

Historical Context – 1983 Algae Bloom and Potomac Estuary Modeling

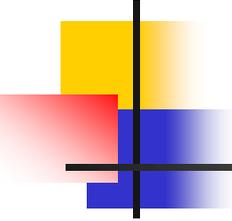
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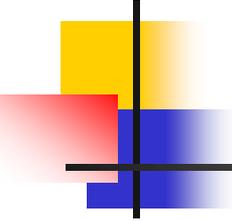
Metropolitan Washington Council of Governments

July 11, 2011



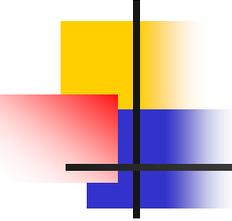
Early History

- 1938 Blue Plains opens as 130 mgd primary treatment plant
- 1948 Congress enacts 1st Federal Water Pollution Control Act
- 1956 Congress extends and amends FWPCA
- 1957-8 First Potomac Enforcement Conference sets goal of secondary treatment for Potomac wastewater plants
- 1965 President Johnson declares Potomac “a national disgrace” and sets 1975 cleanup goals
- 1966 drought: Potomac estuary experiences very low dissolved oxygen, major algal blooms
- 1969 – Potomac Enforcement Conference



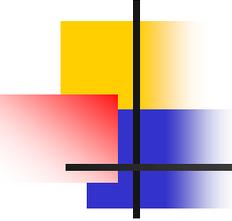
1969 Potomac Enforcement Conference Limits for Blue Plains

- 96% reduction in TP, 85% in TN
- At 309 mgd, TP = 0.22 mg/l and TN = 2.4 mg/l
- Technology did not exist to achieve TN levels and there is some debate about whether limit was TN or intended to be TKN
- PREC appears to have taken 3 years to be concluded allowing time for EPA technical studies
- Compliance expected by 1977



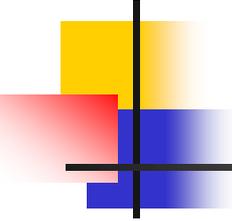
1971 EPA Tech Report #35

- Study requested by Secretary of Interior in Nov. 1969
- Study included the determination of maximum pound loading limits for various pollutants to confirm and refine PREC limits and also an evaluation of the feasibility of using the upper Potomac estuary as water supply source



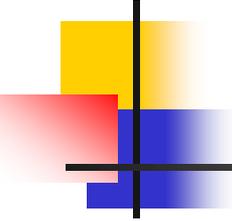
1971 EPA Tech Report #35 ...

- Modeled freshwater inflow of 300 cfs to estuary with goal of limiting TP to 0.067 mg/l, inorgN to 0.5 mg/l and chl-a to 25 µg/l
- Set maximum TP and TN loadings for zones in Potomac estuary
- Led to Blue Plains limits of TP=560 lb/d, TN=6130 lb/d (Note: Q=309 mgd)
- Study includes a host of assumptions about water withdrawals and wastewater flows that are significantly different from what actually happened



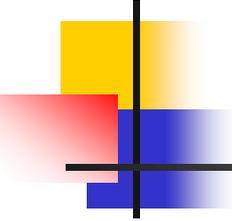
History: 1970-1974

- 1970 EPA created
- 1972 Clean Water Act Passed, established NPDES system, set “fishable and swimmable goals”, water quality standard regulatory scheme
- 1974 Blue Plains NPDES permit set at TP=560 lb/d and TN=6,130 lb/d with compliance by 1978



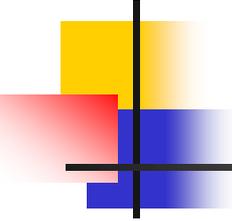
History: 1974-1979

- 1974 Blue Plains treatment capacity limited to 309 mgd when Dept. of Interior refuses to allow filling of mudflats (1969 design was for 419 mgd to handle year 2000 flows)
- 1975 EPA Regional Administrator deletes TN requirement due to cost, and to allow time for studying the effectiveness of phosphorus control
- 1979 EPA issues renewal permit for Blue Plains with TP limit of 560 lb/d but no TN limit (only TKN)



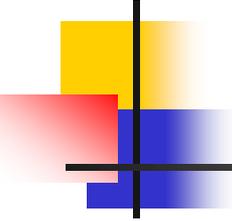
History 1979-1981

- 1979 Staged compliance order issued simultaneously with final implementation by mid-1983
- 1979 EPA requires Blue Plains Feasibility Study after 208 Planning fails to reach conclusion on regional wastewater plan
- 1979 Permit challenged seeking to reinstate TN limit
- 1981 EPA upholds permit with no TN limit after extensive adjudicatory hearing—evidence presented that water quality had improved in the 1970s (though BP and other plants had not achieved permit limits)



1981-1982

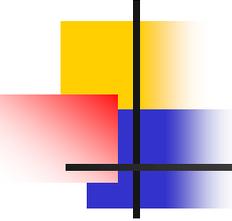
- 1981 Blue Plains Feasibility Study initiated to examine management of regional wastewater needs through 2005; uses PEM for water quality alternatives analyses (for eutrophication)
- 1982 Potomac Eutrophication Model (PEM) calibrated and verified to 1966-1979 data
 - (real time 1-dimensional eutrophication model with tidal average hydrodynamics)
 - 23 main stem segments, 15 embayments
 - 1 algal species, sediment flux – boundary condition
 - Key state variables – P (DIP, PIP, DOP, POP), N (DIN, DON, PON), Chl-a
 - primary focus on freshwater (upper 50 miles of) Potomac estuary
 - developed through COG with major consultant support from HydroQual (Thomann and Fitzpatrick))



1983 – Before the Bloom

- 1983 - Feasibility Study reaches initial conclusion that Blue Plains could be expanded on existing site to 370 mgd, expected 2005 capacity need
- 1983 Feasibility Study examines effluent limits less stringent and more stringent than existing permit, leans toward seasonal TP limit of 0.35/4* , leans against TN removal due to belief that P control will limit algal growth, high cost, and potential for N-fixing blue green algae proliferation

*0.35 mg/l 4/1-10/31; 4 mg/l 11/1-3/31



The 1983 Algae Bloom

“For many who have struggled for years to understand the eutrophication of the Potomac Estuary, have invested large sums of money in nutrient control or have used this marvelous body of water in their recreation or commerce, the occurrence of a severe algal bloom in 1983 was a source of frustration, disappointment, and in some cases anger and accusation. The Potomac Estuary Community, including all those concerned with the water quality, ecology and aesthetic beauty of the estuary have spent more than 15 years in a search for an equitable and effective solution to the algal nuisance conditions of the late 1960s and 1977.

The installation of phosphorus removal at Blue Plains ... was greeted with a firm sense of hope that the estuary was going to be brought under some measure of control. But the Potomac was more elusive than originally thought...In 1983, it was as if the Estuary once more escaped our balanced attempts at control.”

*From the Foreword of the 1983 Expert Panel Report, Robert V. Thomann,
Chairman, March 14, 1985*



Elodea Cove (River Mile 20)

September 8, 1983



Potomac estuary algal bloom

August, 1983

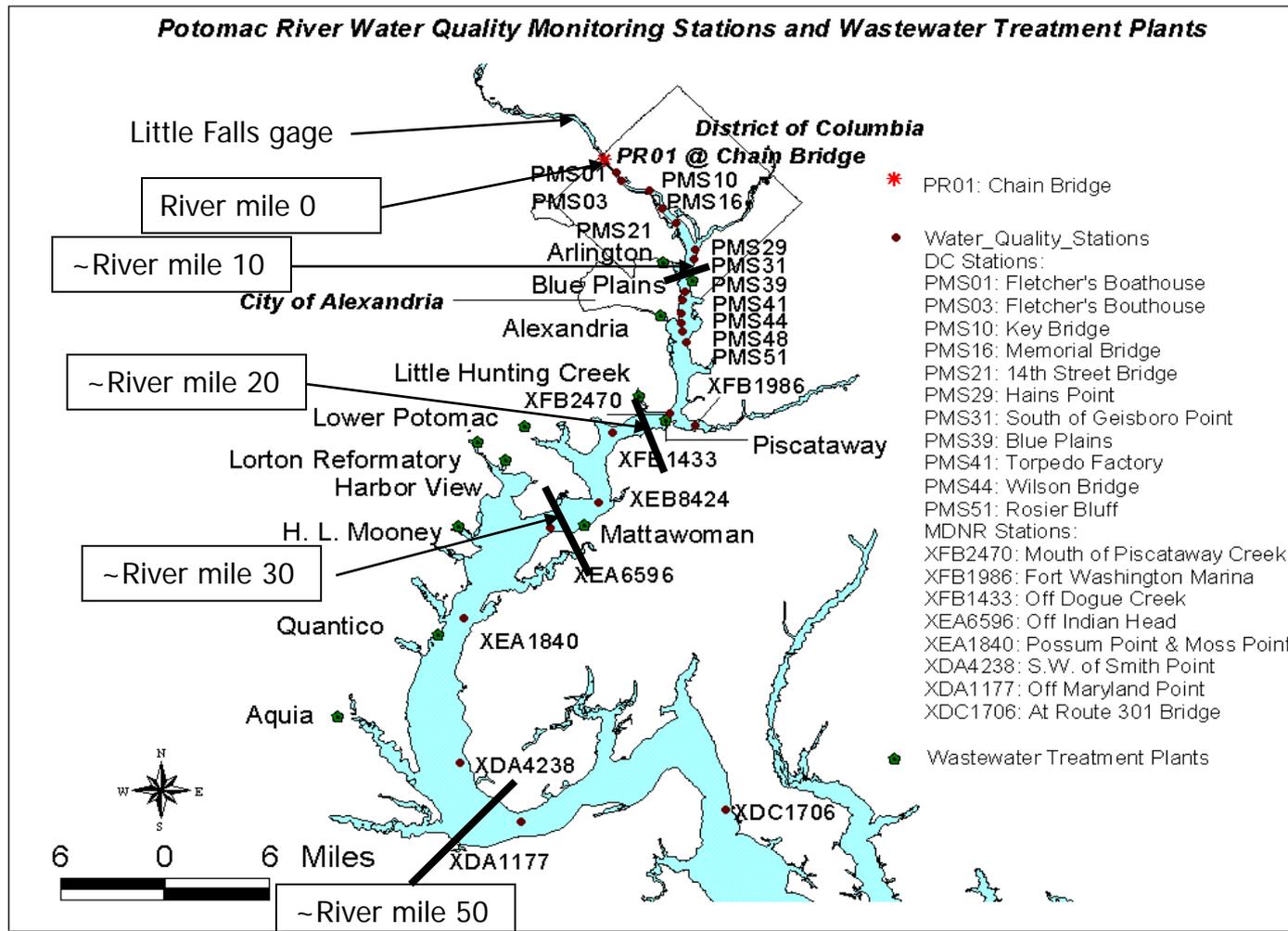


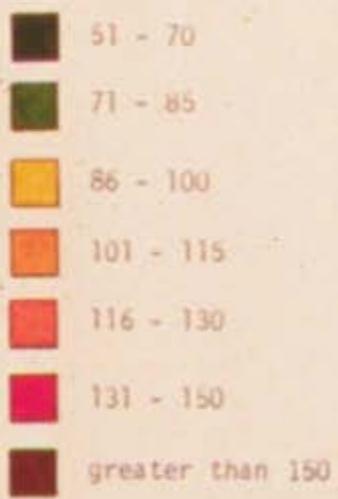
Potomac Estuary Algal Bloom

August, 1983

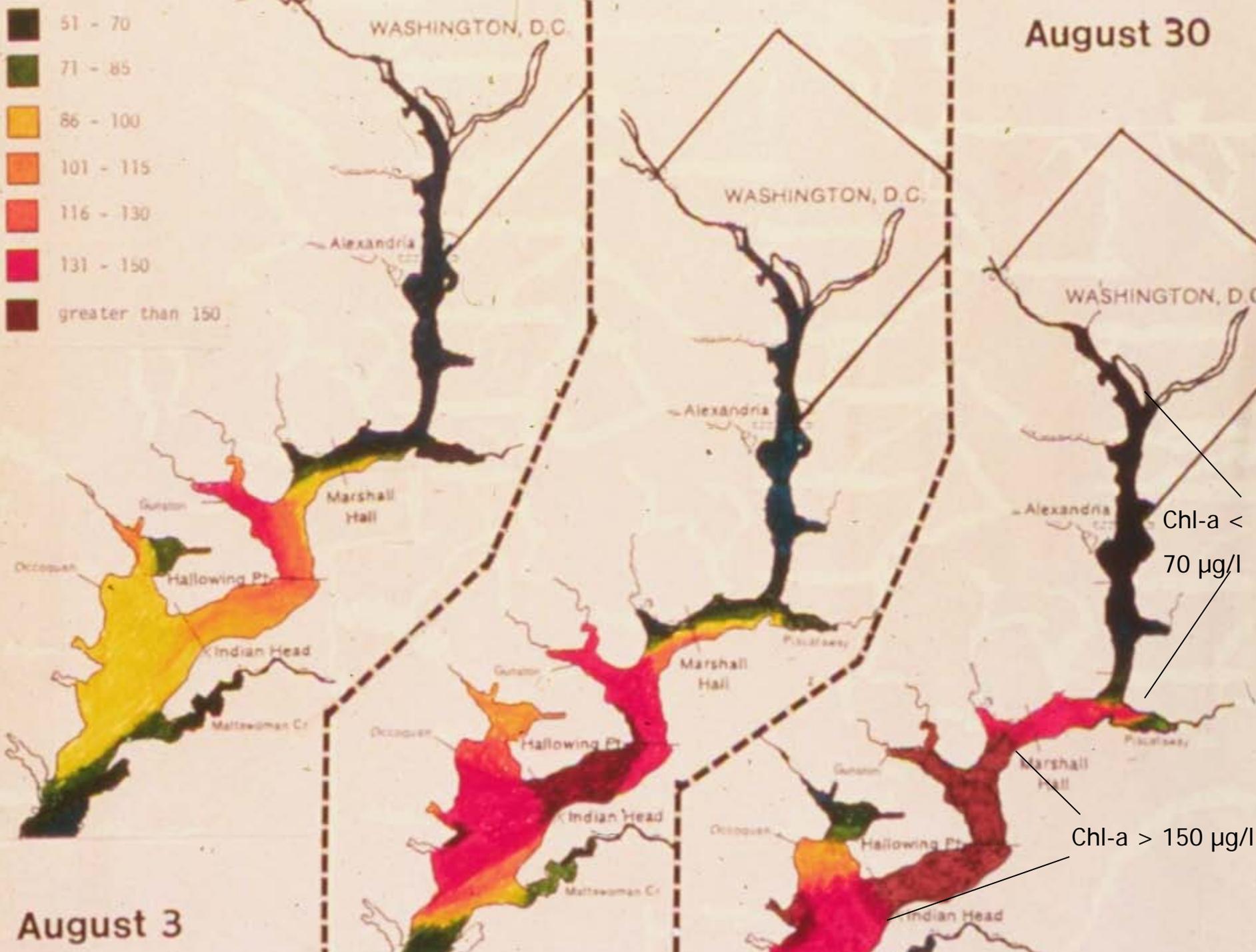


Potomac Estuary Data Stations

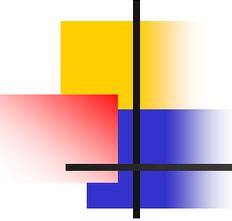




August 30



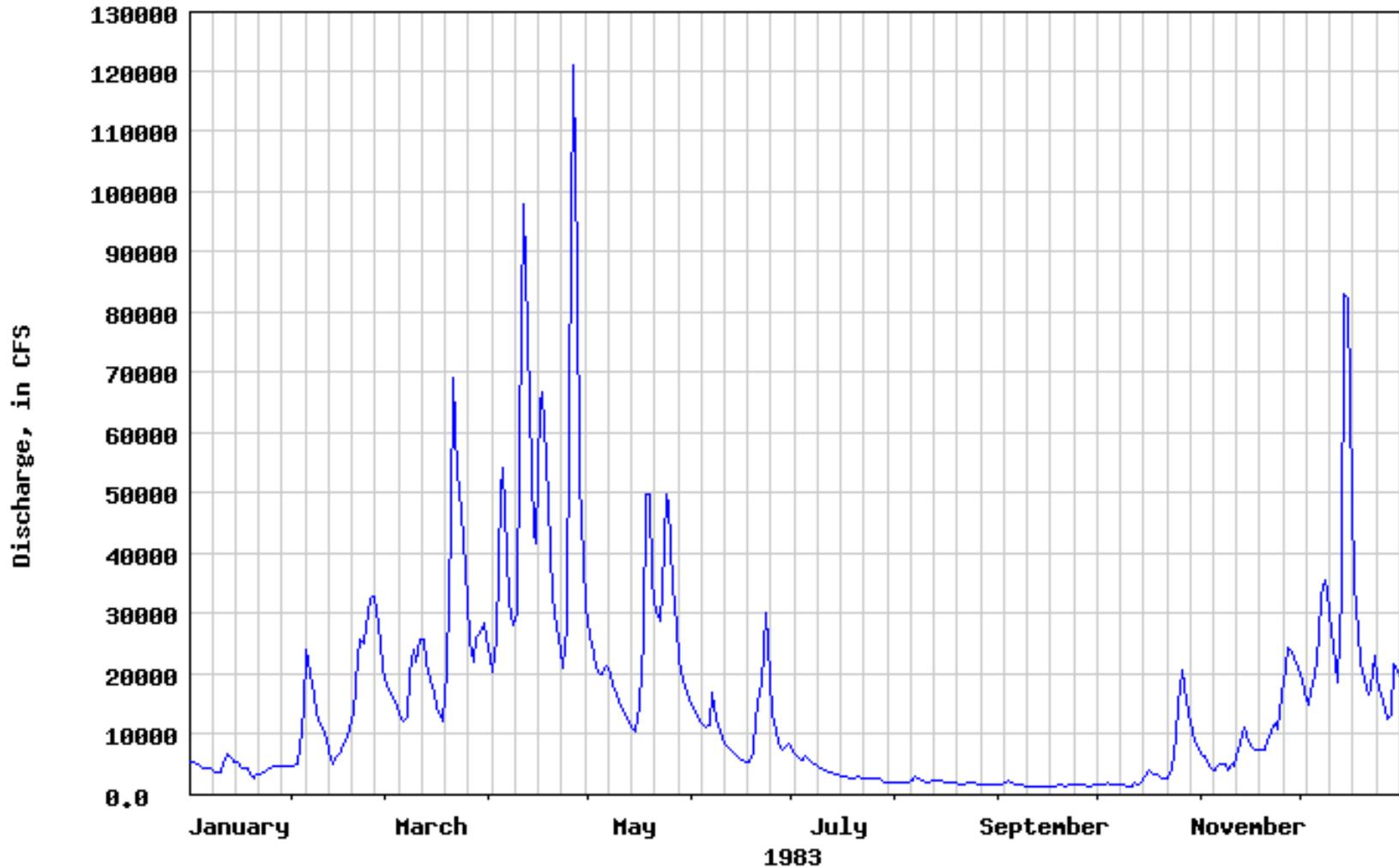
August 3



1983 Algal Bloom Statistics

- Began late July, ended in October
- Wet spring, hot dry summer, low wind
- Blue Plains
 - TP 1,250 lb/d (approx. 0.5 mg/l)
 - TN 40,000 lb/d (approx. 16 mg/l)
- Peak Chl-a levels 250 µg/l with up to 800 µg/l in embayments—primary species *Microcystis aeruginosa* (blue-green algae also dominant in 1960s)
- pH levels over 10 in bloom area
- Unusually low upper estuary alkalinity

1983 Hydrograph: Little Falls

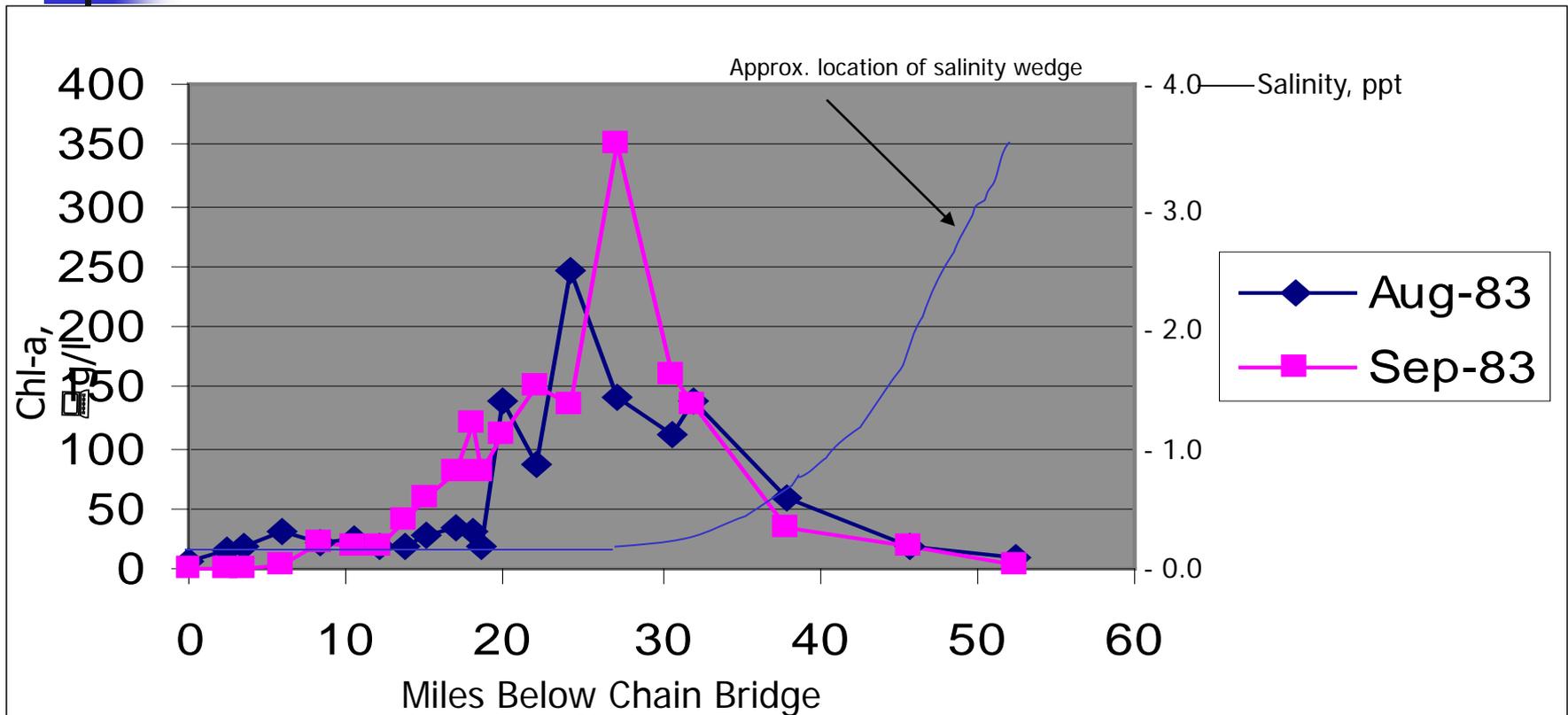


Summer avg=3899 cfs; Aug-Sep avg=1692 cfs

Legend: — Discharge, in CFS
— Estimated Discharge, in CFS

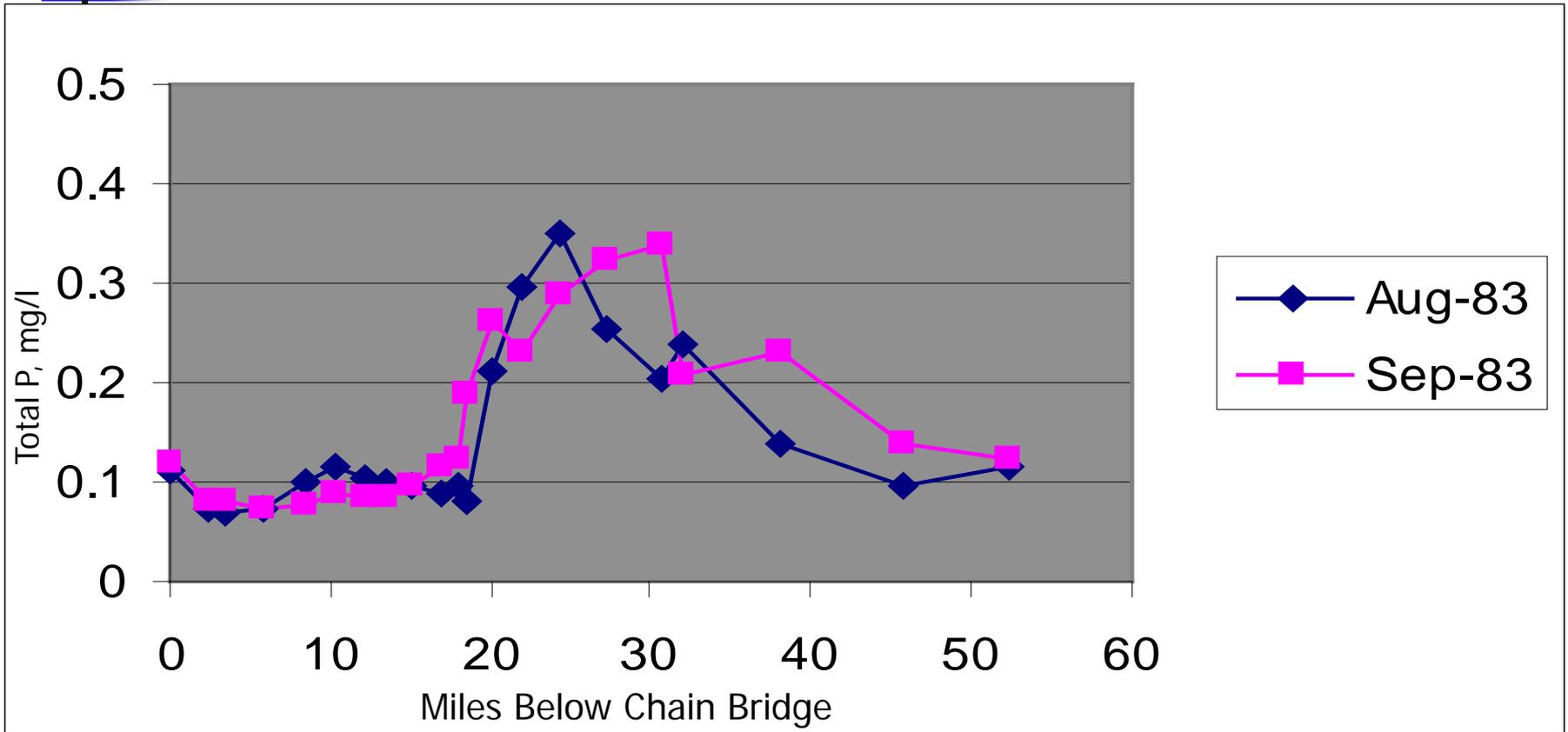


1983 Chlorophyll-a: August, 1983 and September, 1983



Note: data points represent weekly averages

1983 Total Phosphorus: August, 1983 and September, 1983



Note: data points represent weekly averages

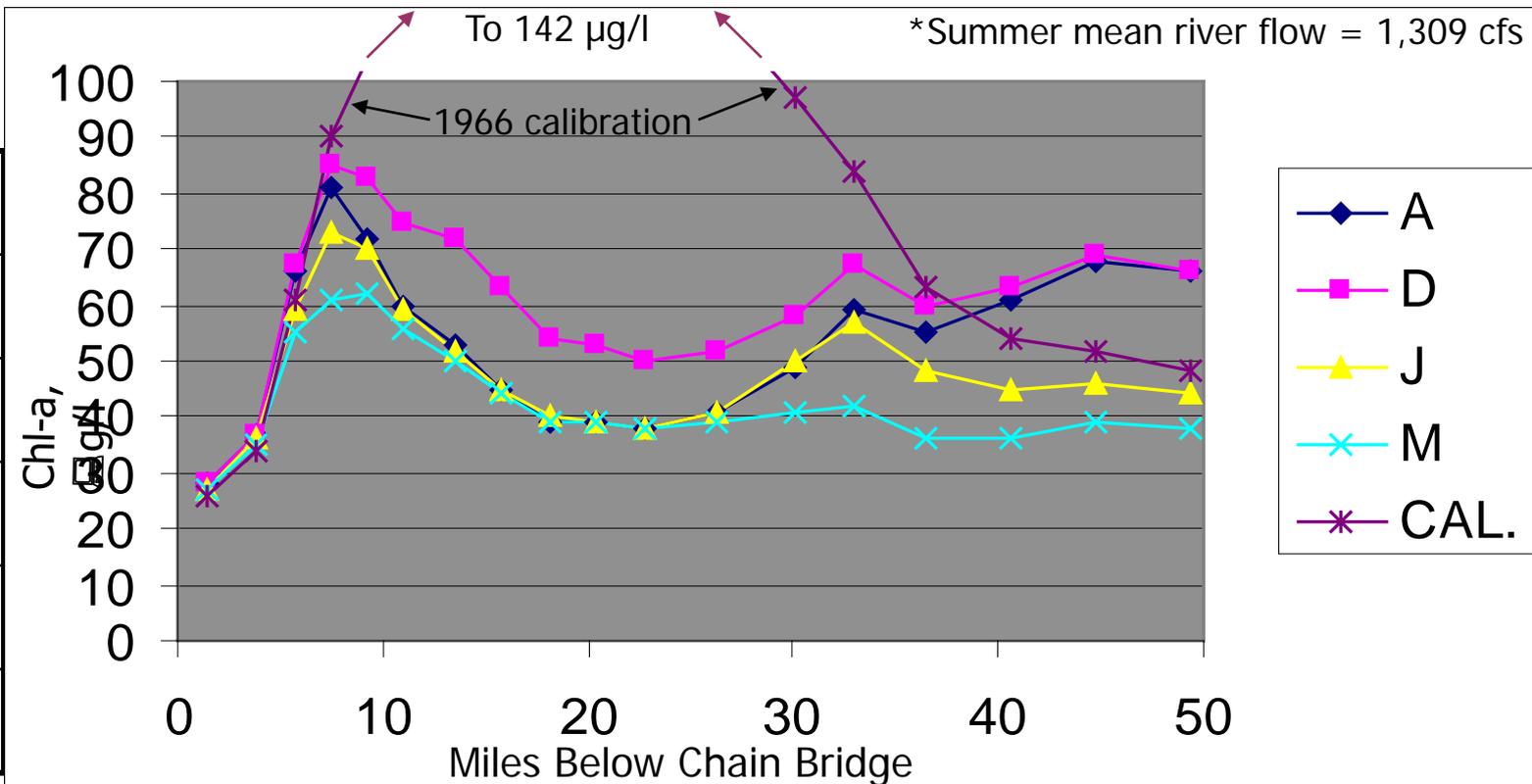


Blue Plains Feasibility Study Model Results (1966, chl-a)

Extreme low flow hydrology (1966)

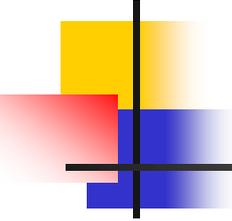
*Summer mean river flow = 1,309 cfs

Alt.	TP	TN
A	0.18	14
D	0.35	14
J	0.18	5
M	0.18	3
CAL	8	20



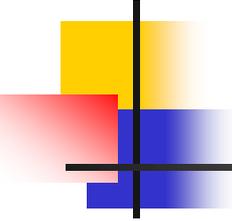
*Summer defined as day 170-260 (approx. calendar summer)





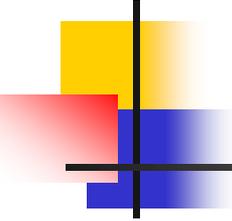
Blue Plains Feasibility Study Recommendations (8/1984)

- Until such time as a program formulated around the model based effluent limits can be further evaluated and recent algal conditions resolved, it is recommended that:
 - TP = 0.18 mg/l
 - TKN = 1.99 mg/l (No TN removal)
- These are “hold the line” limits – e.g., load remains same while flow increases from 309 mgd to 370 mgd at Blue Plains



1983 Algal Bloom Expert Panel Conclusions (3/1985)

- Environmental conditions ideal
- Intensification of bloom to 250 $\mu\text{g/l}$ due to positive feedback system: algal growth raises pH, increases sediment phosphorus flux thereby supporting greater growth of algae
- Low alkalinity (from high spring runoff) in estuary contributing factor
- PEM predicted phosphorus controls should have limited bloom to about 100 $\mu\text{g/l}$ chl-a
- >100 $\mu\text{g/l}$ chl-a defines an undesirable Potomac nuisance algal bloom



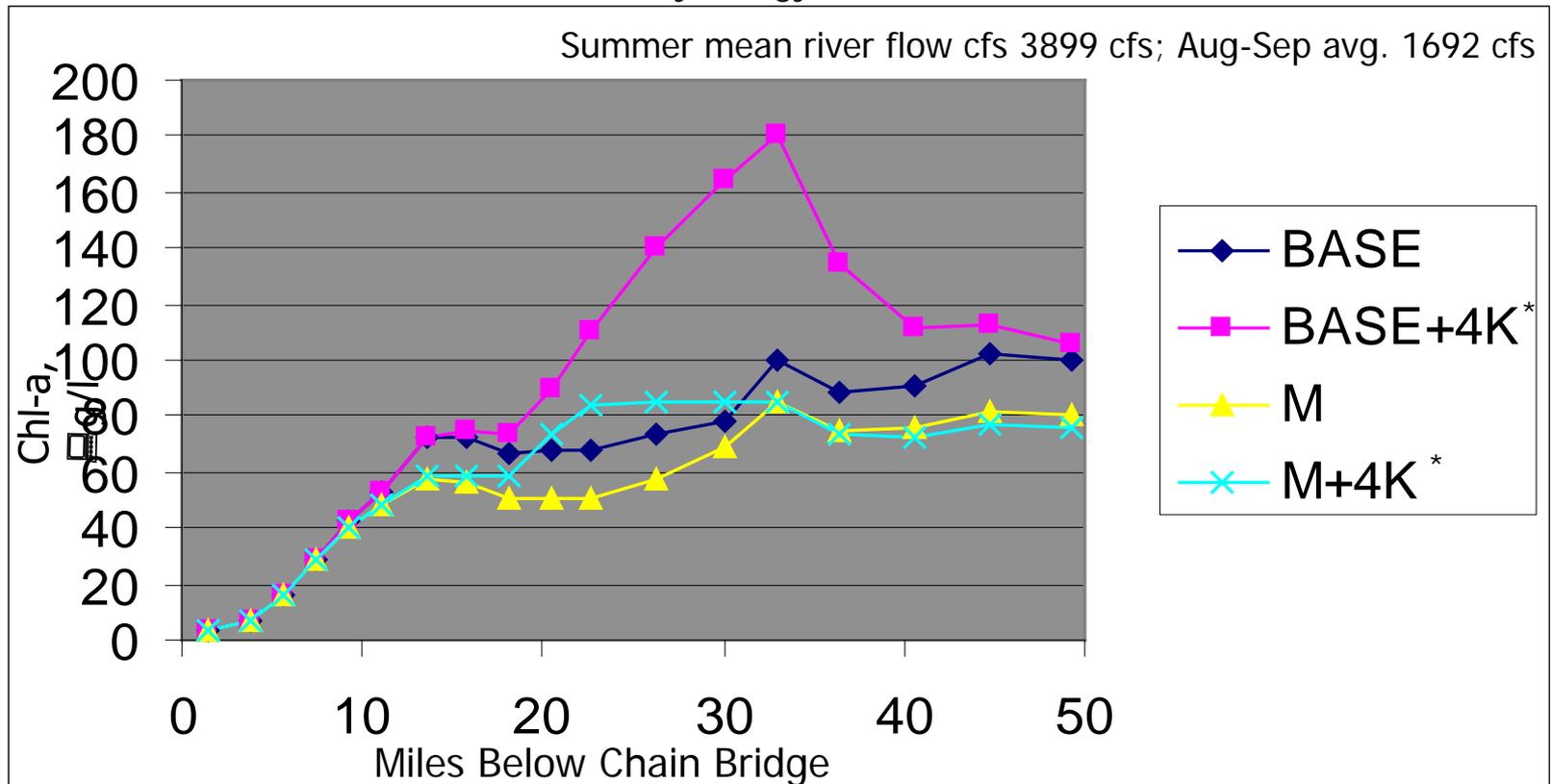
1983 Algal Bloom Expert Panel Recommendations (3/1985)

- Study means of controlling alkalinity
- Upgrade PEM
- To reduce likelihood of massive blooms >250 $\mu\text{g/l}$, maintain TP control at point sources, attempt to control sediment P (via pH control), reduce upstream loading sources
- To keep algal levels <100 $\mu\text{g/l}$ chl a , control TN and TP at point sources OR reduce upstream TP and TN while maintaining point source TP control

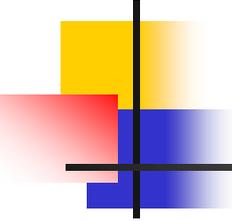
PEM Post-Audit Analyses: August 28, 1983

1983 Hydrology

Summer mean river flow cfs 3899 cfs; Aug-Sep avg. 1692 cfs



* "4K" refers to 4000 lb/d extra sediment phosphorus load artificially added to model in bloom area to simulate pH-enhanced sediment release



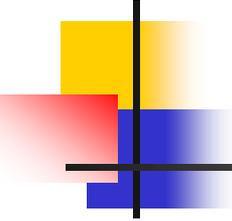
Expert Panel – Modeling, Monitoring, Research Recommendations

■ Field and lab studies

- Evaluate pH effects on P and N sediment release
- Evaluate interaction of phytoplankton growth dynamics and pH, CO₂ and alkalinity balance
- Evaluate relationship between alkalinity in wastewater discharges and in the water column
- Continue/expand regular Potomac estuary monitoring program

■ Upgrade PEM

- Include pH, CO₂ and alkalinity chemistry/sediment chemistry
- 2-D downstream estuarine circulation
- More algal groups



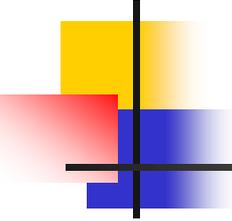
1985 Interim Control Decision:

- **Phosphorus**

- “Maryland, Virginia, DC and EPA agreed that a year round total phosphorus effluent limit of 0.18 mg/l should be required at all facilities discharging to the upper estuary (above mile 50 from Chain Bridge).”

- **Nitrogen**

- “Maryland, Virginia, DC and EPA agreed that in view of the remaining unresolved technical questions regarding the water quality benefits of nitrogen control and the substantial costs involved, it is premature to require point source nitrogen control at this time. However, denitrification must be retained as a real option for the future.”



1985 – early 1990s

- Seitzinger conducts studies on pH-mediated sediment phosphorus flux; demonstrates strong relationship
- PEM was partially upgraded (1988) to include an ability to model the pH-alkalinity chemistry observed in the 1983 bloom. Control of another “1983” bloom via alkalinity control did not appear promising.
- The potential for promoting nitrogen-fixing blue-green algae was examined (early 1990s). Under extreme low flow, such blooms may be favored but could be limited with phosphorus controls.
- All Potomac estuary wastewater treatment plants have regularly met the 0.18 mg/l P limit since 1985.
- Removal of nitrogen through BNR is ongoing at Blue Plains and being installed at the other facilities.
- Monitoring of the Potomac estuary has continued through the coordinated monitoring program.
- Ches. Bay Water Quality Model developed but does not explicitly model the algal speciation and chemistry in the Potomac estuary