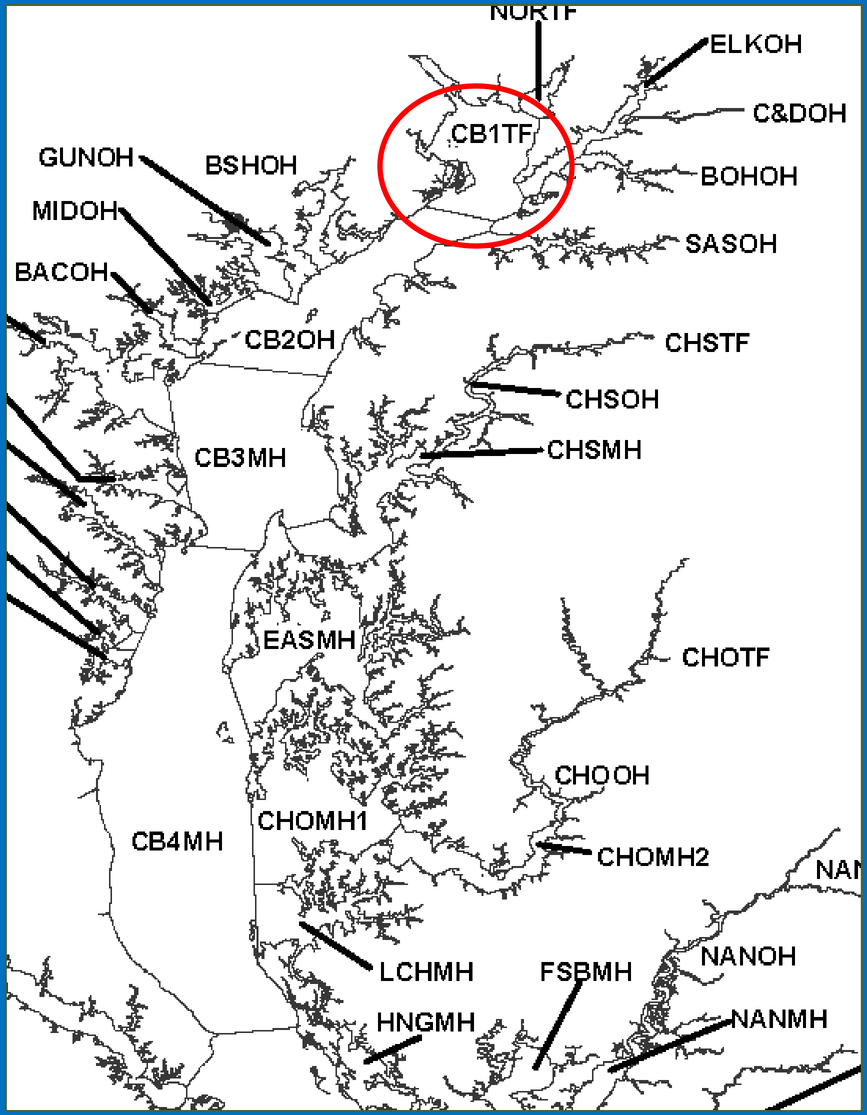
Mainstem Bay LSRWA6-LSRWA3
Bottom Dissolved Oxygen Summer 1999
mg/L
Kilometers



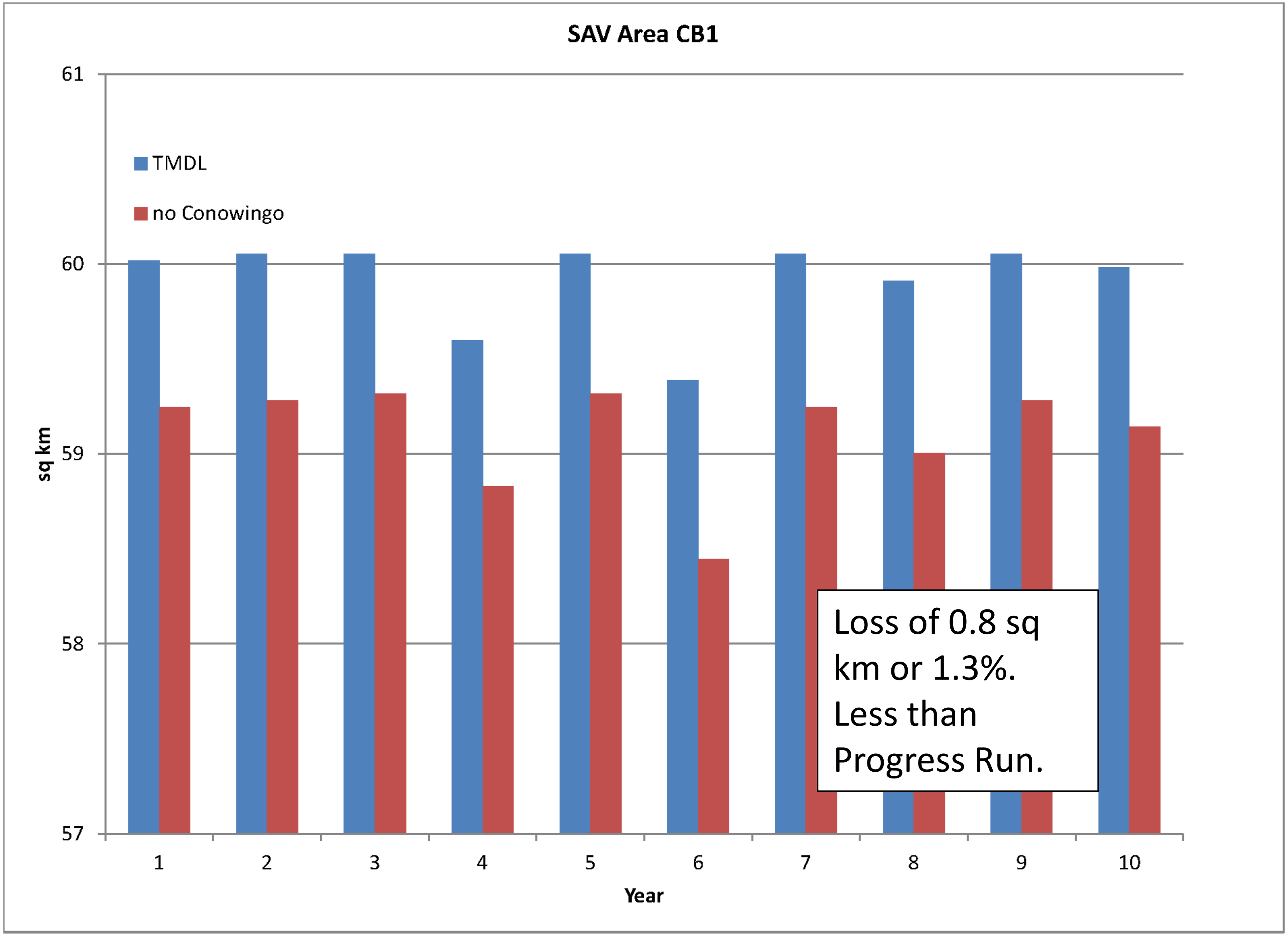
Mainstem Bay LSRWA 3
Bottom Dissolved Oxygen Summer 1996
mg/L
Kilometers

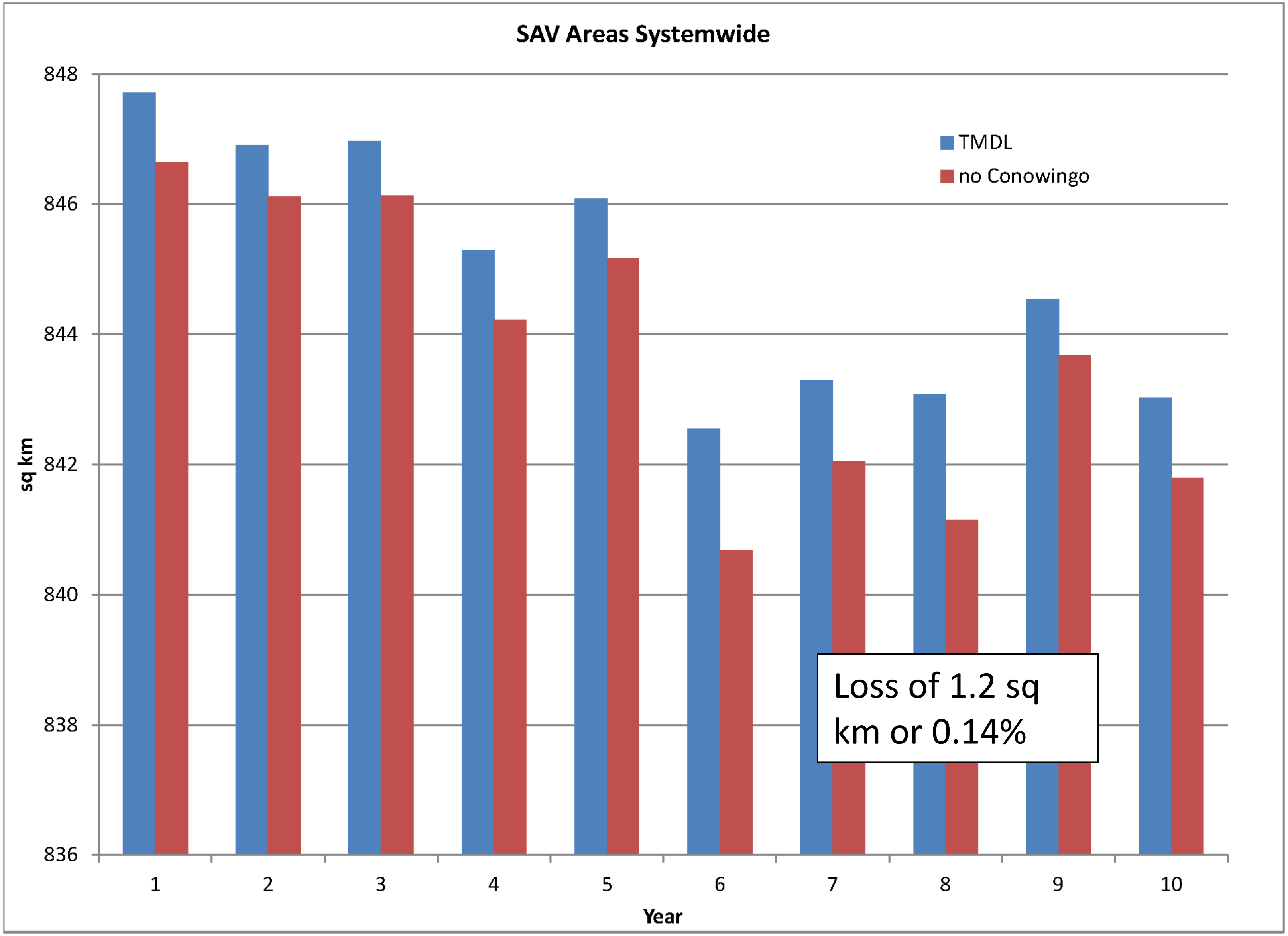


Mainstem Bay LSRWA 3
Bottom Dissolved Oxygen Summer 1999
mg/L
Kilometers

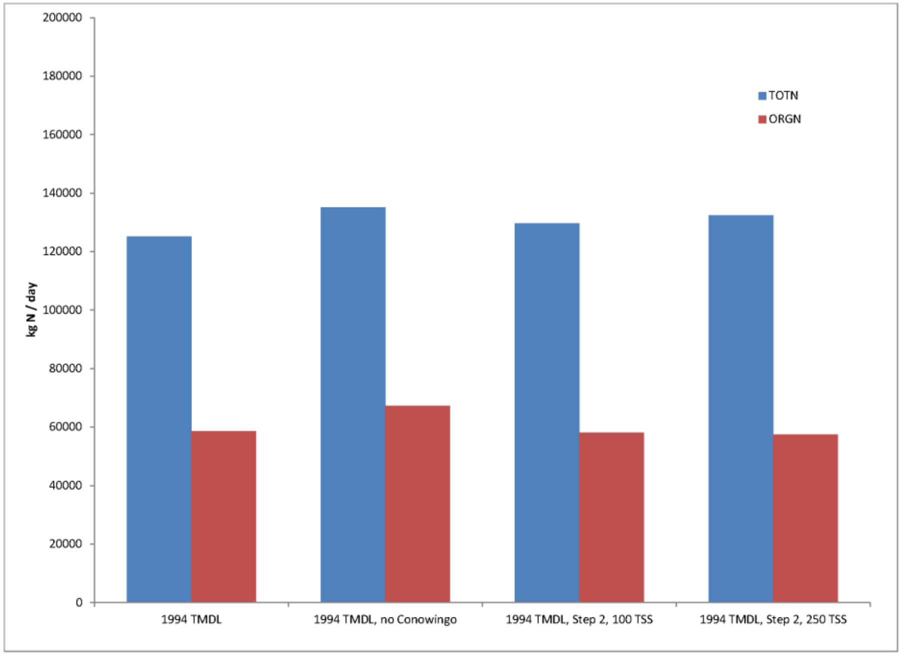


Examine equilibrium SAV area in CB1TF and system-wide.


SAV Area CB1
61
60
59
58
57
sq km
TMDL
no Conowingo
1
2
3
4
5
6
7
8
9
10
Year
Loss of 0.8 sq km or 1.3%. Less than Progress Run.

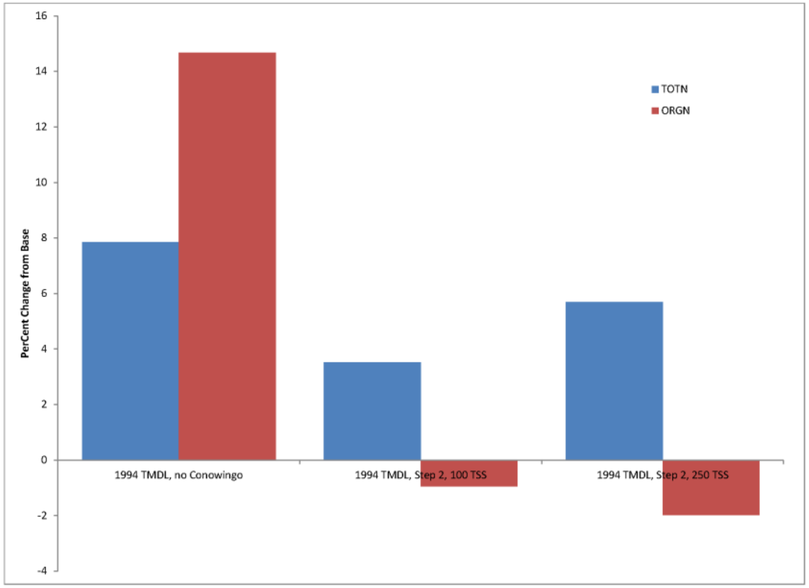

SAV Areas Systemwide
848
846
844
842
840
838
836
sq km
1
2
3
4
5
6
7
8
9
10
Year
TMDL
no Conowingo
Loss of 1.2 sq km or 0.14%

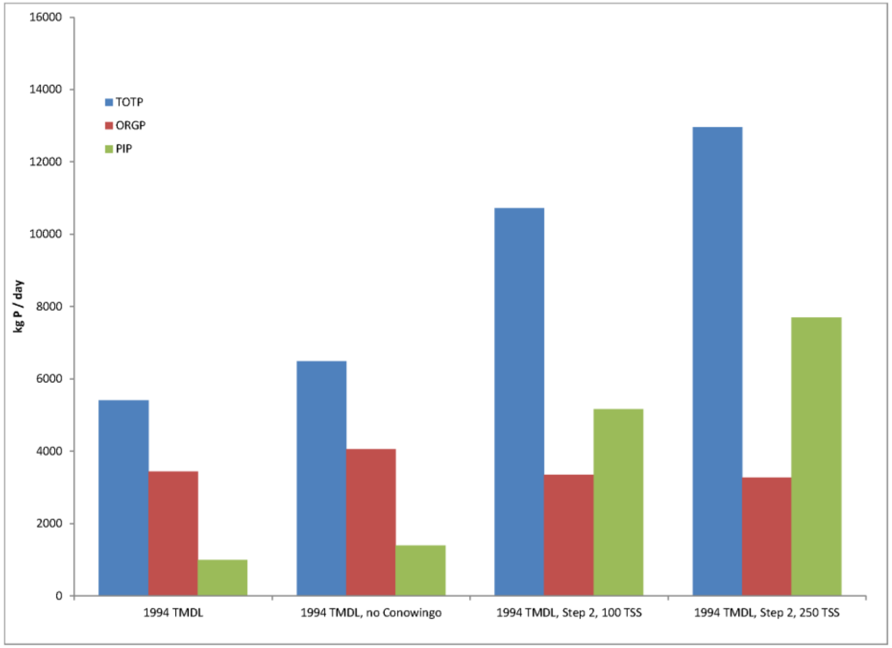
Let's Move on to Step 2



1994 (average hydrology) TMDL nitrogen loads.

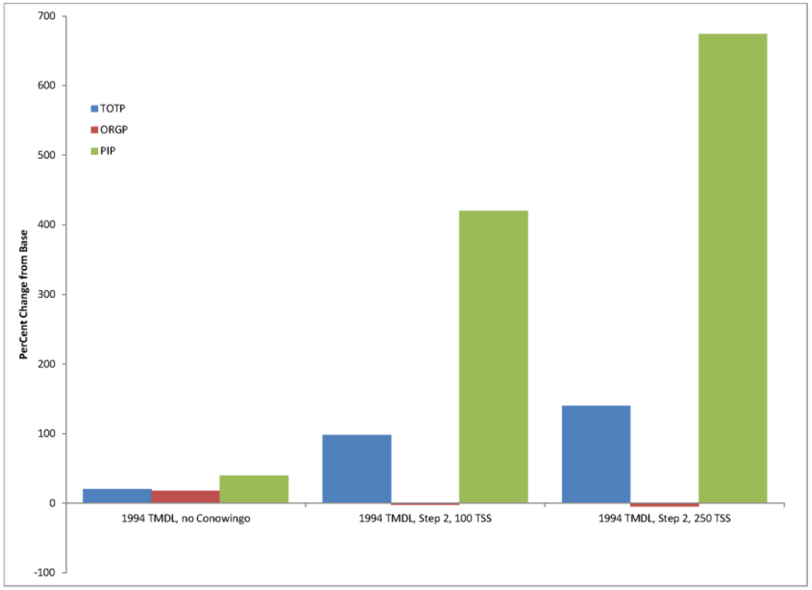
PerCent change in nitrogen loads.

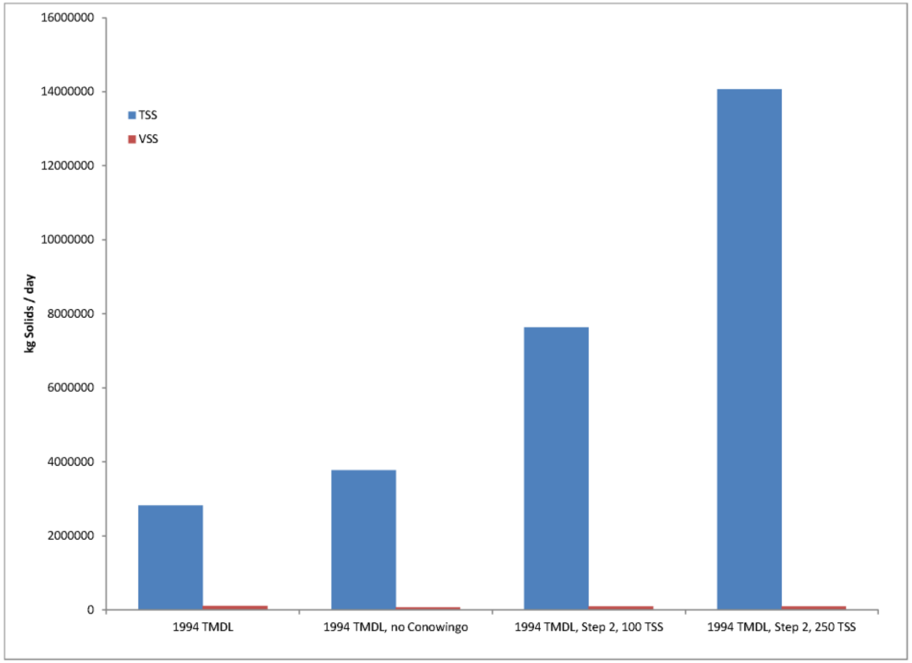




1994 (average hydrology) TMDL phosphorus loads.

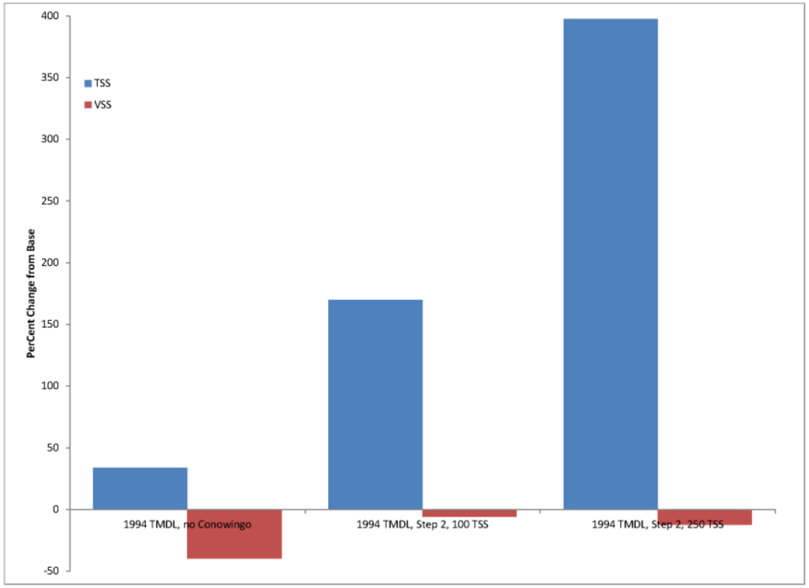
PerCent change in phosphorus loads.

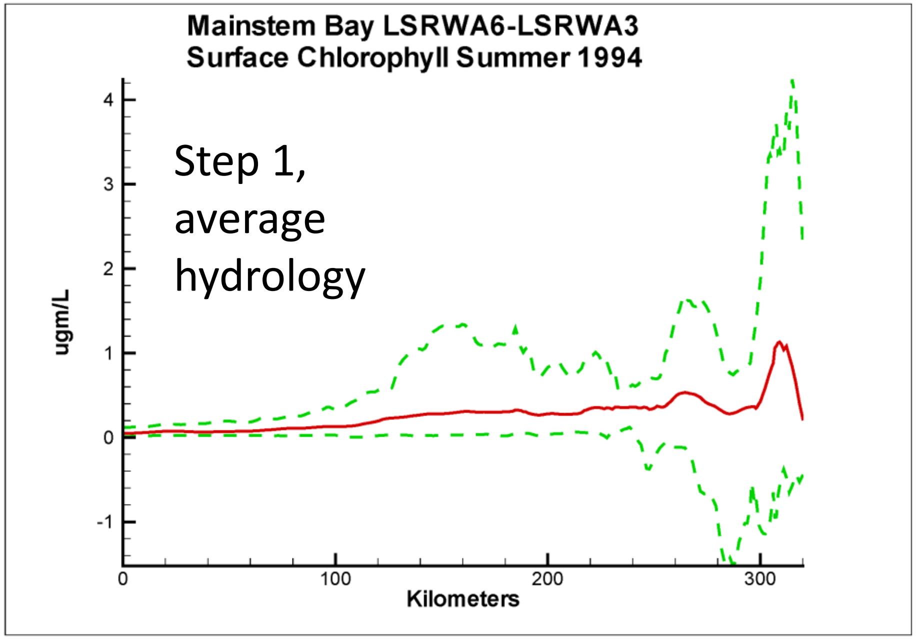


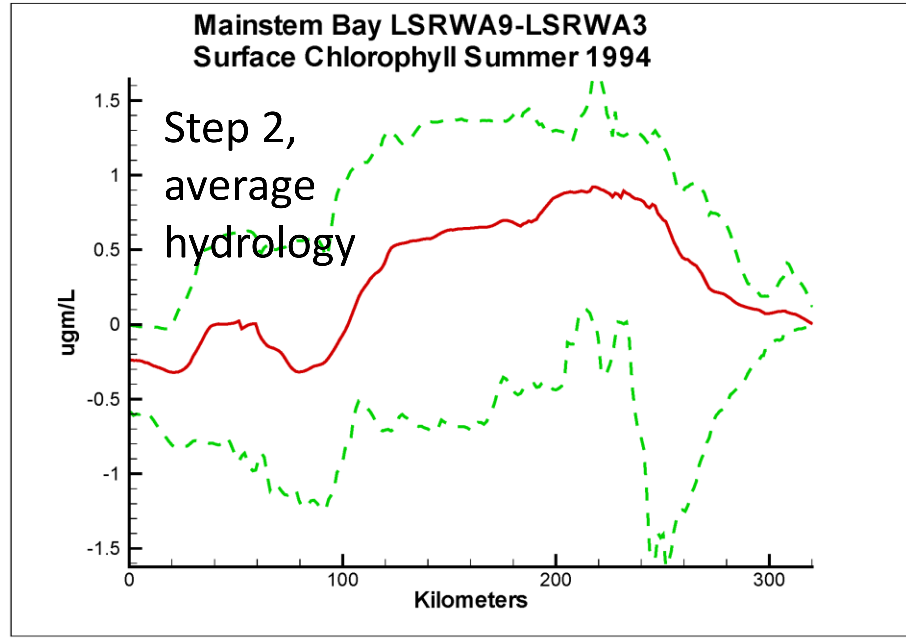


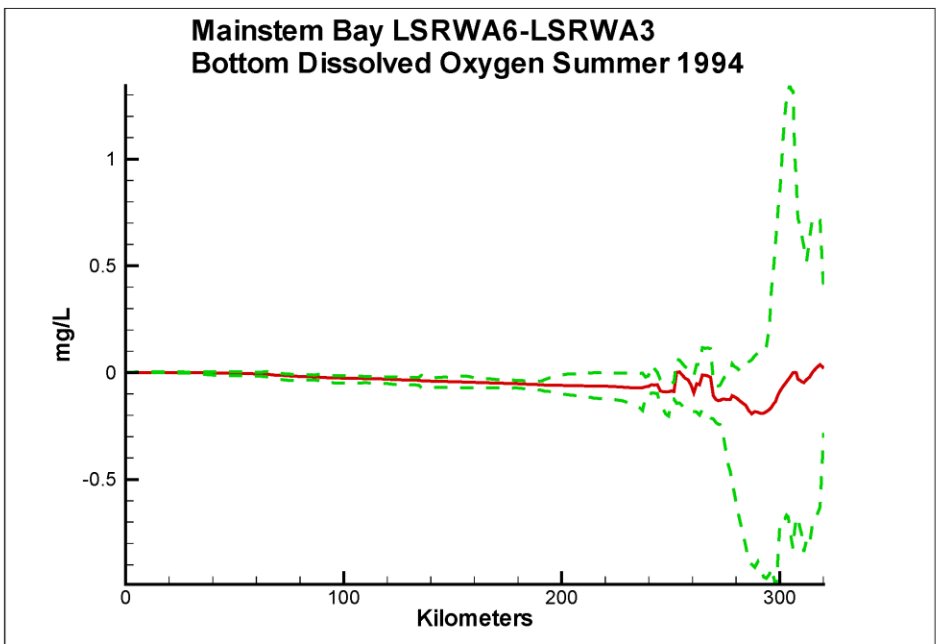
1994 (average hydrology) TMDL solids loads.

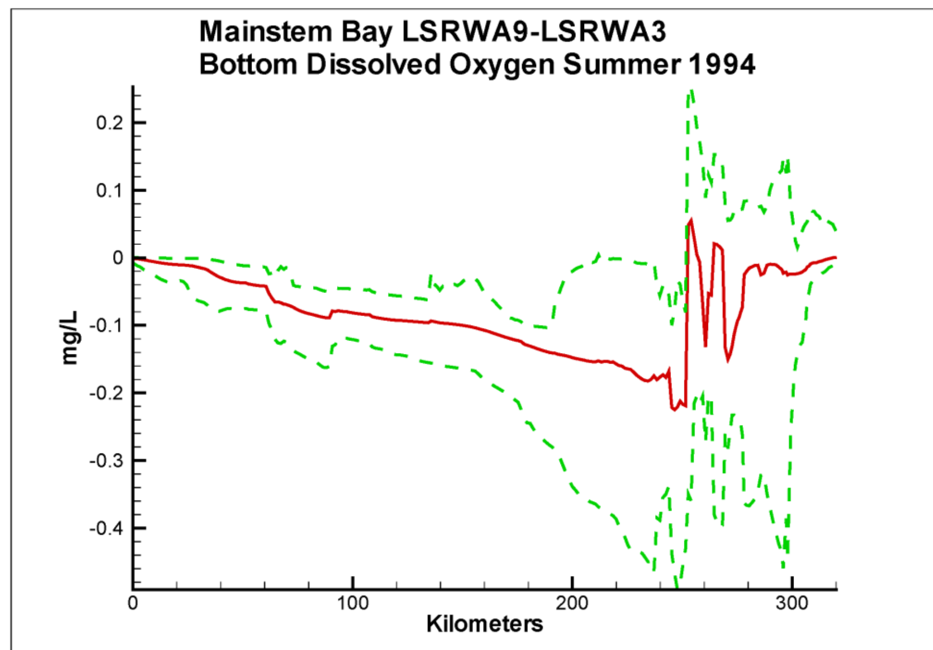
PerCent change in solids loads.

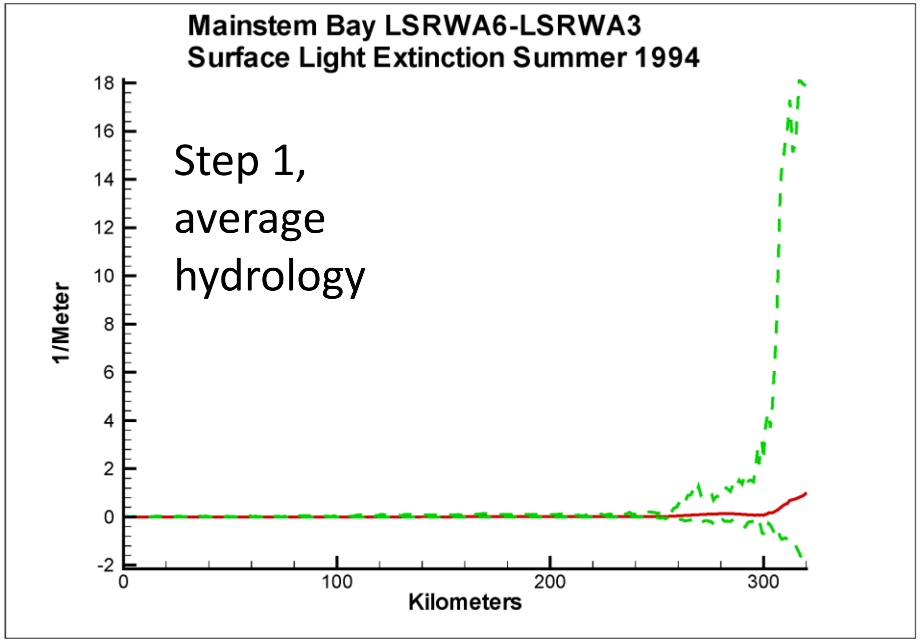


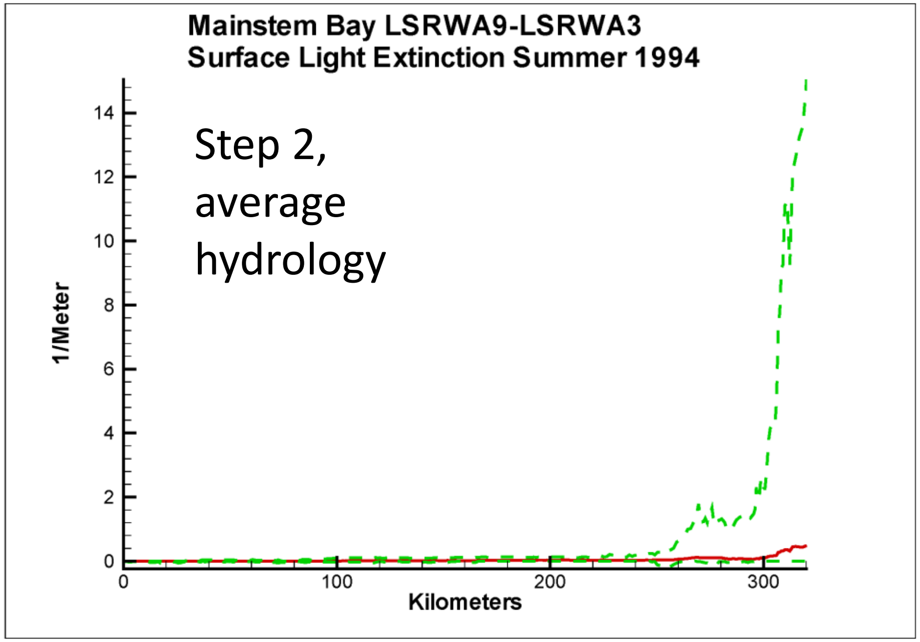

Mainstem Bay LSRWA6-LSRWA3
Surface Chlorophyll Summer 1994
Step 1, average hydrology
ugm/L
Kilometers
4
3
2
1
0
-1
0
100
200
300

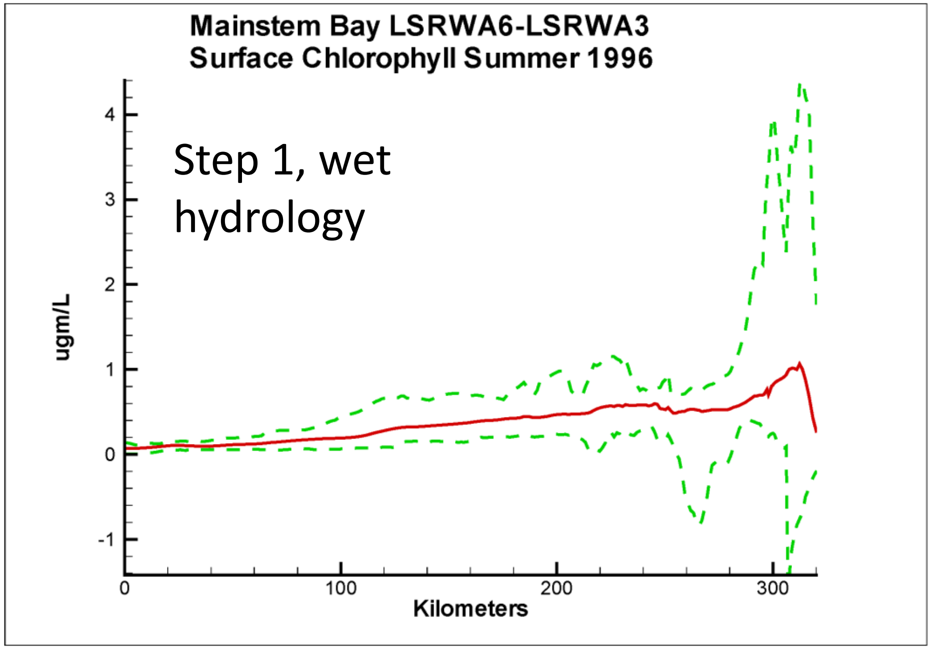

Mainstem Bay LSRWA9-LSRWA3
Surface Chlorophyll Summer 1994
Step 2, average hydrology
ugm/L
Kilometers
1.5
1
0.5
0
-0.5
-1
-1.5
0
100
200
300

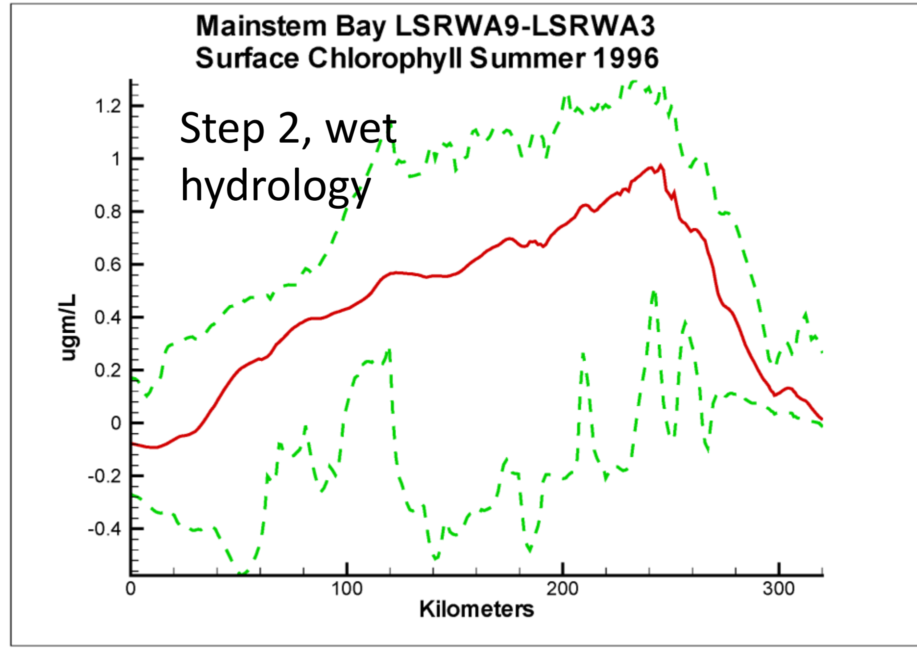

Mainstem Bay LSRWA6-LSRWA3
Bottom Dissolved Oxygen Summer 1994
mg/L
Kilometers
1
0.5
0
-0.5
0
100
200
300

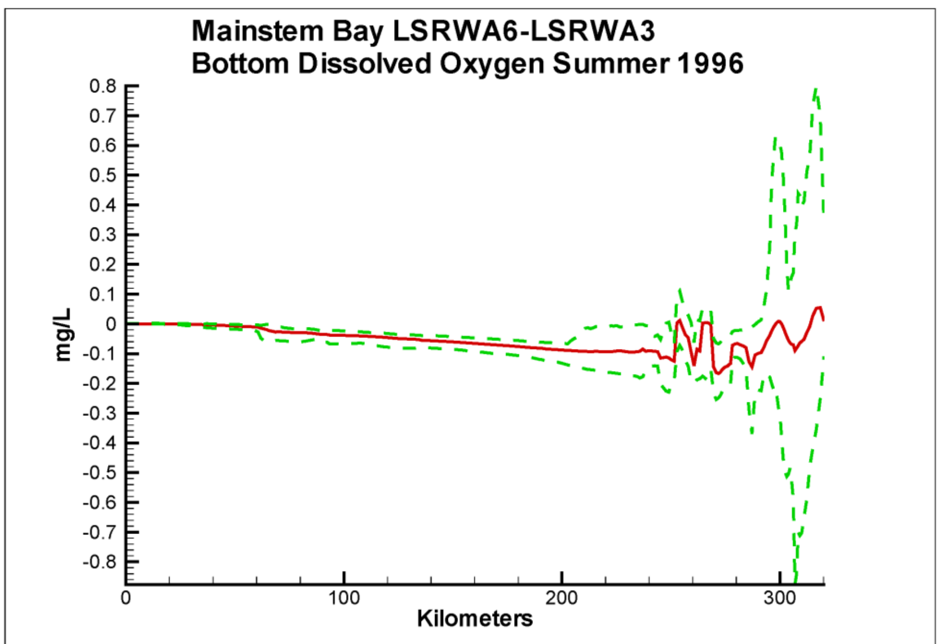

Mainstem Bay LSRWA9-LSRWA3
Bottom Dissolved Oxygen Summer 1994
mg/L
Kilometers
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0
100
200
300

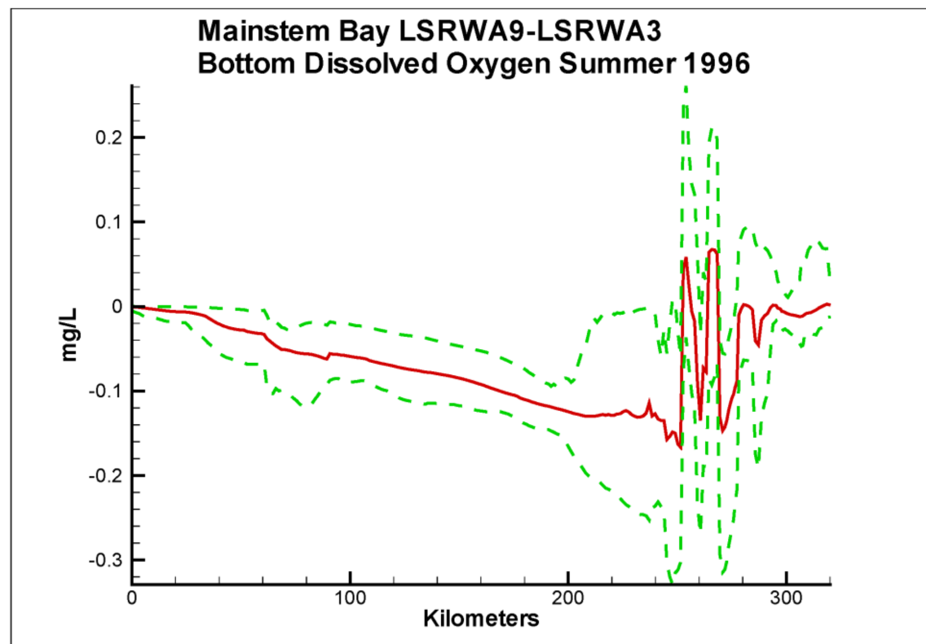

Mainstem Bay LSRWA6-LSRWA3
Surface Light Extinction Summer 1994
Step 1,
average
hydrology
1/Meter
Kilometers
18
16
14
12
10
8
6
4
2
0
-2
0
100
200
300

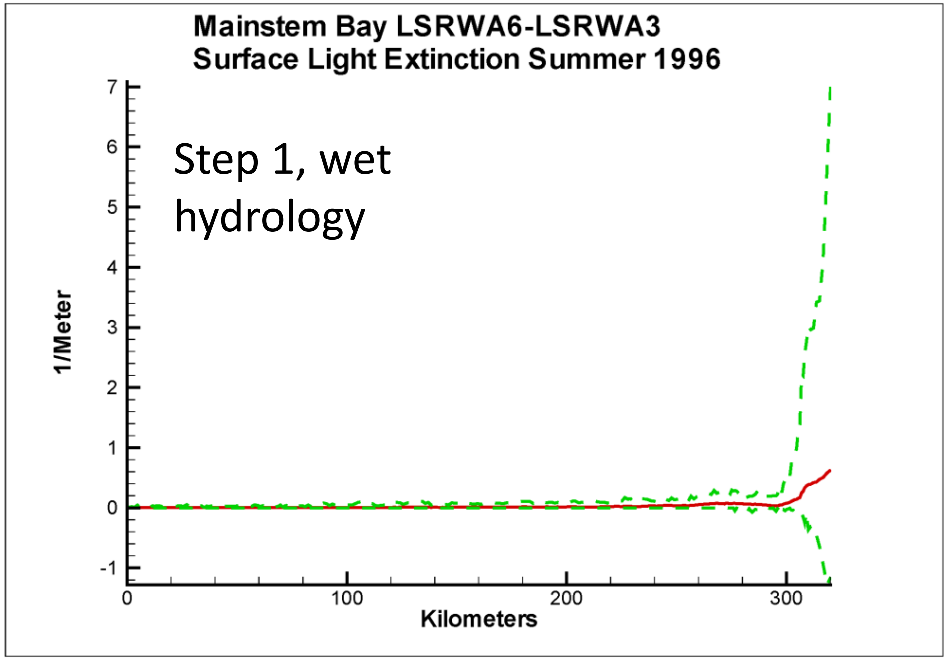

Mainstem Bay LSRWA9-LSRWA3
Surface Light Extinction Summer 1994
Step 2,
average
hydrology
1/Meter
Kilometers
14
12
10
8
6
4
2
0
0
100
200
300


Mainstem Bay LSRWA6-LSRWA3
Surface Chlorophyll Summer 1996
Step 1, wet hydrology
ugm/L
Kilometers

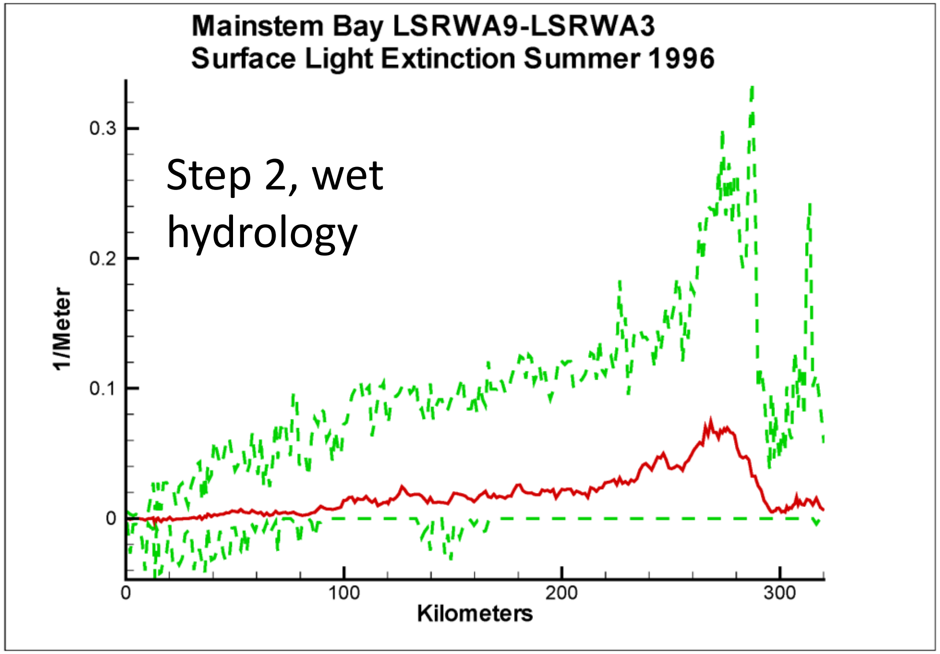

Mainstem Bay LSRWA9-LSRWA3
Surface Chlorophyll Summer 1996
Step 2, wet hydrology
ugm/L
Kilometers


Mainstem Bay LSRWA6-LSRWA3
Bottom Dissolved Oxygen Summer 1996
mg/L
Kilometers

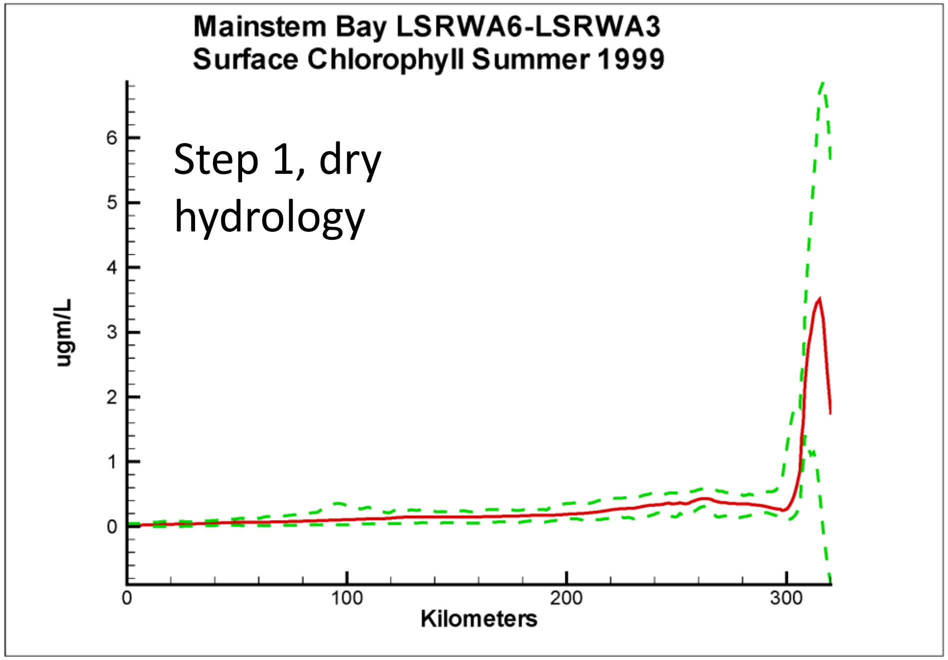

Mainstem Bay LSRWA9-LSRWA3
Bottom Dissolved Oxygen Summer 1996
mg/L
Kilometers

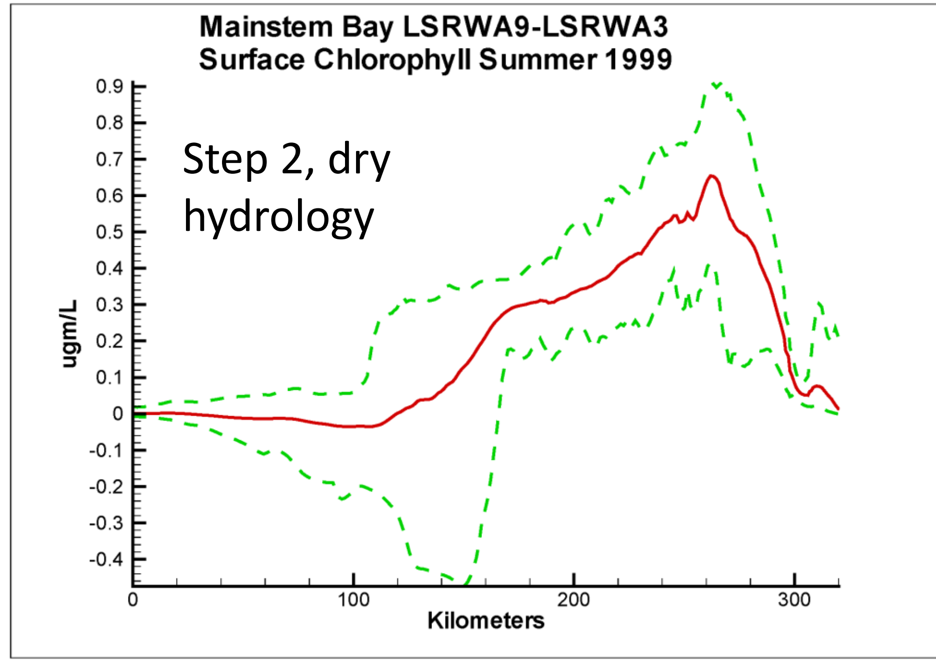


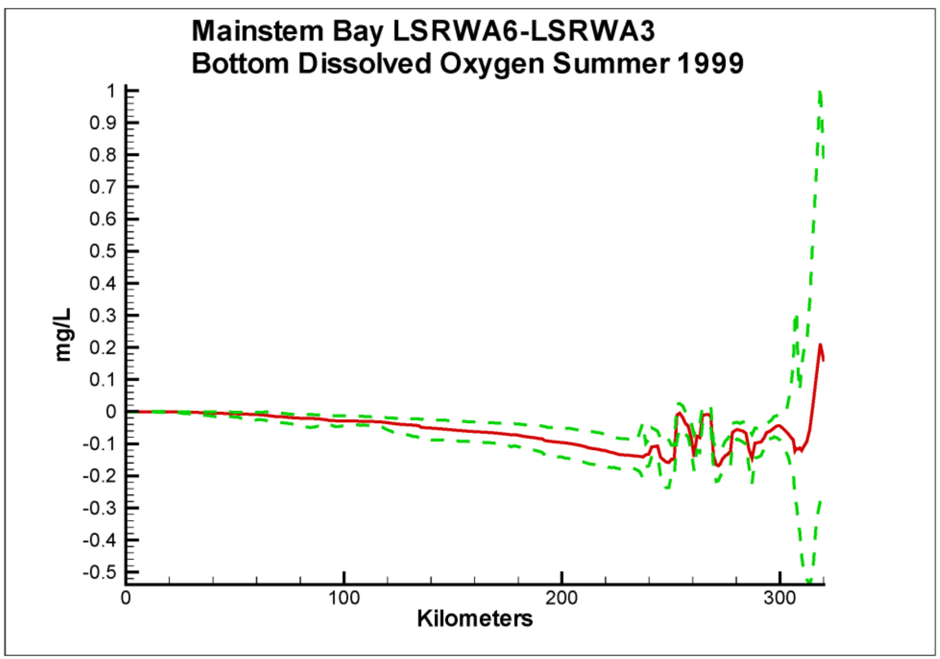
Mainstem Bay LSRWA6-LSRWA3
Surface Light Extinction Summer 1996
Step 1, wet hydrology
1/Meter
Kilometers
7
6
5
4
3
2
1
0
-1
0
100
200
300

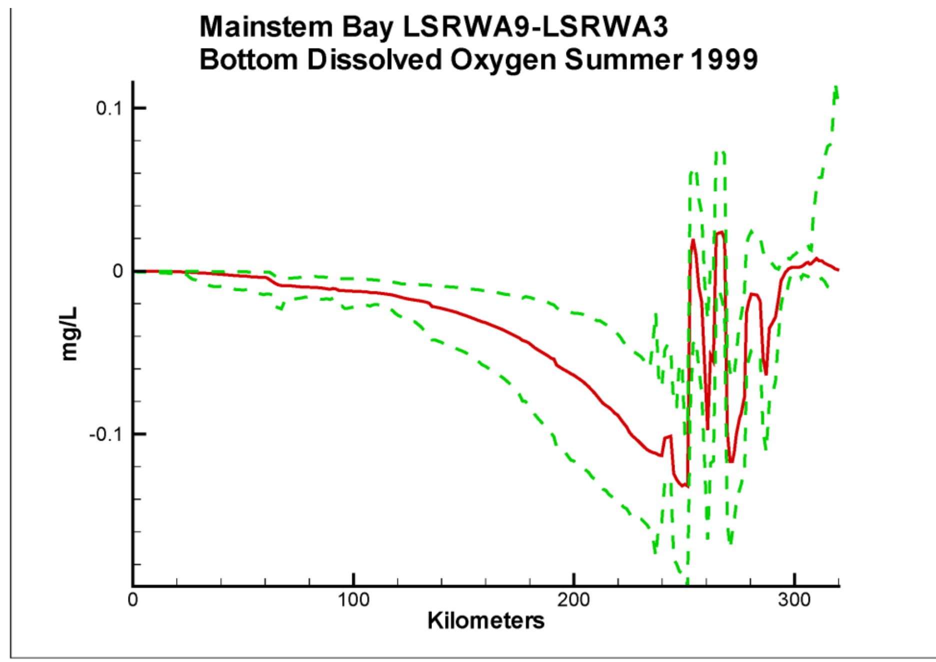


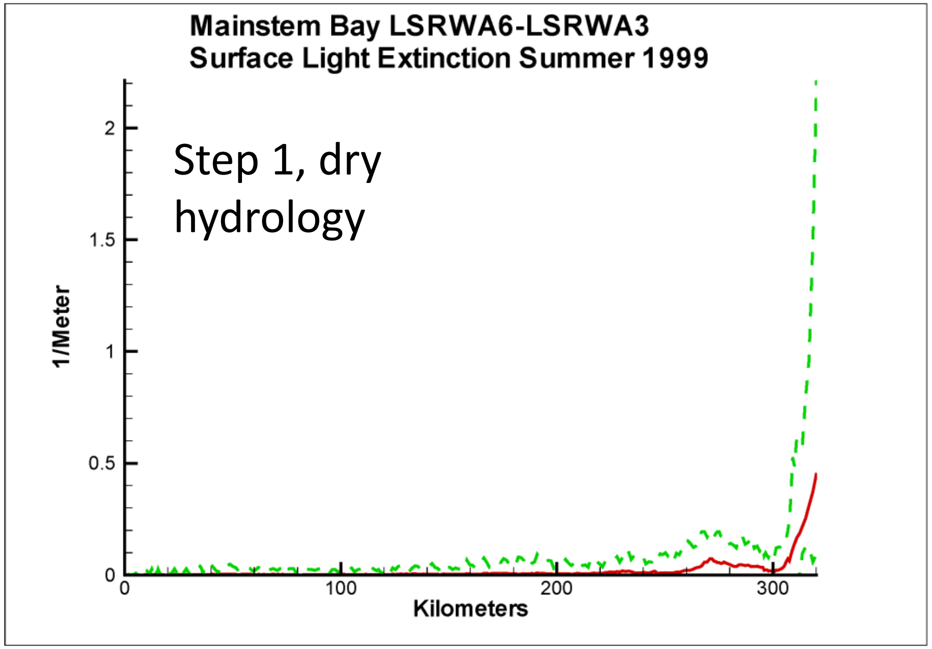
Mainstem Bay LSRWA9-LSRWA3
Surface Light Extinction Summer 1996
Step 2, wet hydrology
1/Meter
Kilometers
0.3
0.2
0.1
0
0
100
200
300

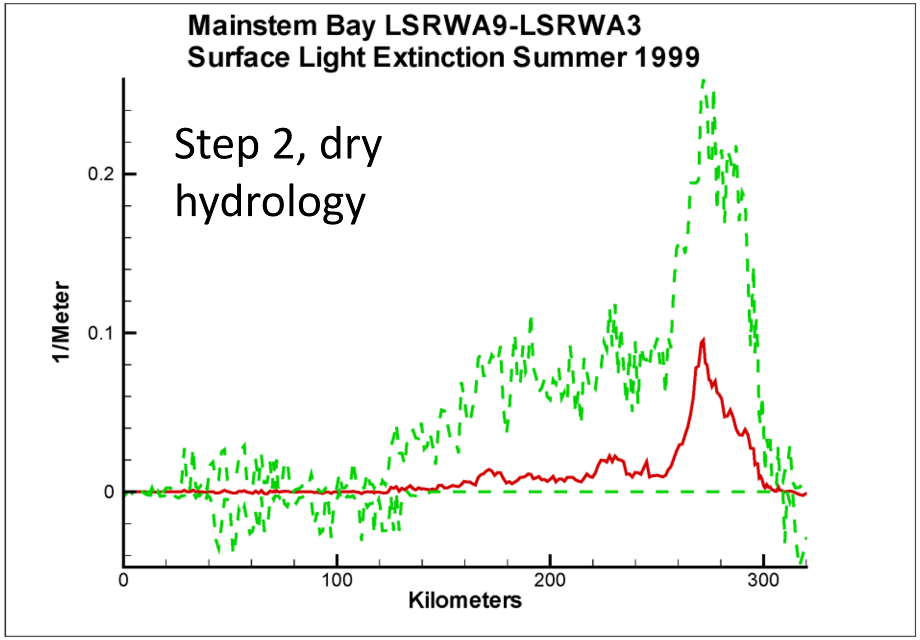

Mainstem Bay LSRWA6-LSRWA3
Surface Chlorophyll Summer 1999
Step 1, dry
hydrology
ugm/L
Kilometers
0
100
200
300
1
2
3
4
5
6

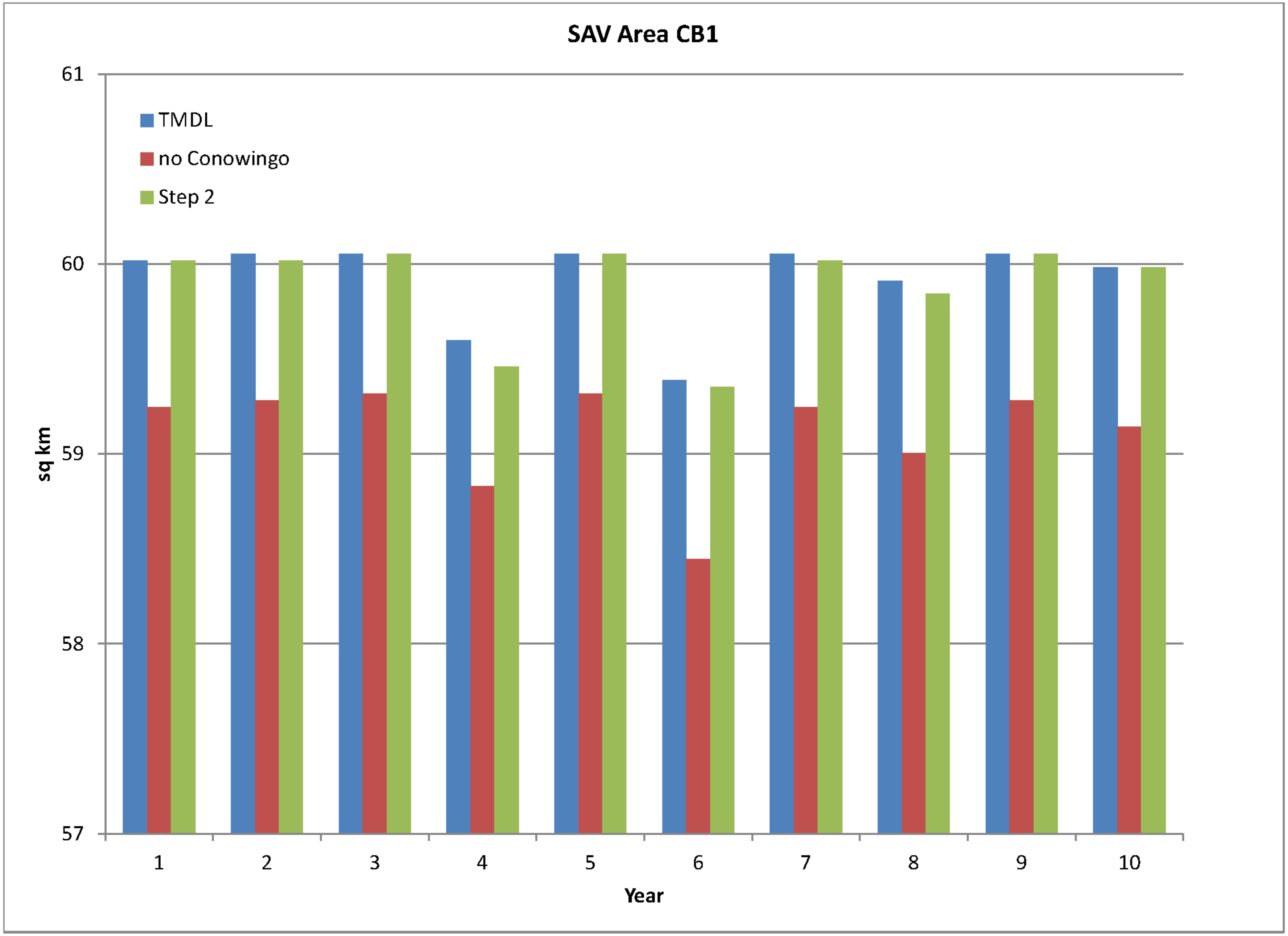

Mainstem Bay LSRWA9-LSRWA3
Surface Chlorophyll Summer 1999
Step 2, dry
hydrology
ugm/L
Kilometers
0
100
200
300
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4


Mainstem Bay LSRWA6-LSRWA3
Bottom Dissolved Oxygen Summer 1999
mg/L
Kilometers
0
100
200
300
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5

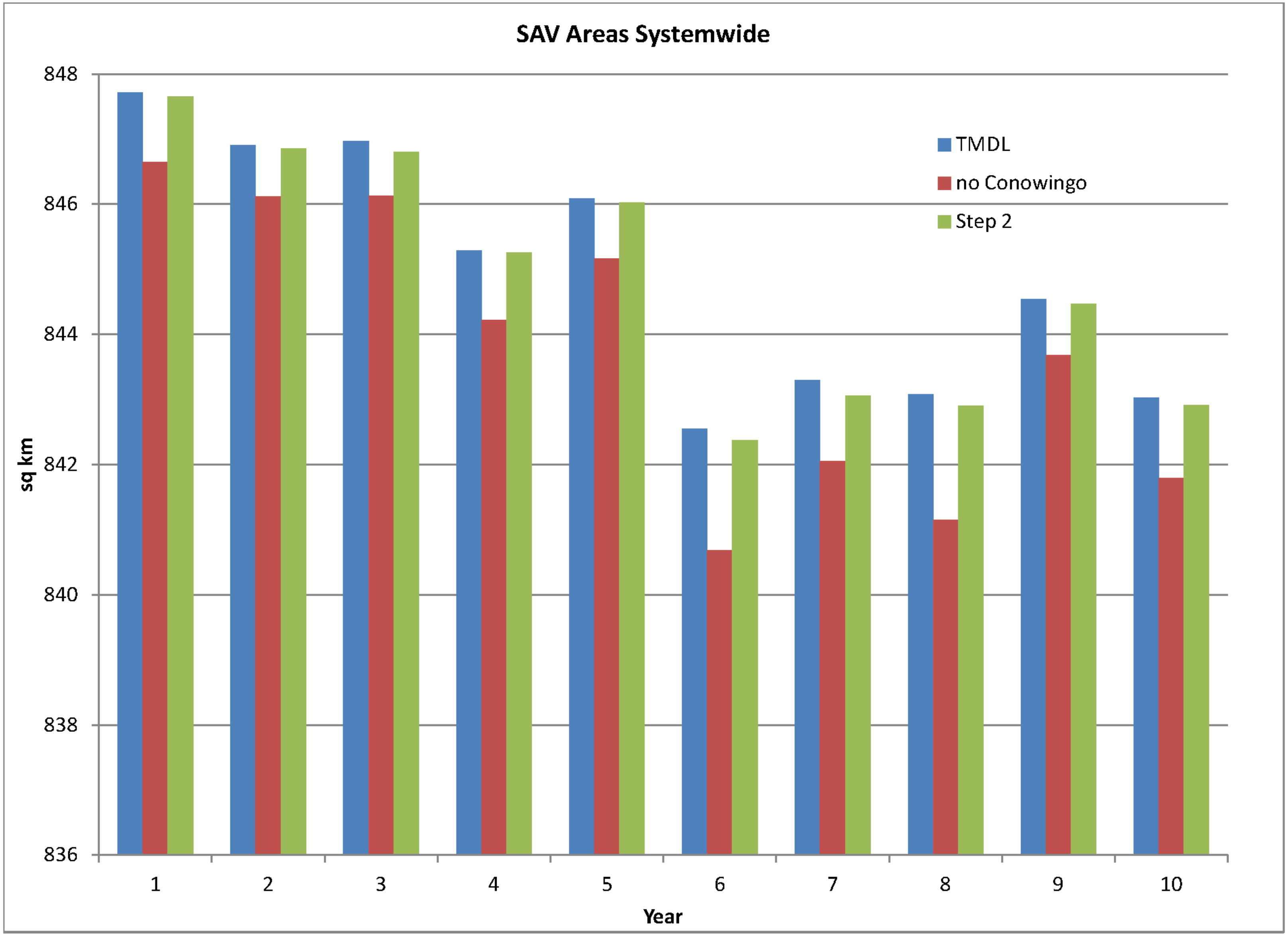

Mainstem Bay LSRWA9-LSRWA3
Bottom Dissolved Oxygen Summer 1999
mg/L
Kilometers
0
100
200
300
0.1
0
-0.1


Mainstem Bay LSRWA6-LSRWA3
Surface Light Extinction Summer 1999
Step 1, dry hydrology
1/Meter
0
0.5
1
1.5
2
0
100
200
300
Kilometers


Mainstem Bay LSRWA9-LSRWA3
Surface Light Extinction Summer 1999
Step 2, dry hydrology
1/Meter
0
0.1
0.2
0
100
200
300
Kilometers

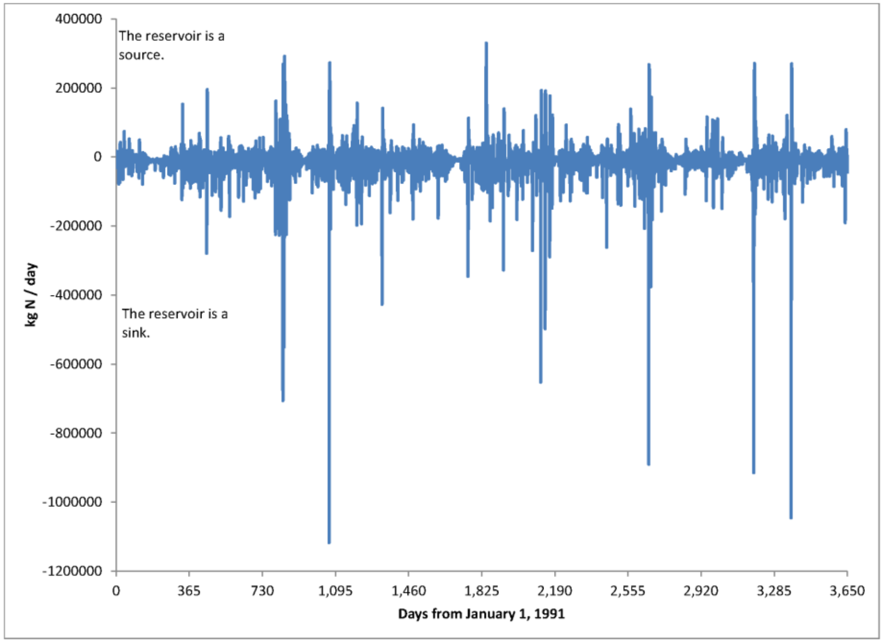


SAV Area CB1
61
60
59
58
57
TMDL
no Conowingo
Step 2
sq km
1
2
3
4
5
6
7
8
9
10
Year


SAV Areas Systemwide
848
846
844
842
840
838
836
sq km
1
2
3
4
5
6
7
8
9
10
Year
TMDL
no Conowingo
Step 2

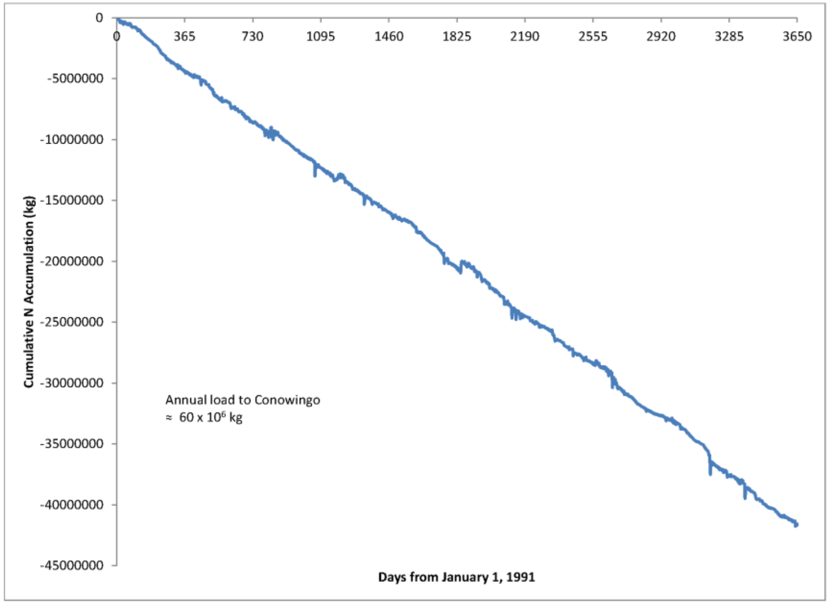
Net Source or Sink?

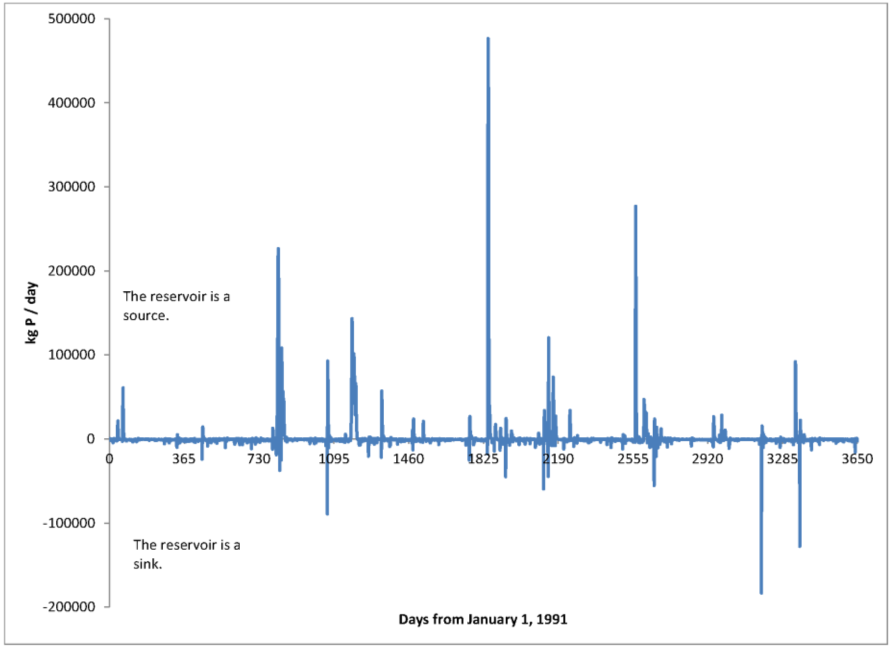
- We have three runs:
  1. 2010 Progress Run
  2. 2010 Progress Run with no Conowingo Reservoir
  3. 2010 Progress Run with Step 2 erosion
- If we take 3 minus 2, we get settling (negative) or scour (positive). We can also run a total to get accumulation (negative) or erosion (positive).



Daily Nitrogen Erosion/Settling

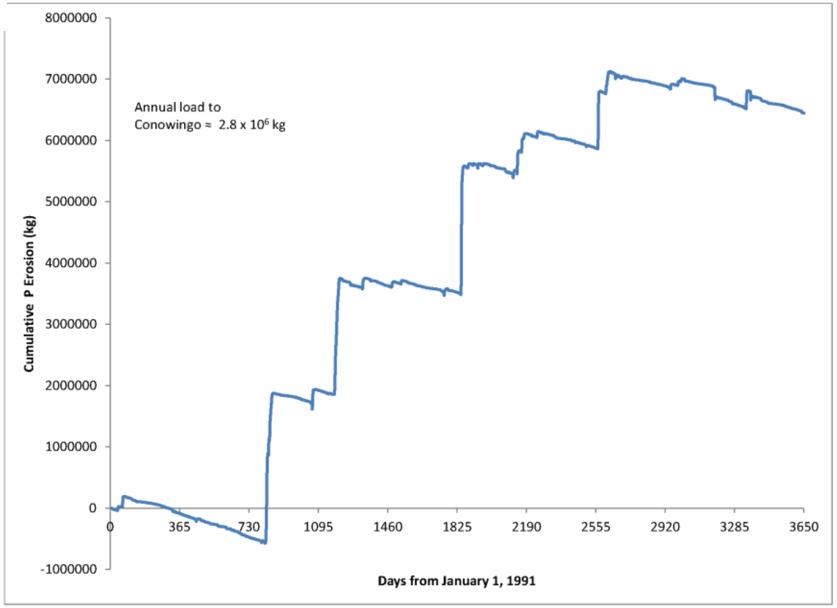
Cumulative Nitrogen Accumulation

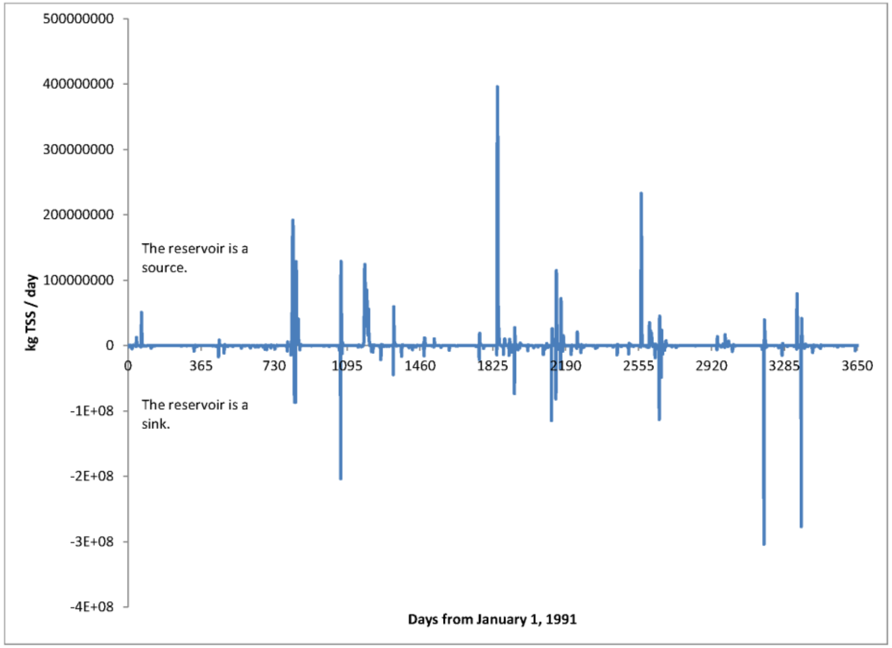




Daily Phosphorus Erosion/Settling

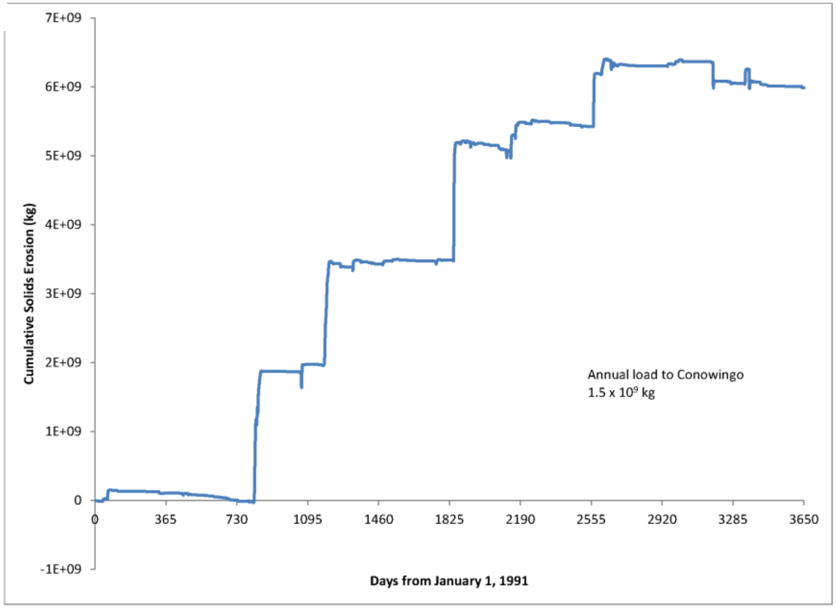
Cumulative Phosphorus Erosion





Daily Solids Erosion/Settling

Cumulative Solids Erosion



Net Source or Sink?

- We are overestimating the net erosion of TSS and P in our Step 2 runs and/or
- We are overestimating the frequency of scour events.
  - Possibly our threshold for erosion is too low.
  - The bed should armor during scour events.
  - Or we could have a greater settling velocity of solids in the reservoir.
  - The reservoir should fill back in following a major scour event.
- We really need a mass balance in the bed of the Conowingo Reservoir.

I’m Puzzled

- I really don’t know what we expect the future Conowingo Reservoir to look like.
- A system with no settling and constant leakage of suspended material over the dam?
- A system with a frequent string of small erosion events that resembles constant leakage?
- A system with rare, major erosion events followed by periods of infilling?
- ??????

Present Indications

- All runs (constant spillage vs. erosion events) indicate summer-average DO depression 0.1 to 0.2 mg/L below currently-projected TMDL levels.
- All runs indicate summer-average chlorophyll increase 1 ug/L above currently-projected TMDL levels.

Present Indications

- All runs indicate minimal effect on projected SAV coverage.
  - We consider light availability only. Not scour or burial or similar effects.
  - We have not examined a major growing-season storm.
- Effects of spillage events are concentrated in the upper 20 km of the bay .
- Effects of erosion events move much further down the bay and even into the lower Potomac River.