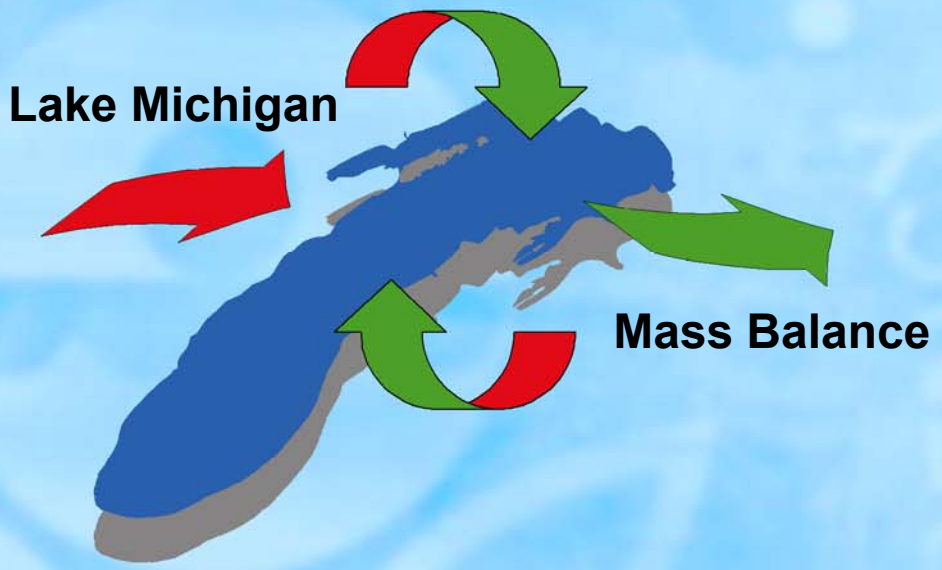
Lake Michigan Monitoring
Coordination Council
June, 2004
Muskegon, Michigan



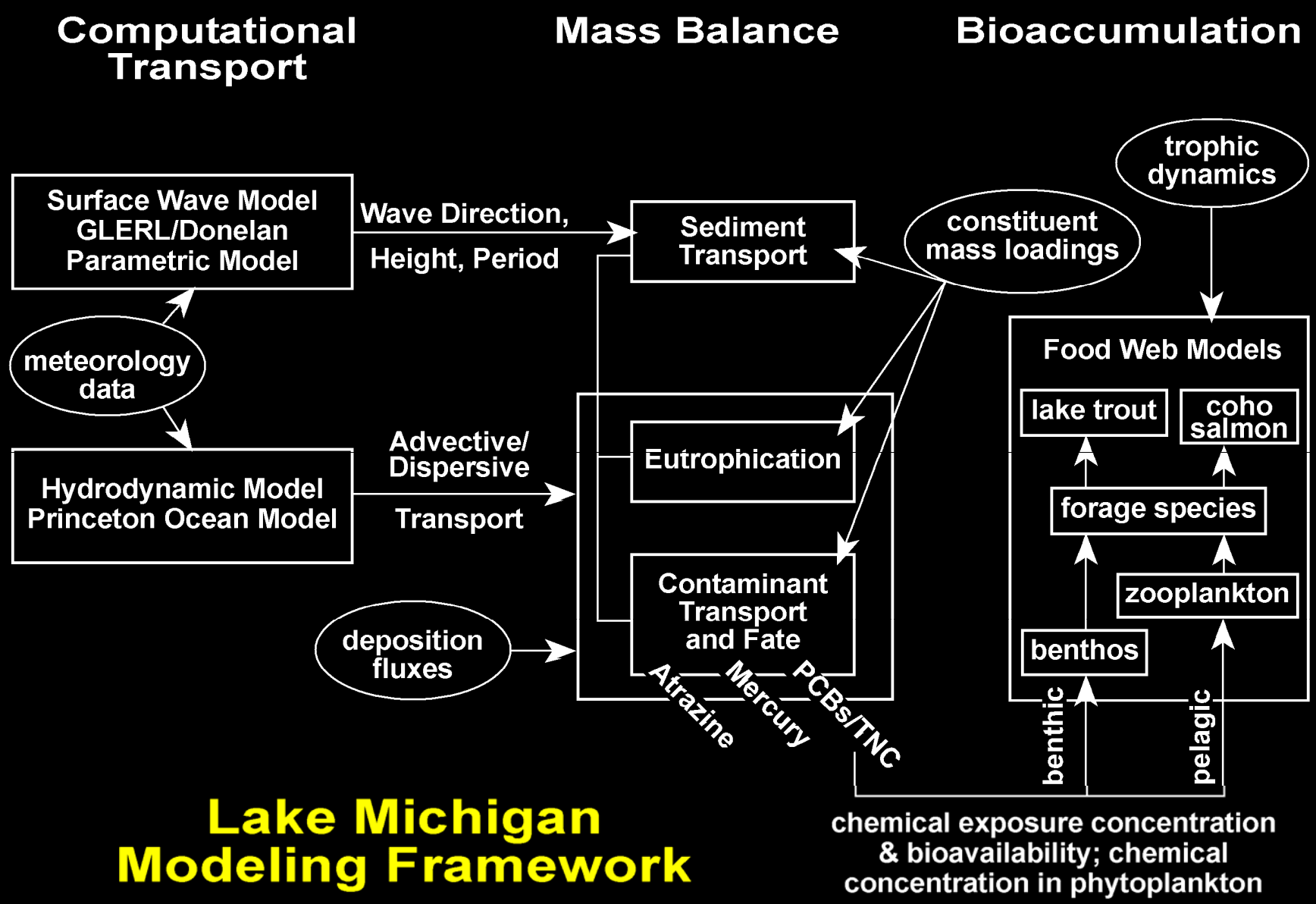
Russell G. Kreis, Jr., USEPA, ORD – Grosse Ile
Glenn J. Warren, USEPA, GLNPO
James Pauer, Welso – Grosse Ile
Paul J. Horvatin, USEPA, GLNPO
Kenneth R. Rygwelski, USEPA, ORD – Grosse Ile
Xiaomi Zhang, Welso – Grosse Ile
Kay Morrison, CSC – Grosse Ile

Lake Michigan Mass Balance Study Objectives

- Determine loading rates for critical pollutants from major source categories (tributaries, atmospheric, sediments)
- Comprehensively evaluate the relative loading rates by media
- Develop predictive capabilities through mathematical modeling
- Forecast the environmental benefits of specific load reduction alternatives
- Improve understanding of ecosystem cycling and dynamics of bioavailable contaminants

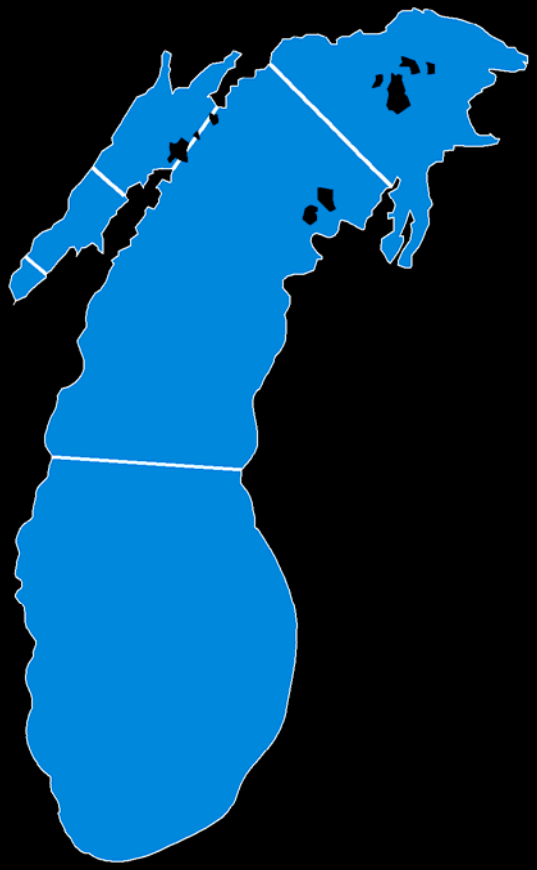
Lake Michigan Mass Balance Contaminants

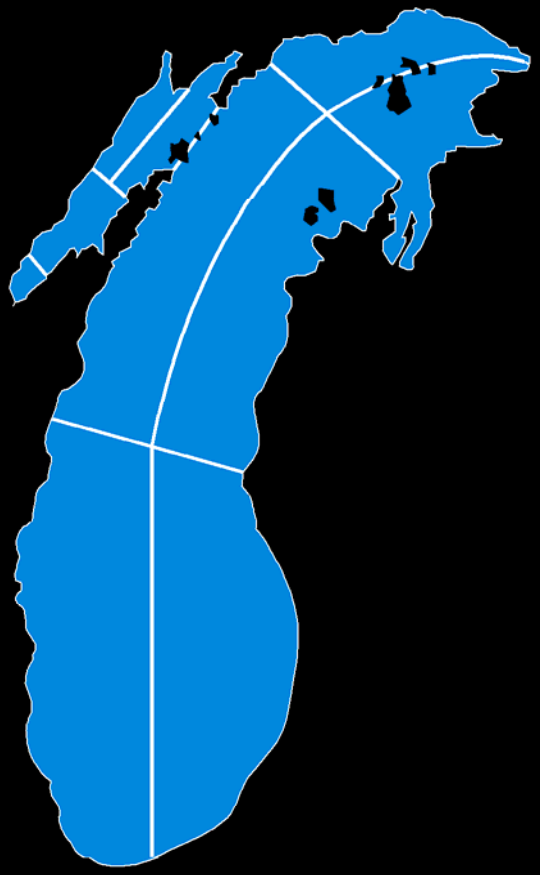
- **Nutrients / Dissolved Oxygen**
  concern for over-production of algae, undesirable species, anoxia/hypoxia, and other symptoms controlled by nutrients
- **Atrazine**
  potential concern for human and ecological effects; current use – herbicide
- **PCB Congeners**
  concern for fish consumption and ecological effects; banned substance
- **Trans-nonachlor**
  concern for fish consumption and ecological effects; cyclopentadiene pesticide, a breakdown product of chlordane; banned substance
- **Total Mercury**
  concern for fish consumption and ecological effects; multiple sources and uses

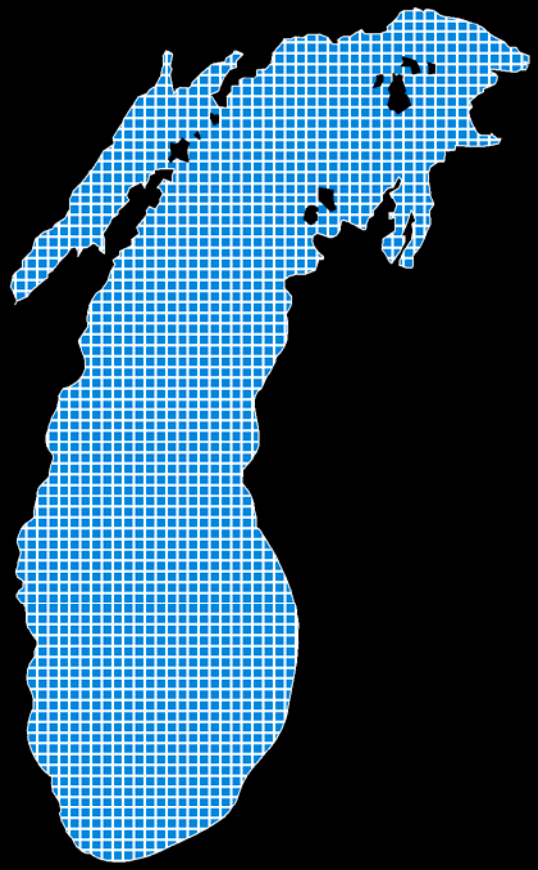


Lake Michigan Modeling Framework

Lake Michigan Mass Balance Project
Water Column Segmentation Scheme





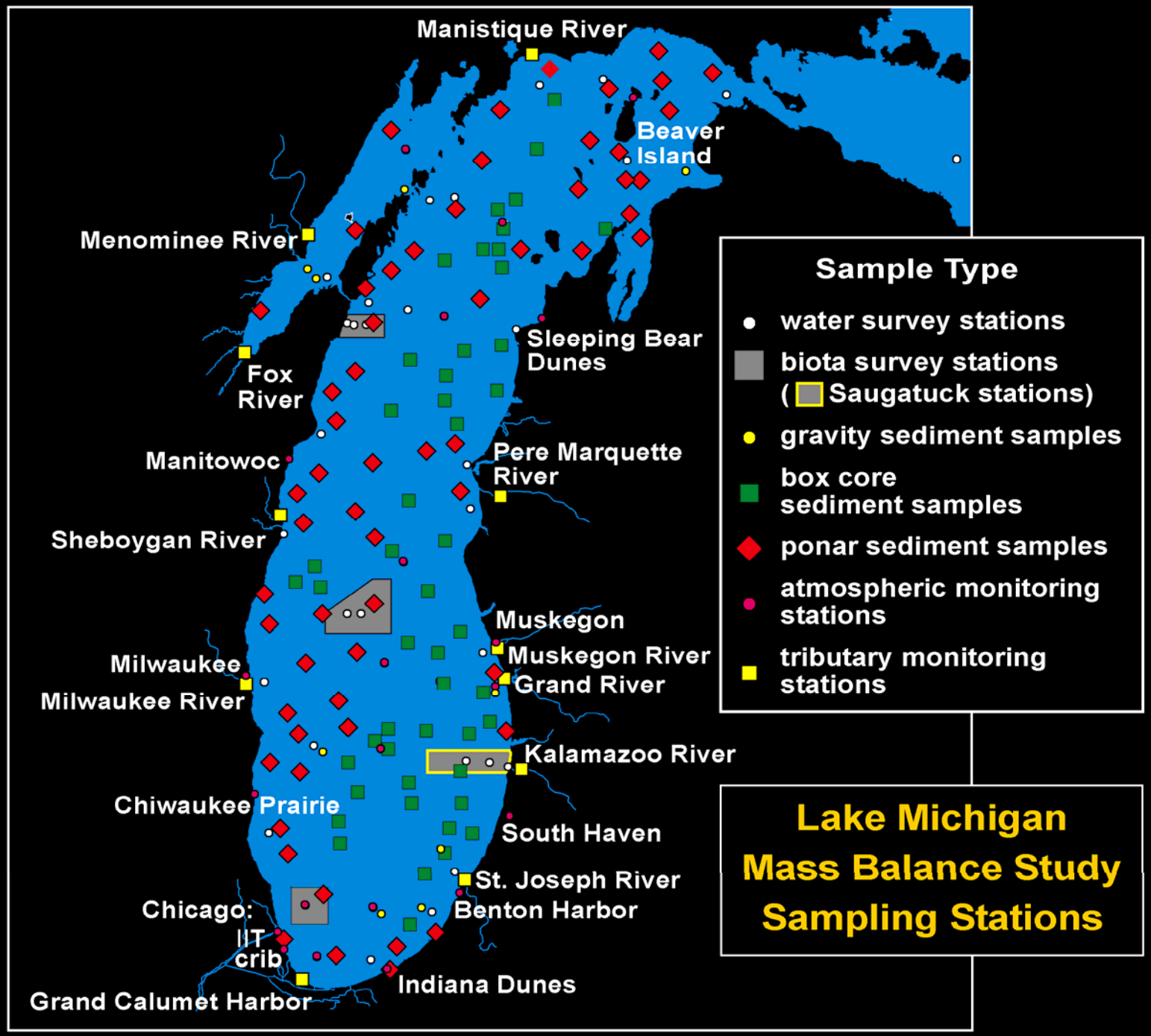


LEVEL 1 - MICHTOX
(Screening)
6 Surface Segments
9 Water Segments

LEVEL 2 - LM-2

10 Surface Segments
41 Water Segments

LEVEL 3 - LM-3
(High Resolution 5 km^2 Grid)
2318 Surface Segments
44,042 Water Segments
19 “Sigma” Levels


Manistique River
Beaver Island
Menominee River
Sleeping Bear Dunes
Fox River
Manitowoc
Pere Marquette River
Sheboygan River
Muskegon
Muskegon River
Milwaukee
Grand River
Milwaukee River
Kalamazoo River
Chiwaukee Prairie
South Haven
St. Joseph River
Chicago:
Benton Harbor
IIT crib
Indiana Dunes
Grand Calumet Harbor
Sample Type
water survey stations
biota survey stations
(Saugatuck stations)
gravity sediment samples
box core sediment samples
ponar sediment samples
atmospheric monitoring stations
tributary monitoring stations
Lake Michigan
Mass Balance Study
Sampling Stations

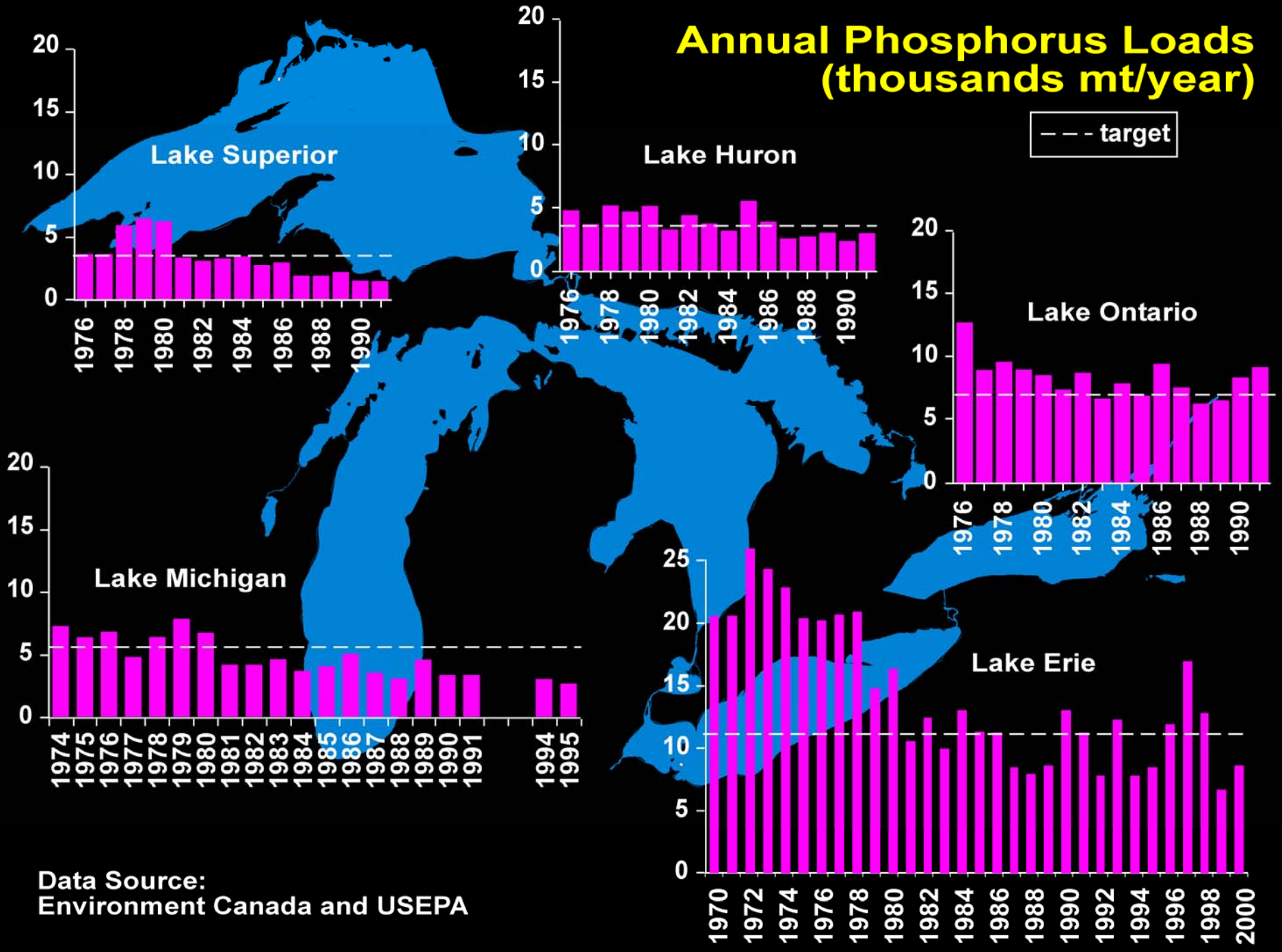
Target Phosphorus Loads and Associated Endpoints for the Great Lakes

	Target P* Load (MTA)	Target P** Concentration (µg/L)	CHL A** Concentration (µg/L)	Secchi (m)	Trophic Status
Lake Superior	3400	5	1	8	oligo
Lake Michigan	5600	7	1 - 3	9 - 12	oligo/meso
Lake Huron	2800	5	0.5 – 1.5	8	oligo
Georgian Bay	620	5			
North Channel	520	5			
Saginaw Bay	440	15	5 - 10	1 - 3	eutro
Lake Erie	11000				
Western Basin		15	5 - 10	1 - 3	eutro
Central Basin		10	3 - 6	4 - 8	meso
Eastern Basin		10	1 - 3	6 - 9	oligo/meso
Lake Ontario	7000	10	1 - 3	6 - 9	oligo/meso

* Great Lakes Water Quality Agreement, 1972; 1978; 1983; 1987

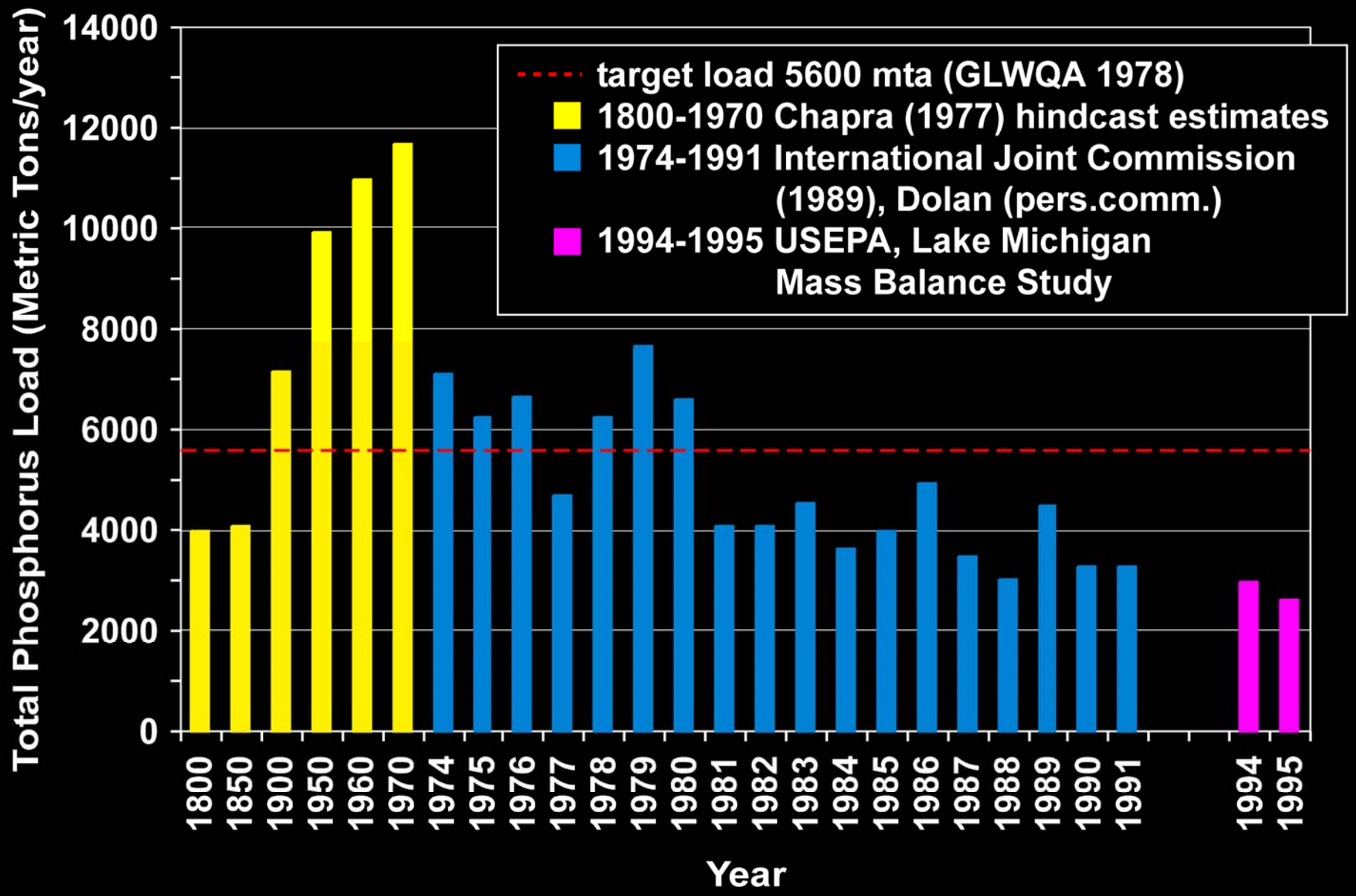
** Great Lakes Water Quality Board, IJC, 1987

Annual Phosphorus Loads (thousands mt/year)

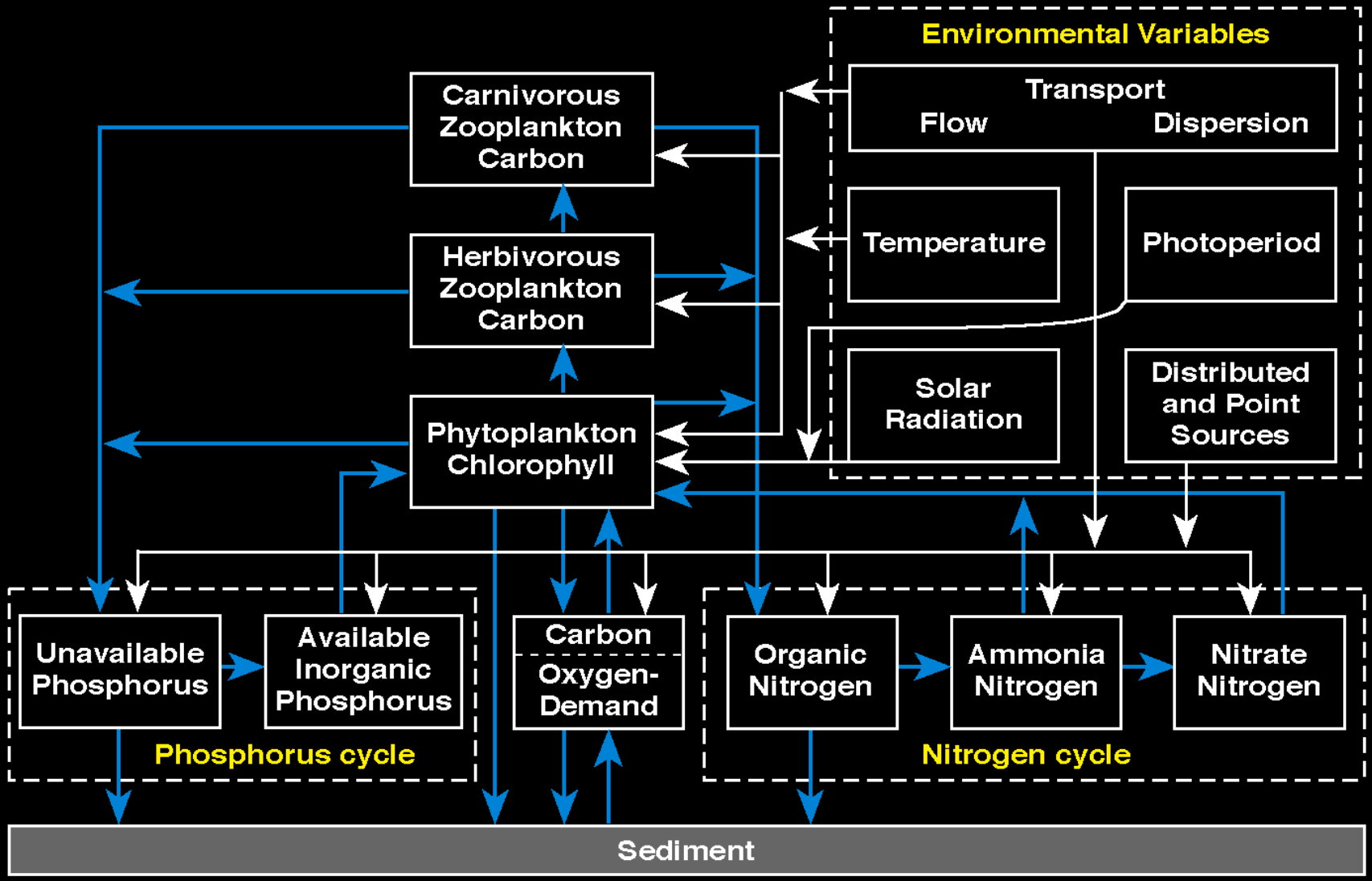


Data Source:
Environment Canada and USEPA

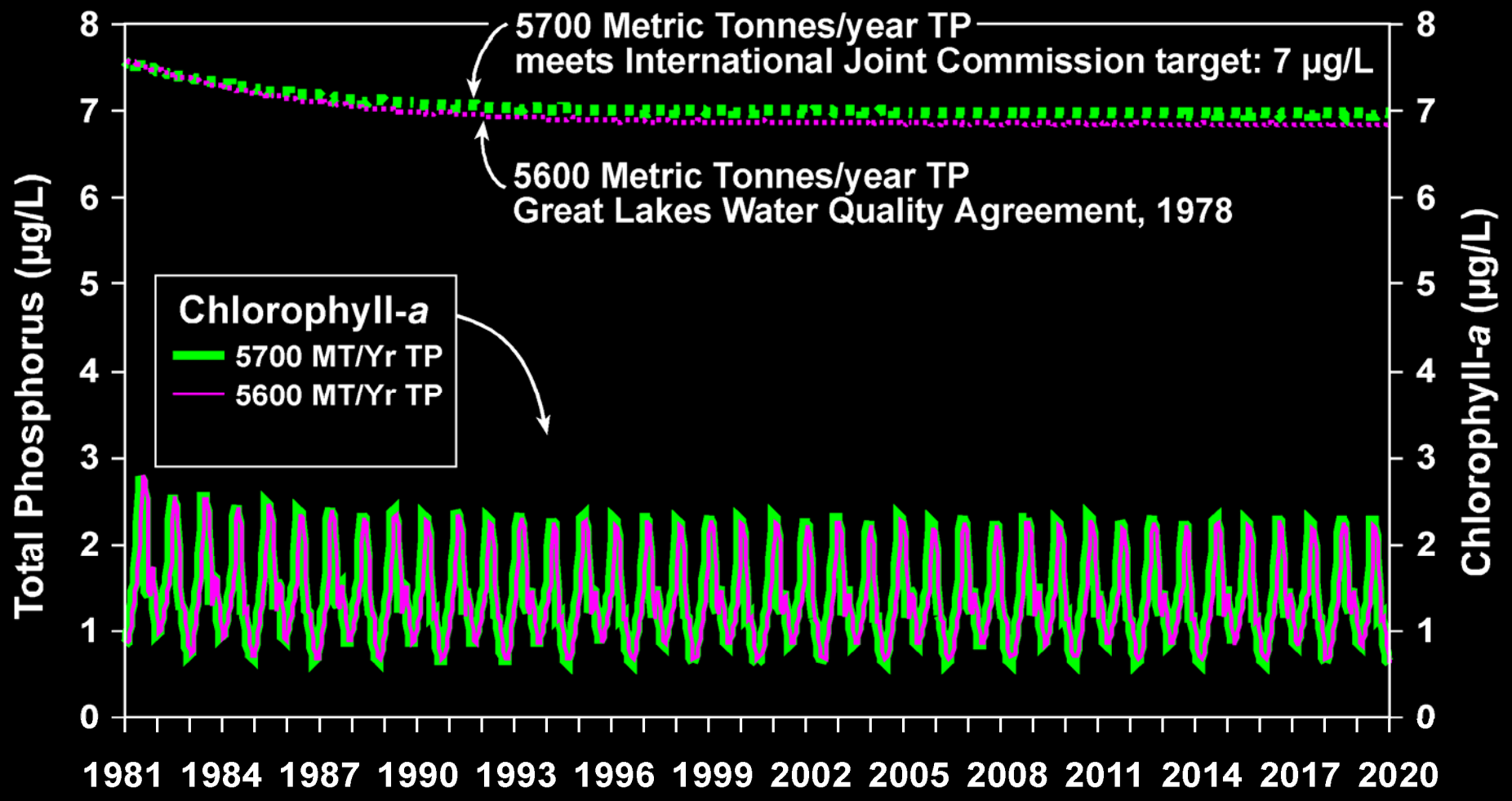
Annual Phosphorus Loading - Lake Michigan



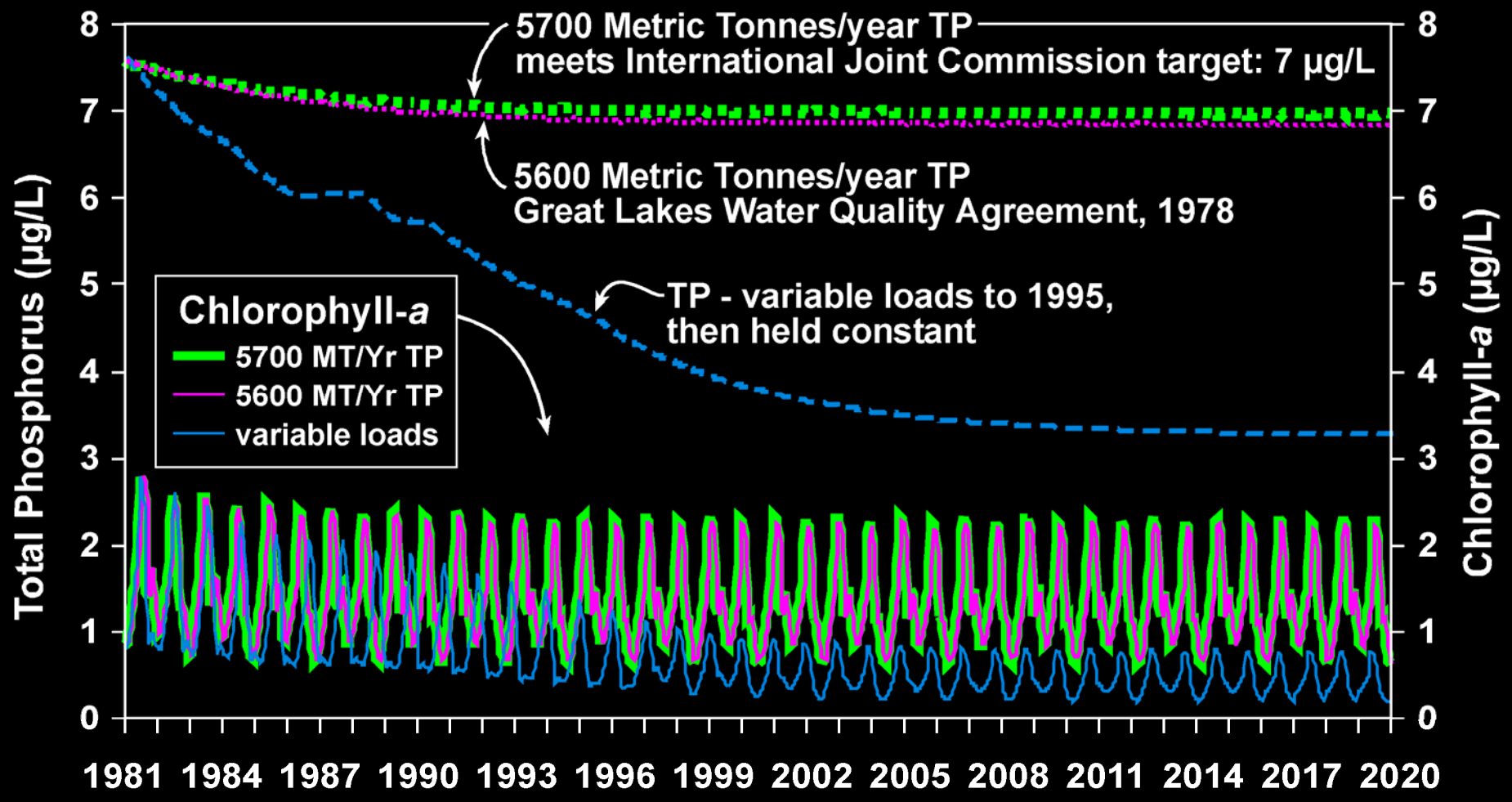
Eutrophication Model Framework

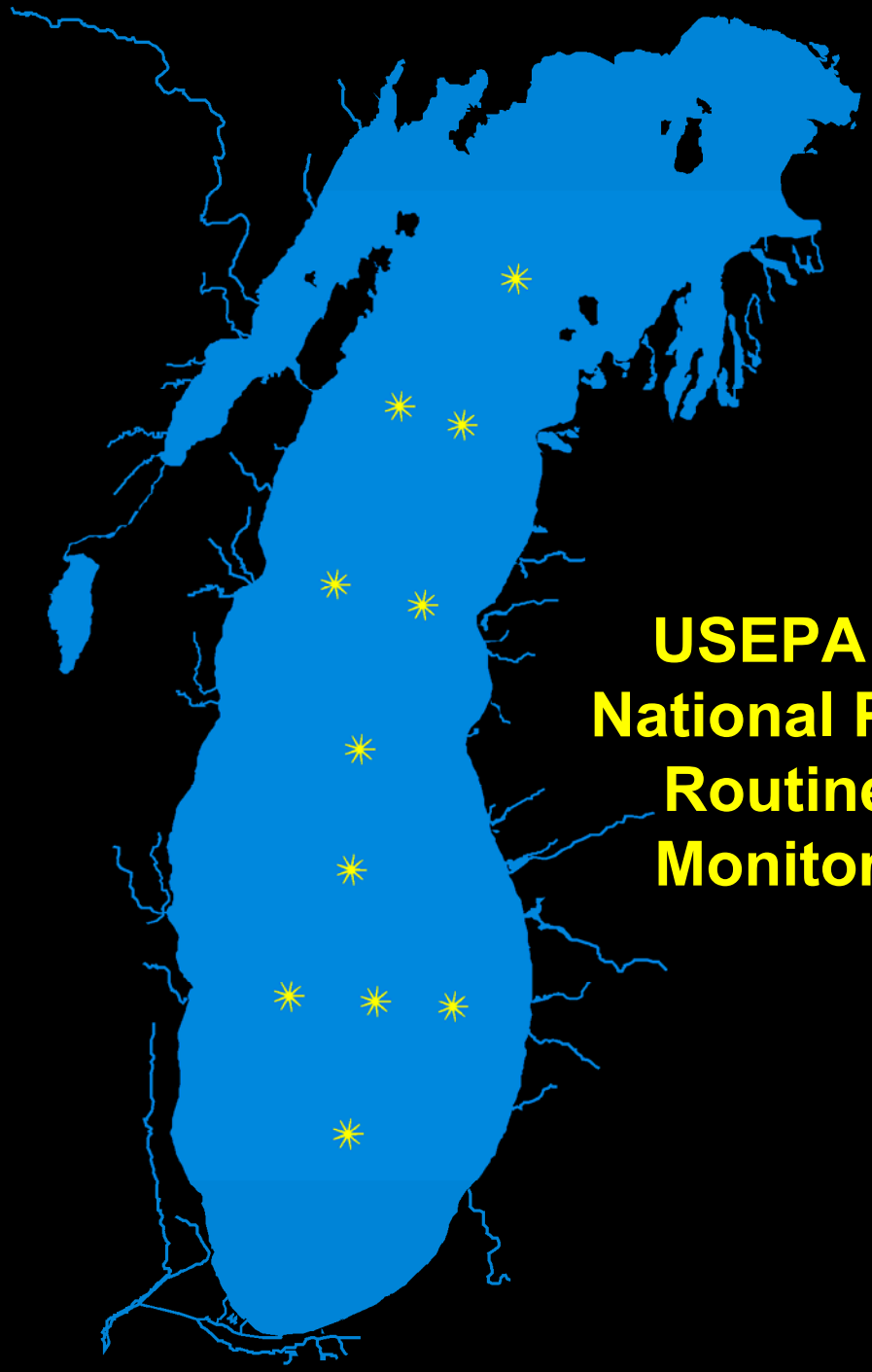


MICH1 Model-Predicted Total Phosphorus (Whole Lake) and Chlorophyll-*a* (Epilimnion) Under Different Phosphorus Loading Scenarios



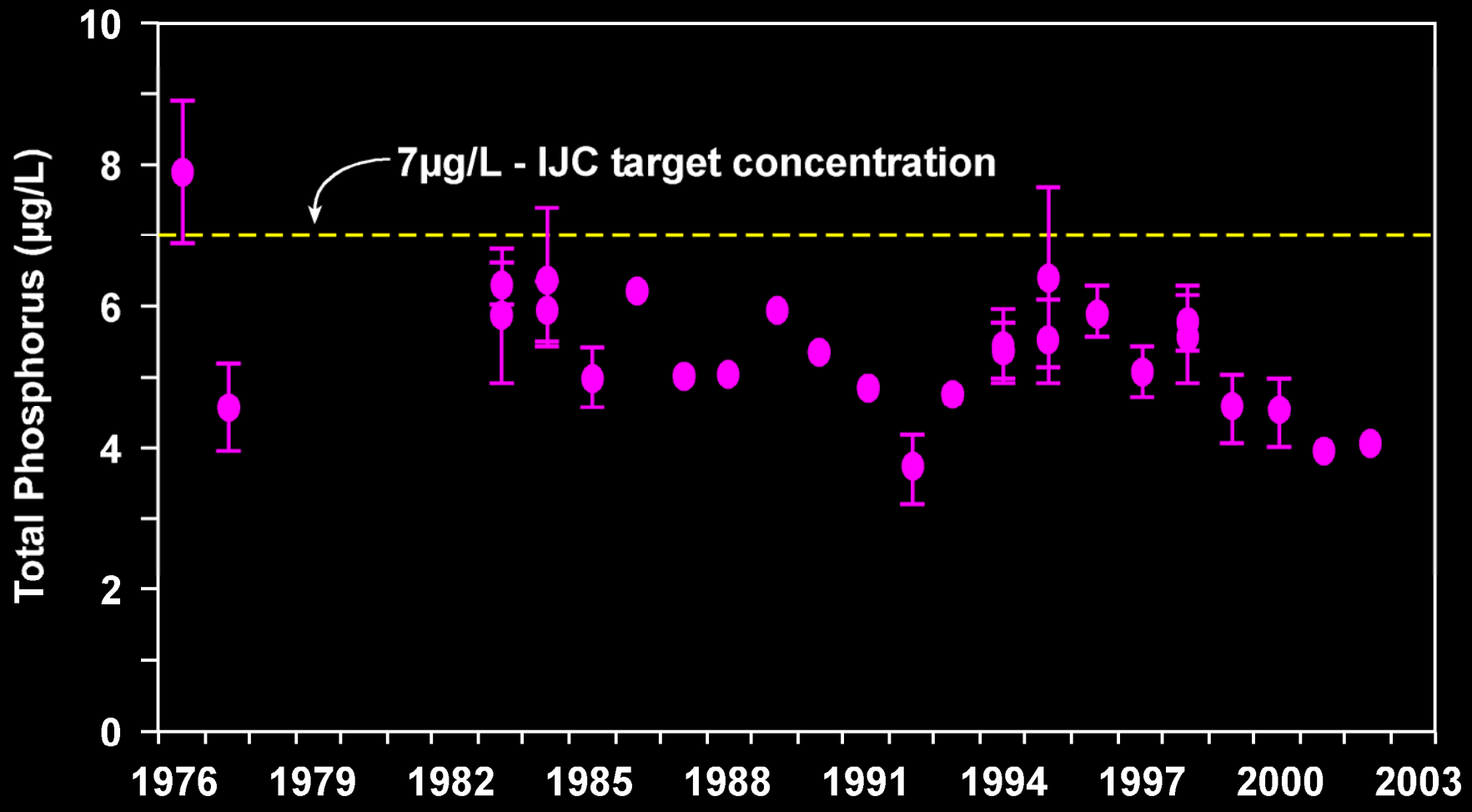
MICH1 Model-Predicted Total Phosphorus (Whole Lake) and Chlorophyll-*a* (Epilimnion) Under Different Phosphorus Loading Scenarios

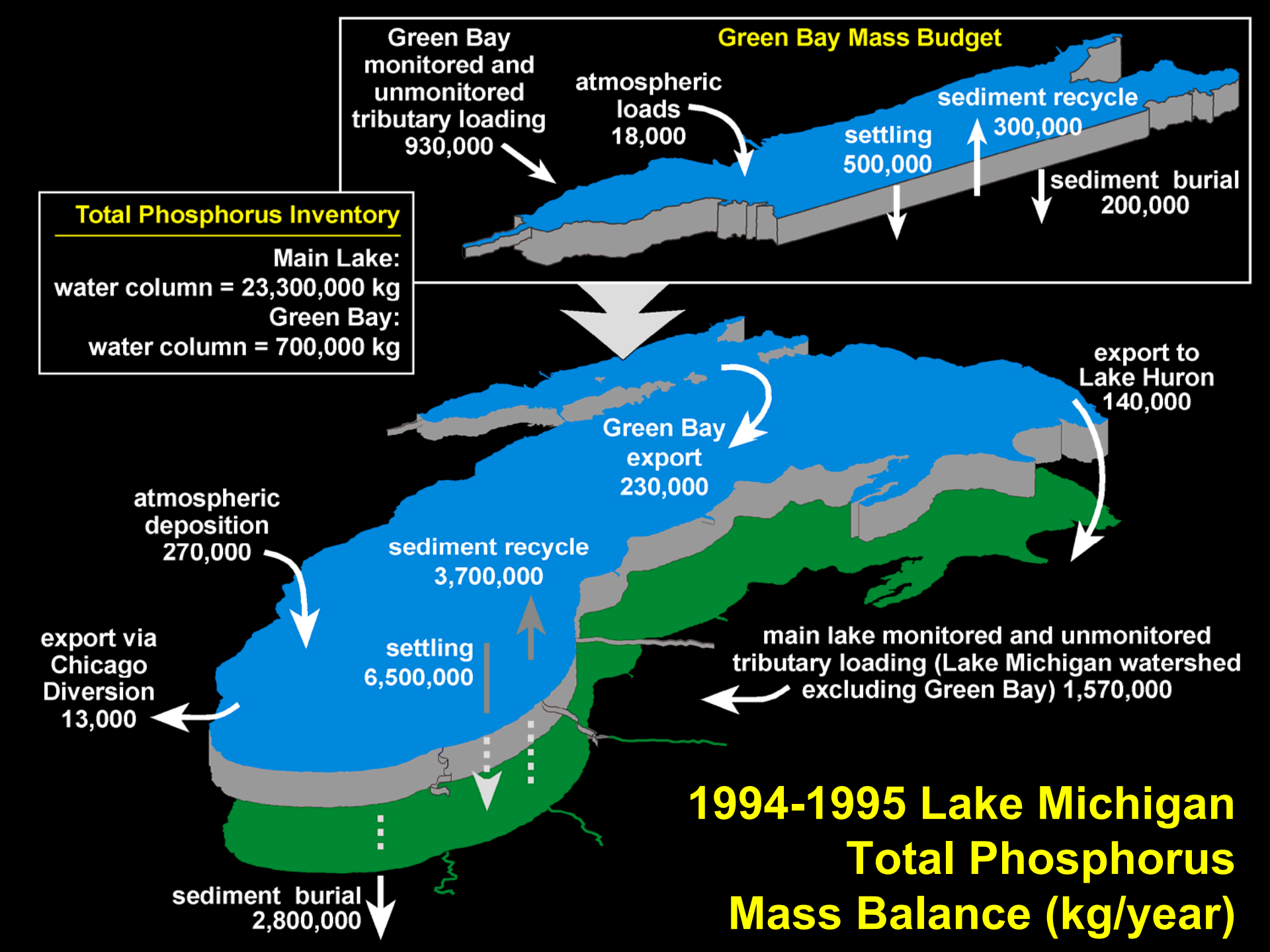




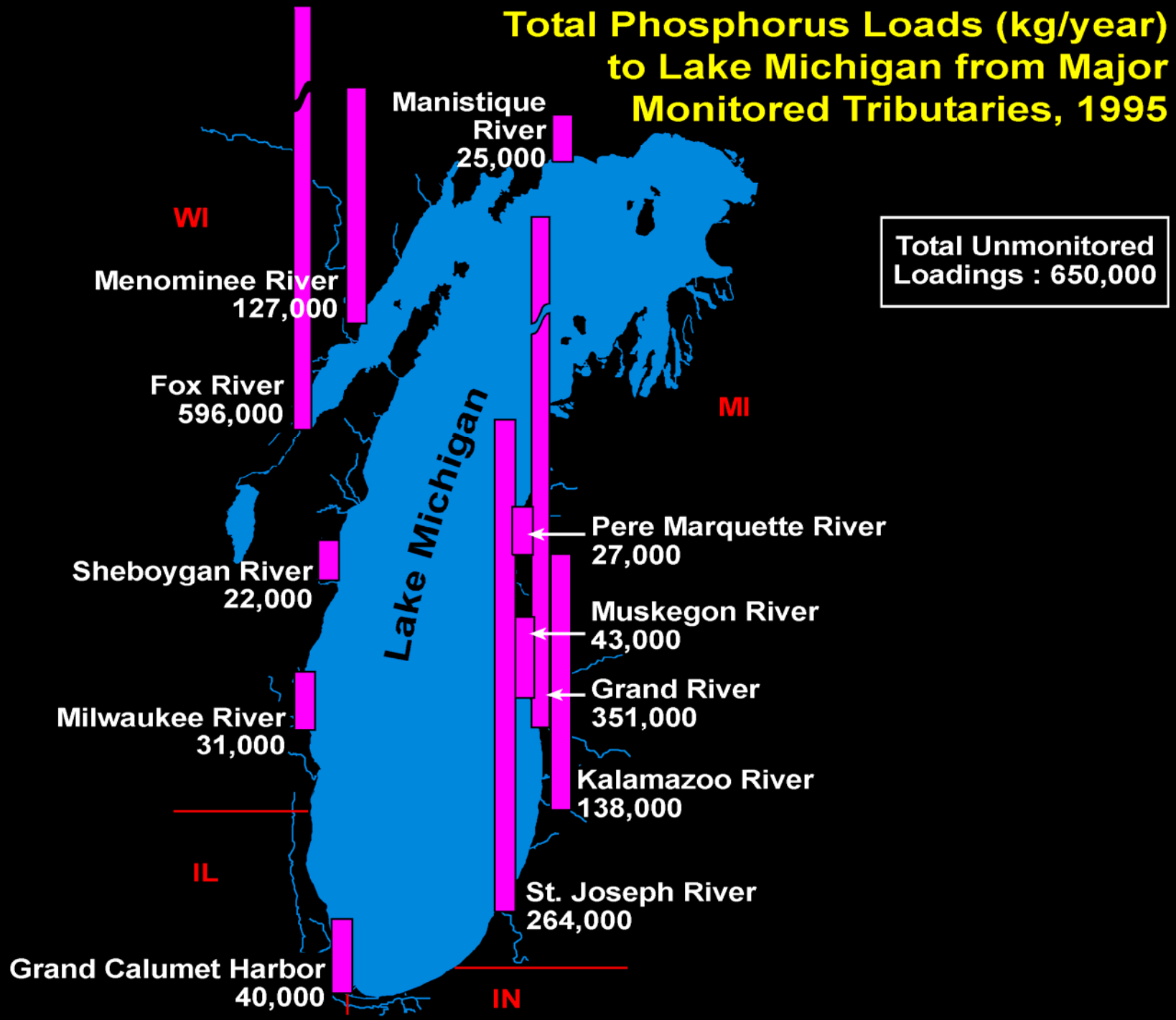
USEPA Great Lakes National Program Office Routine Open Lake Monitoring Stations

Lake Michigan Whole Lake Total Phosphorus
USEPA Great Lakes National Program Office (1976-2002)

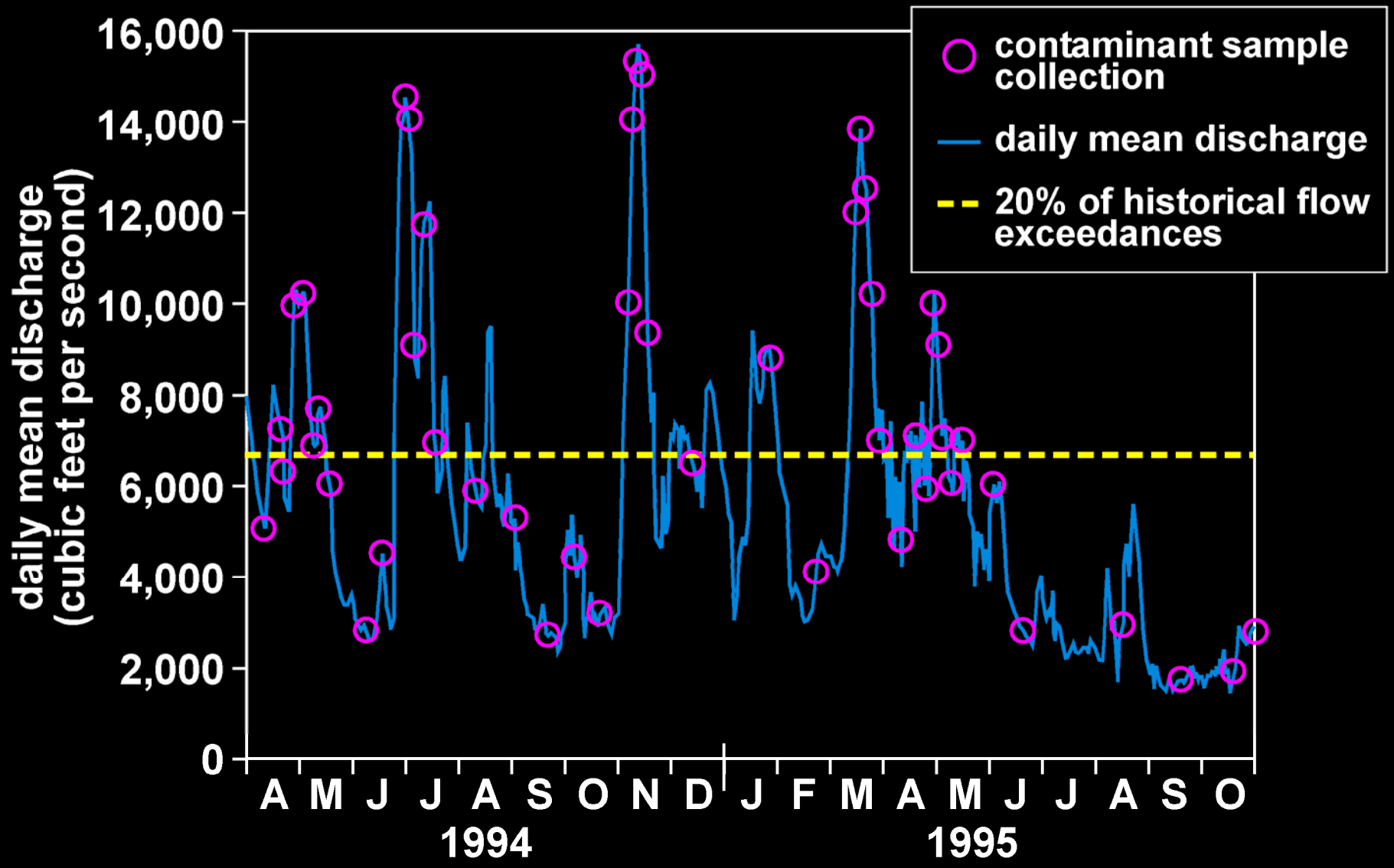



Green Bay Mass Budget
Green Bay monitored and unmonitored tributary loading 930,000
atmospheric loads 18,000
settling 500,000
sediment recycle 300,000
sediment burial 200,000
Total Phosphorus Inventory
Main Lake:
water column = 23,300,000 kg
Green Bay:
water column = 700,000 kg
export to Lake Huron 140,000
Green Bay export 230,000
atmospheric deposition 270,000
sediment recycle 3,700,000
settling 6,500,000
export via Chicago Diversion 13,000
main lake monitored and unmonitored tributary loading (Lake Michigan watershed excluding Green Bay) 1,570,000
sediment burial 2,800,000
1994-1995 Lake Michigan Total Phosphorus Mass Balance (kg/year)

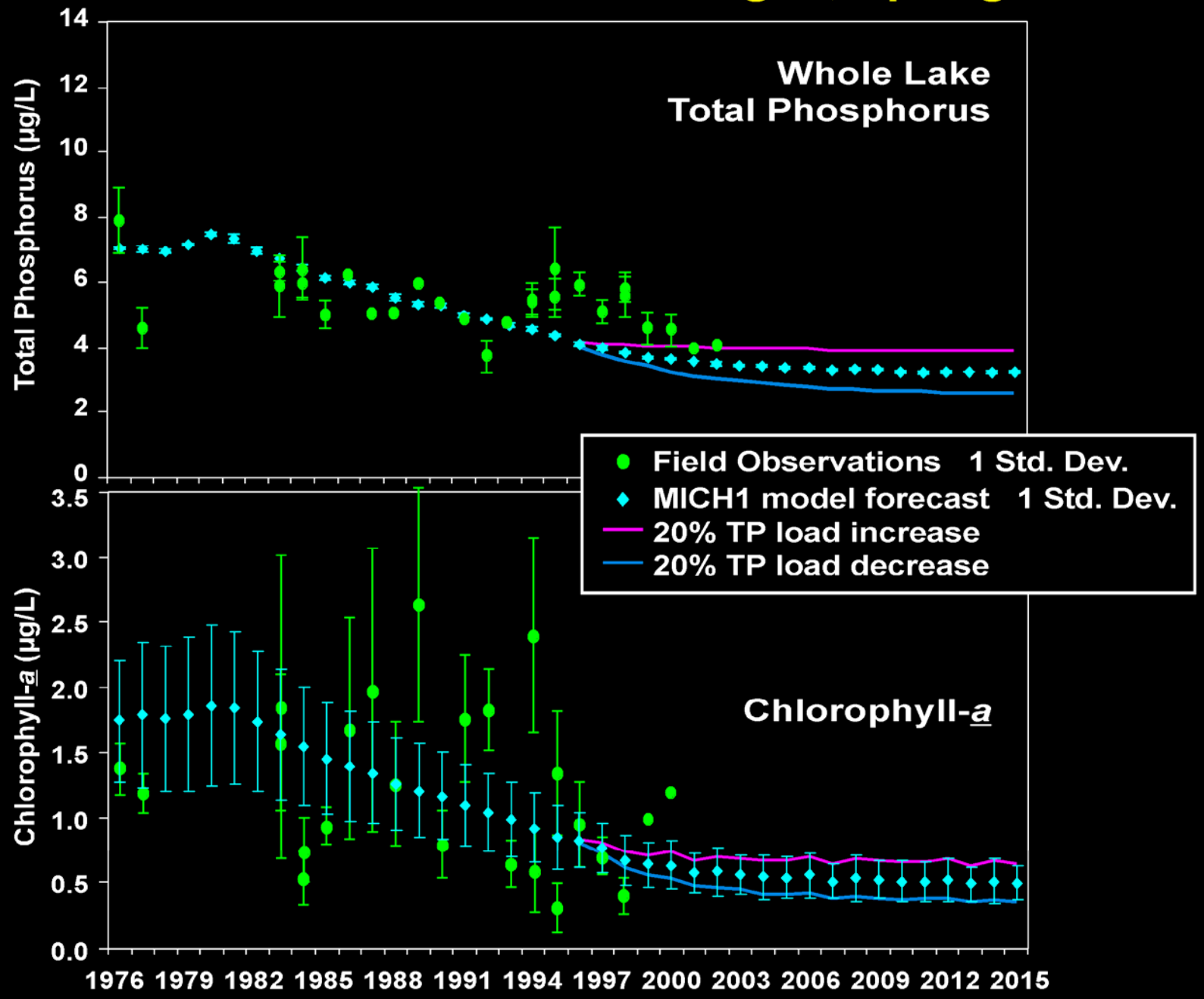
Total Phosphorus Loads (kg/year) to Lake Michigan from Major Monitored Tributaries, 1995



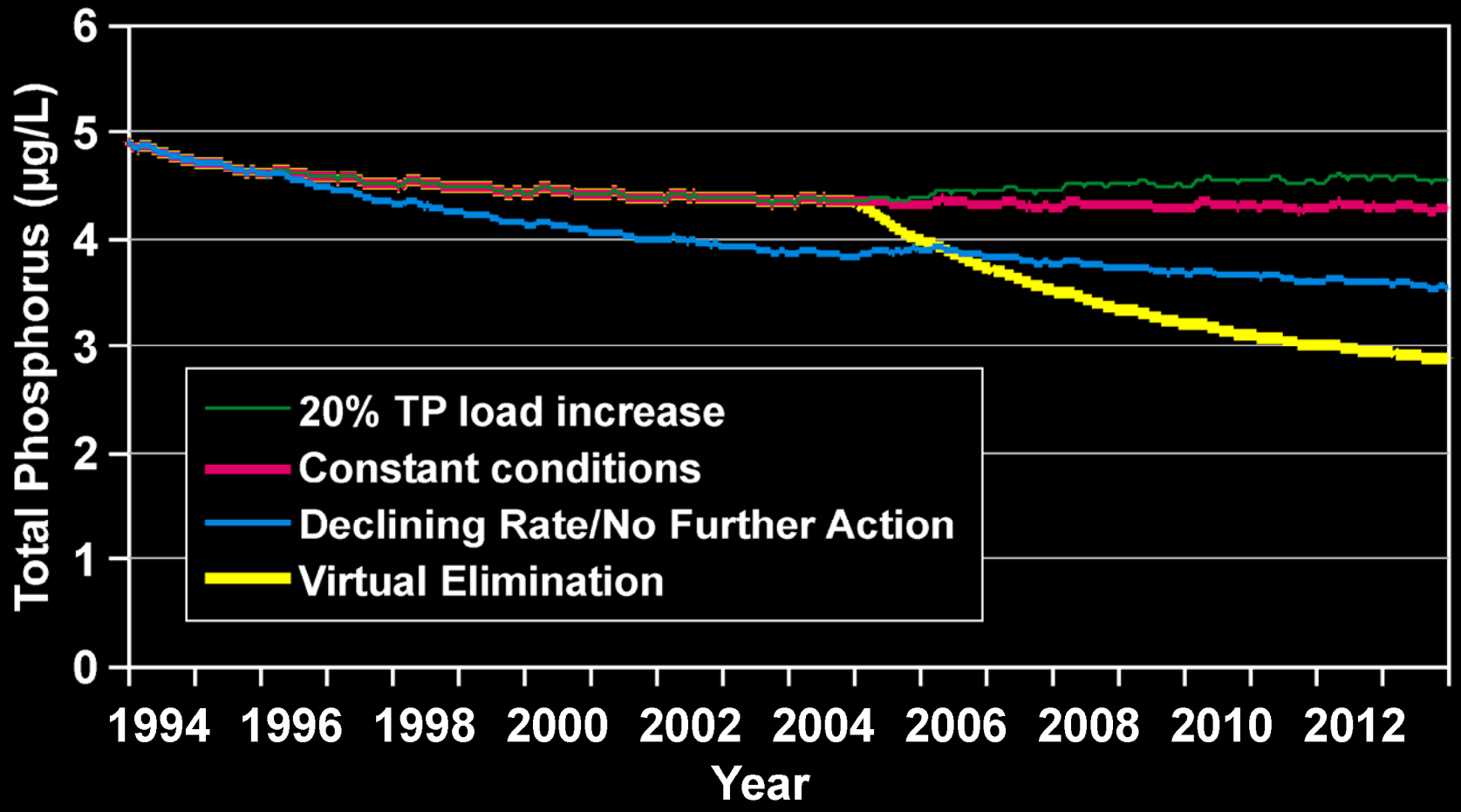
Daily mean flow discharge, times of sample collection, and 20% flow exceedance level at Grand River, Michigan (USGS 1998)

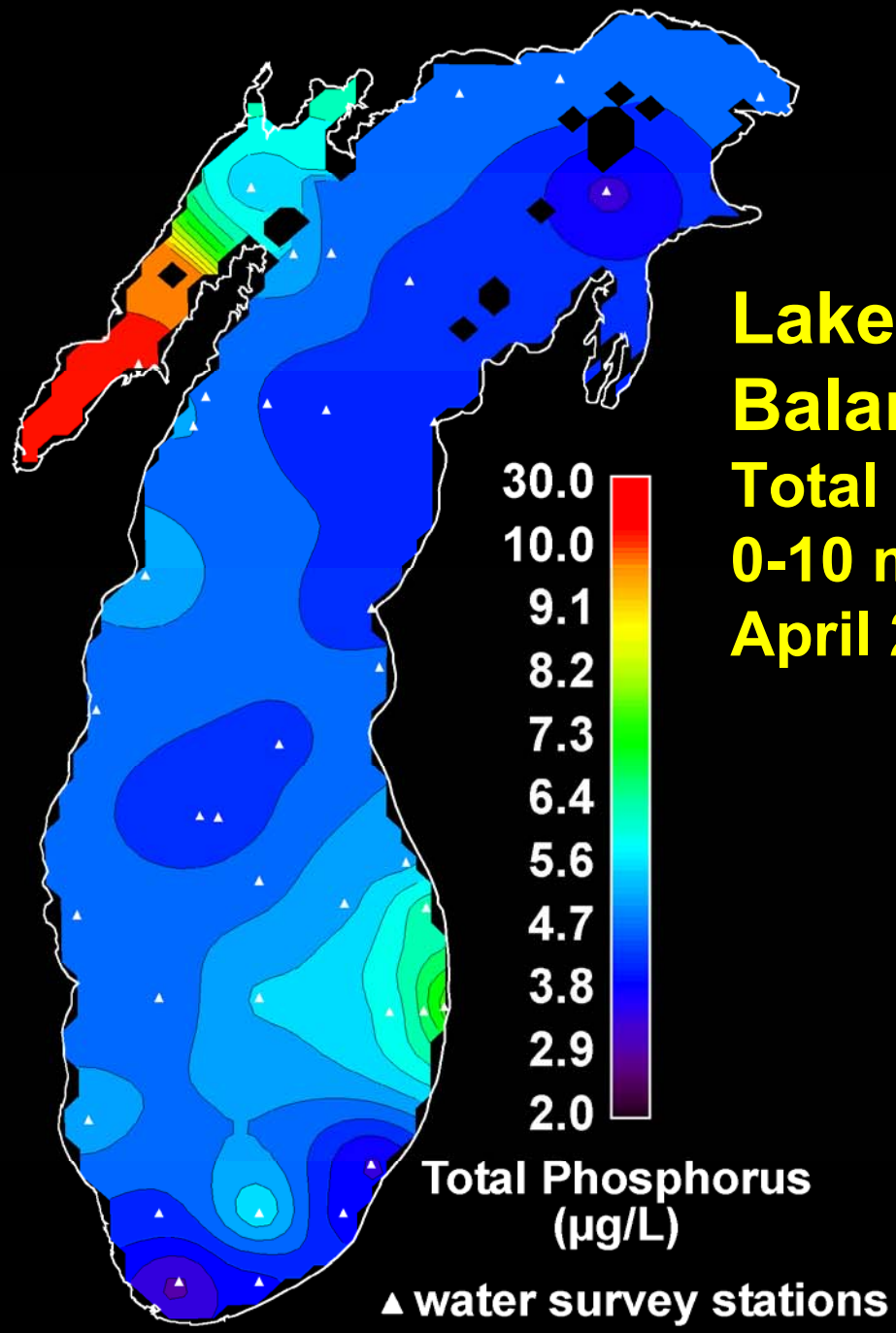


MICH1 Model Predictions Lake Michigan, Spring 1976-2015



LM3-Eutrophication Scenario Forecasts for Total Phosphorus in Lake Michigan





Lake Michigan Mass Balance Study

Total Phosphorus (µg/L) Contour

0-10 meters

April 24 – May 11, 1994

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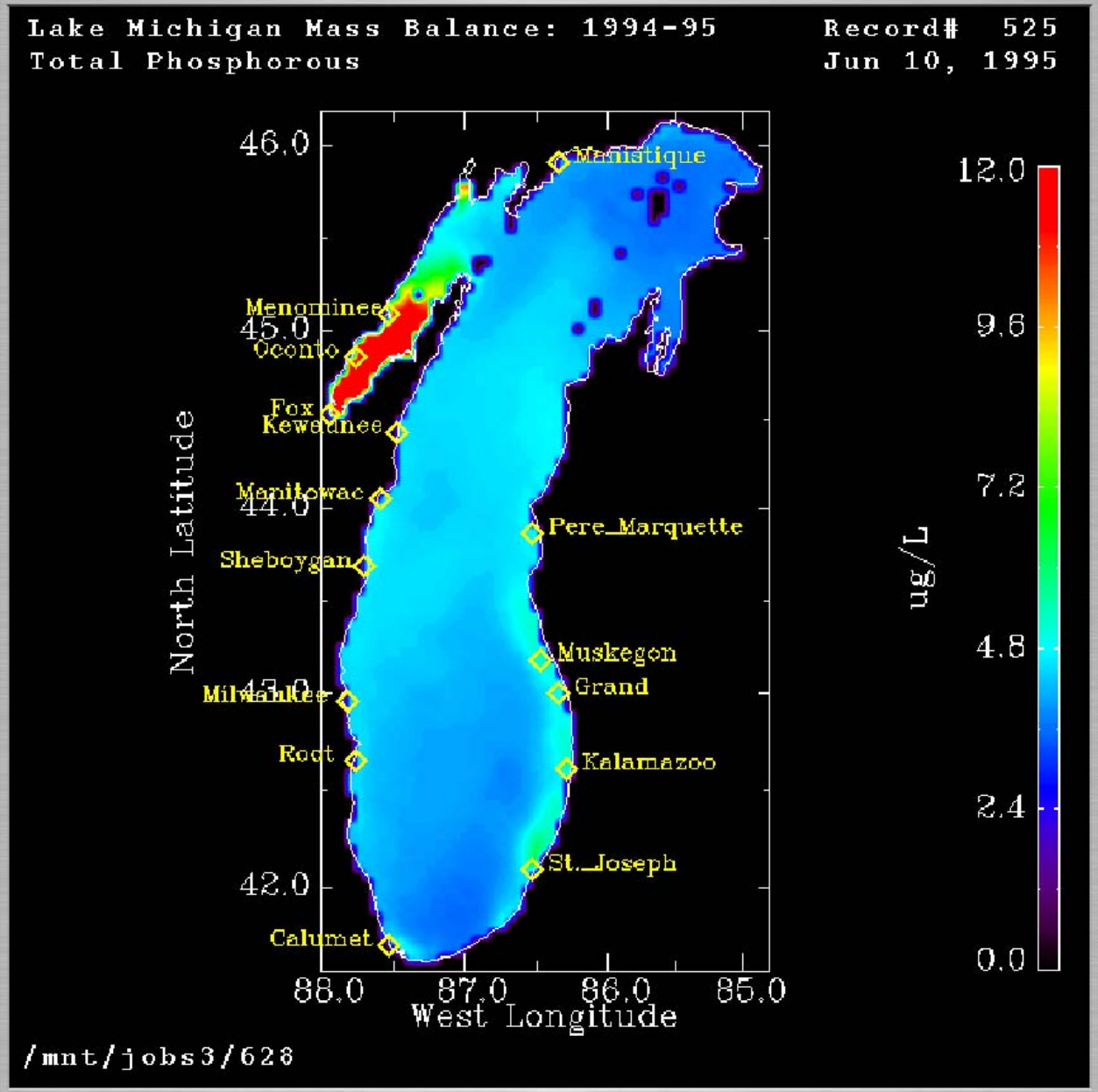

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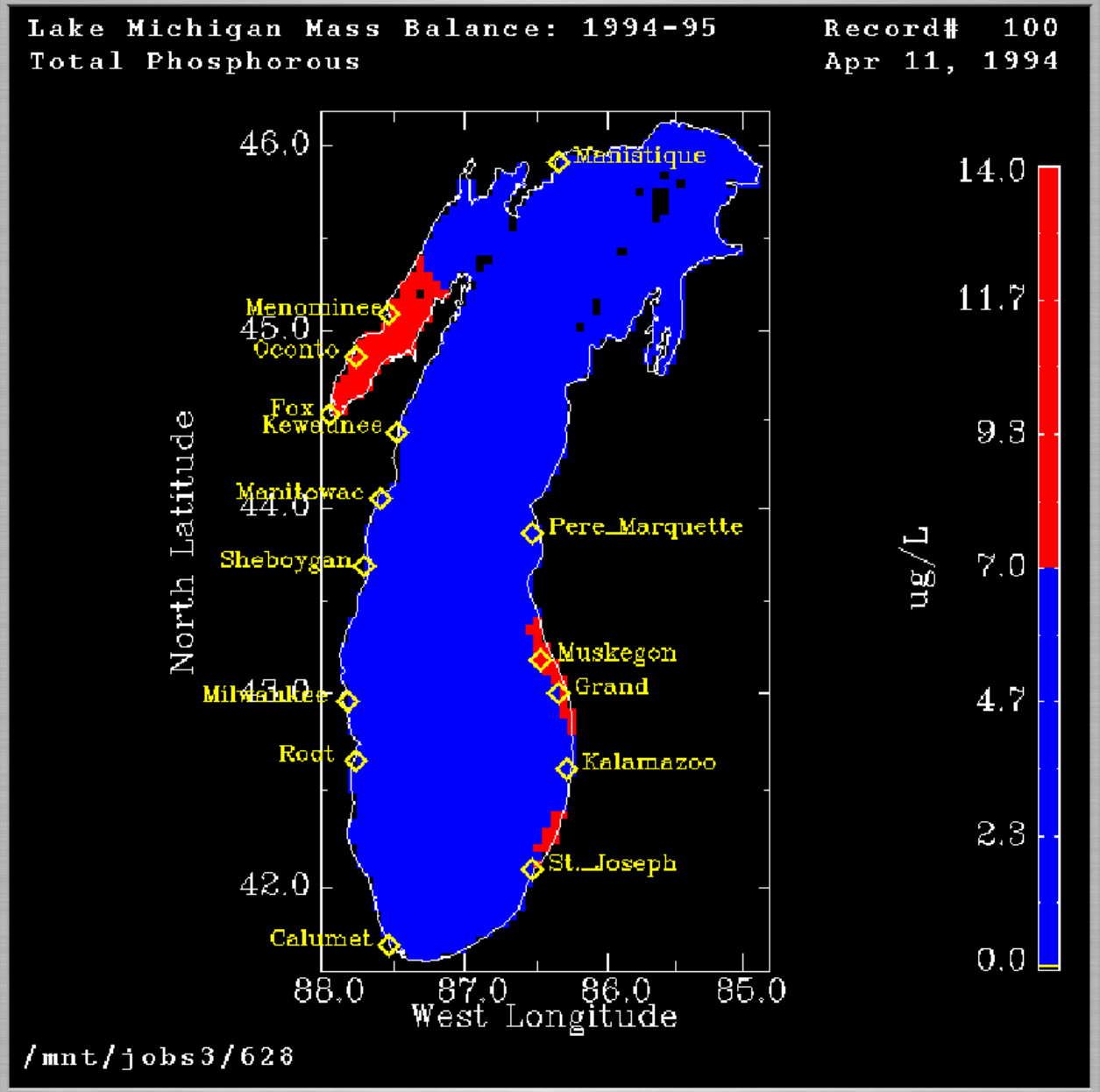

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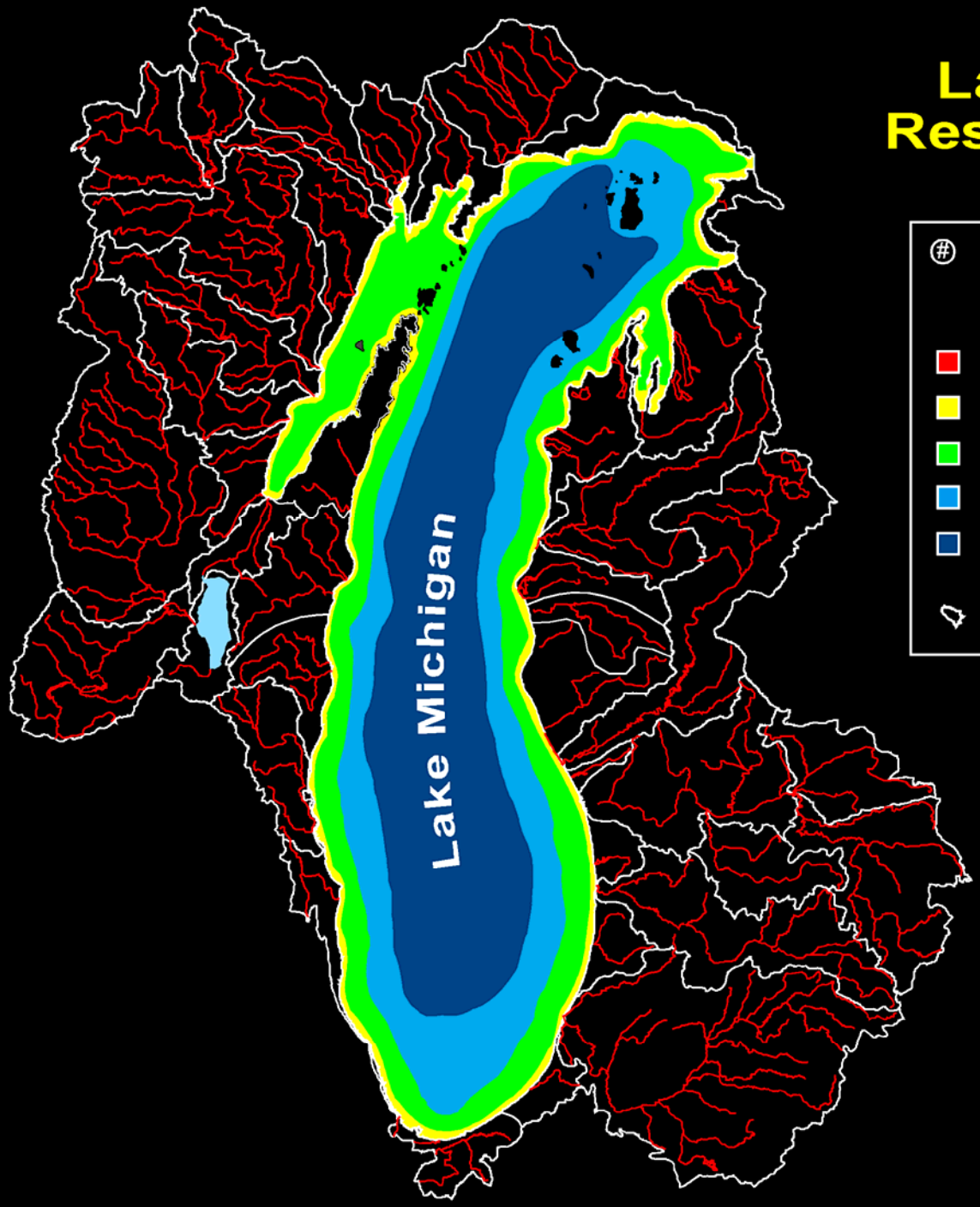
Lake Michigan Resource Classes

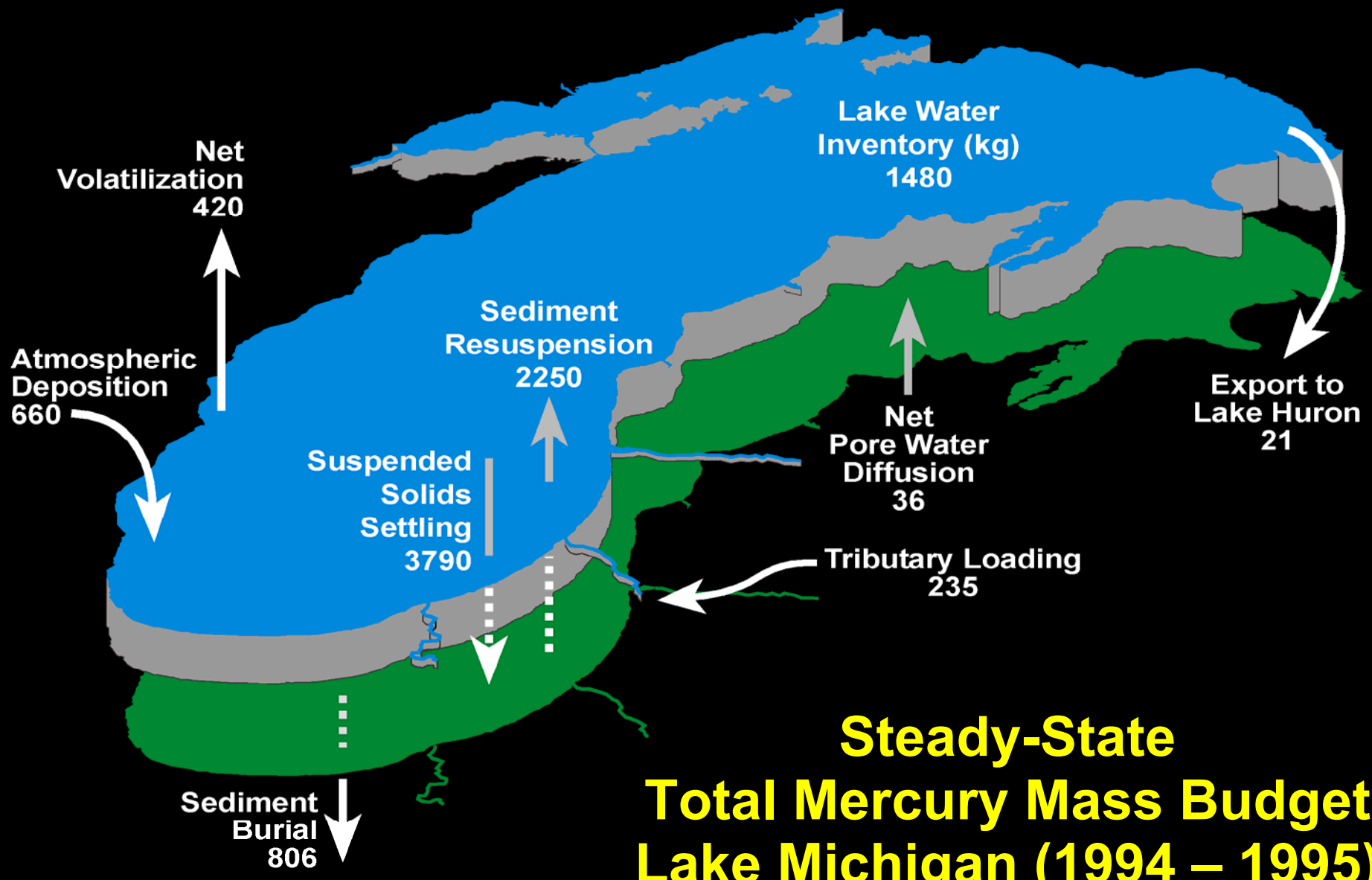


Monitored tributary

Resources Classes

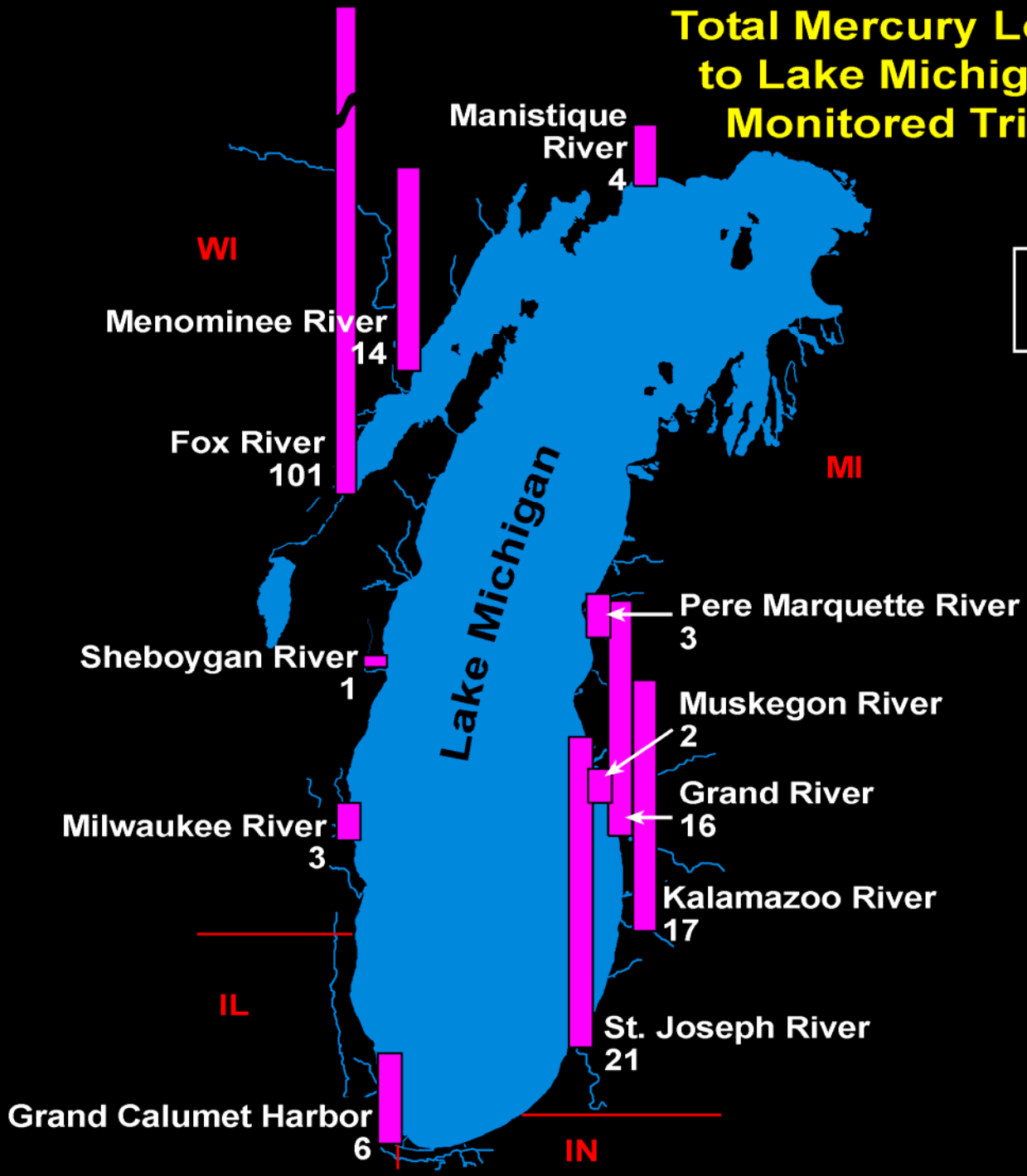
- Watersheds/Rivers
- Near Coastal <2 m
- Nearshore <30 m
- Transition Zone 30-85 m
- Offshore > 85 m

Hydrologic unit boundary

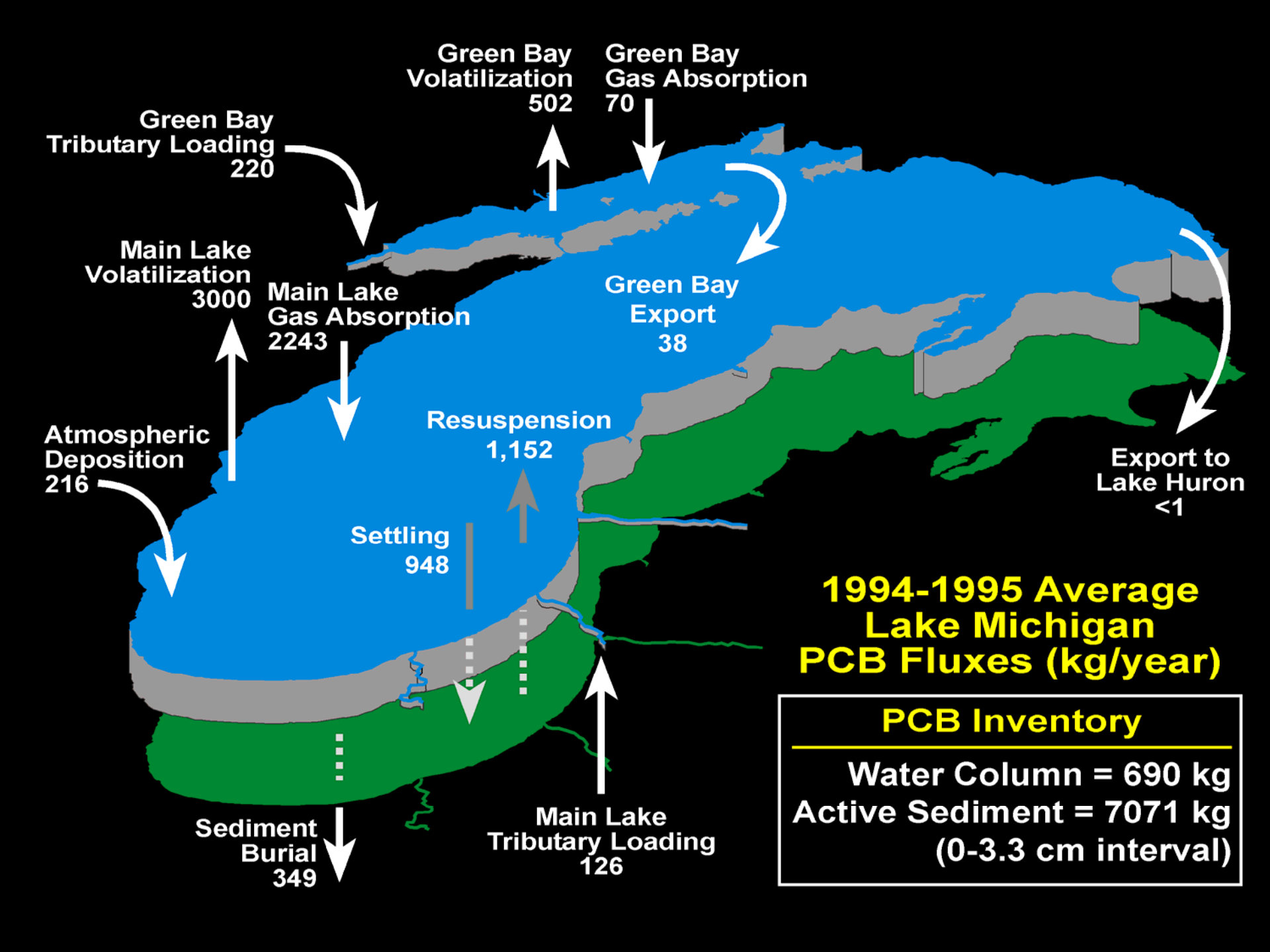


Steady-State Total Mercury Mass Budget Lake Michigan (1994 – 1995) (Sources and Sinks in kg/yr)

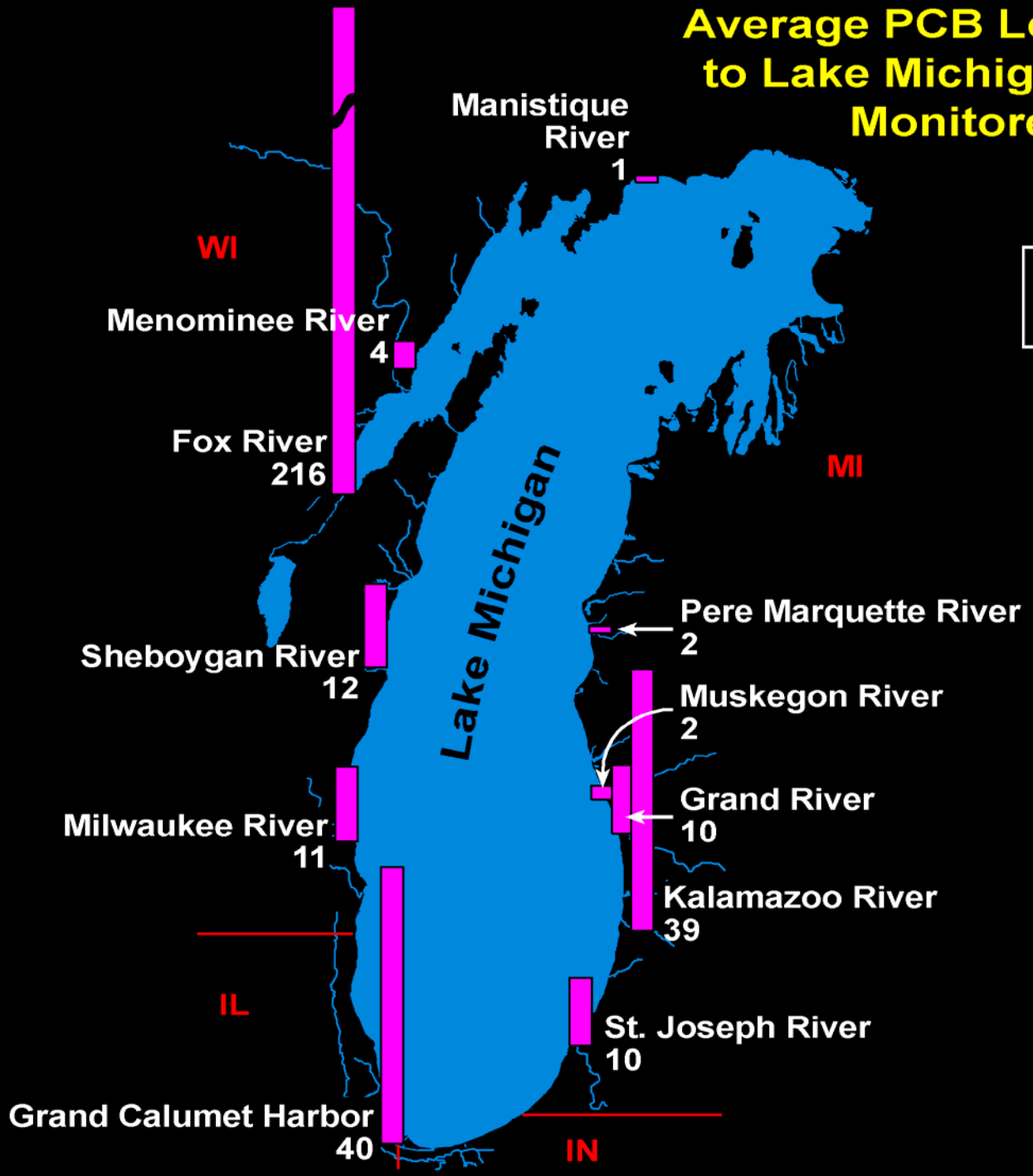
Total Mercury Loads (kg/year) to Lake Michigan from Major Monitored Tributaries, 1995



Total Unmonitored Loadings : 41

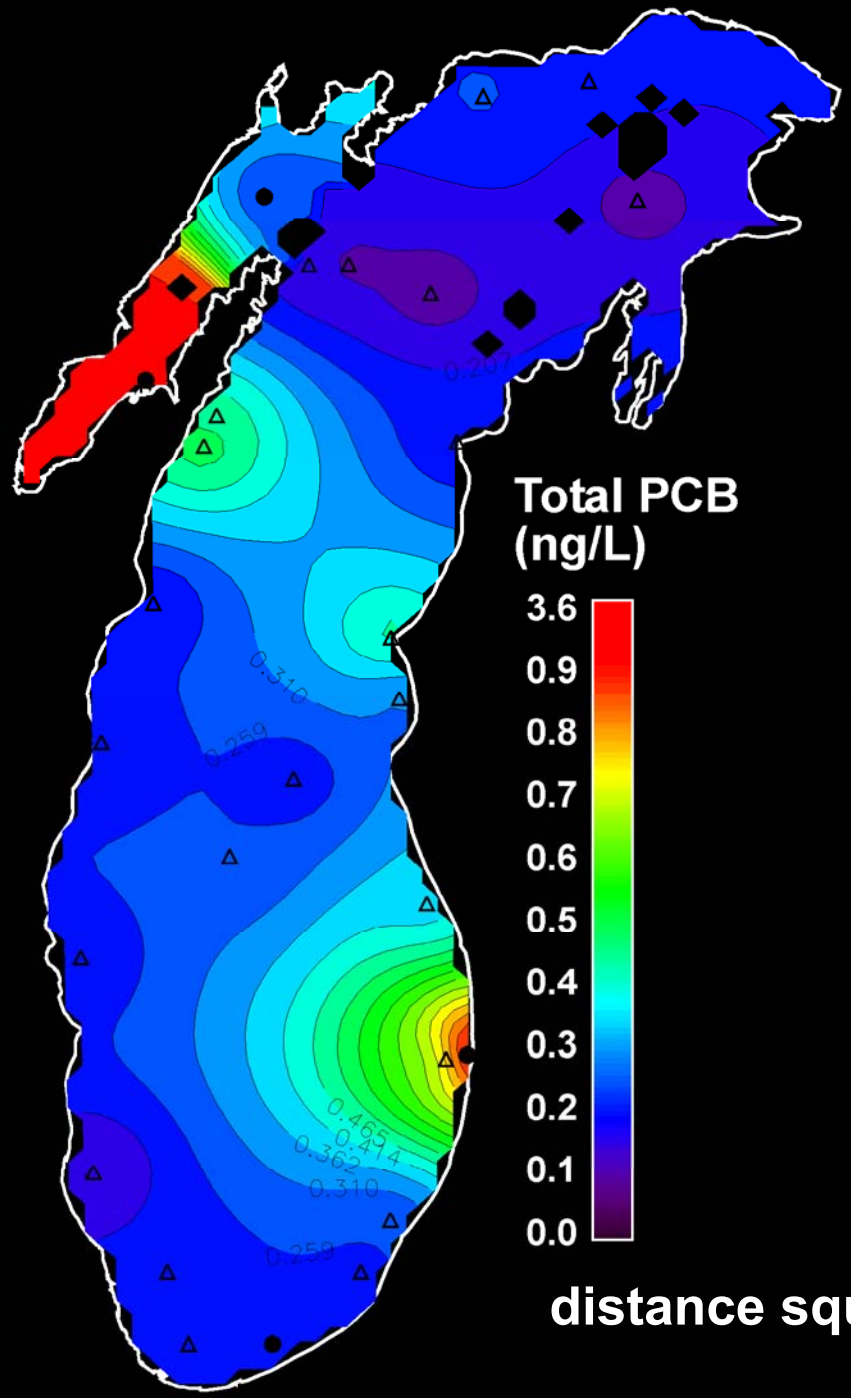

Green Bay Volatilization 502
Green Bay Gas Absorption 70
Green Bay Tributary Loading 220
Main Lake Volatilization 3000
Main Lake Gas Absorption 2243
Green Bay Export 38
Atmospheric Deposition 216
Resuspension 1,152
Settling 948
Export to Lake Huron <1
Sediment Burial 349
Main Lake Tributary Loading 126
1994-1995 Average Lake Michigan PCB Fluxes (kg/year)
PCB Inventory
Water Column = 690 kg
Active Sediment = 7071 kg
(0-3.3 cm interval)

Average PCB Loads (kg/year) to Lake Michigan from Major Monitored Tributaries, 1994-1995



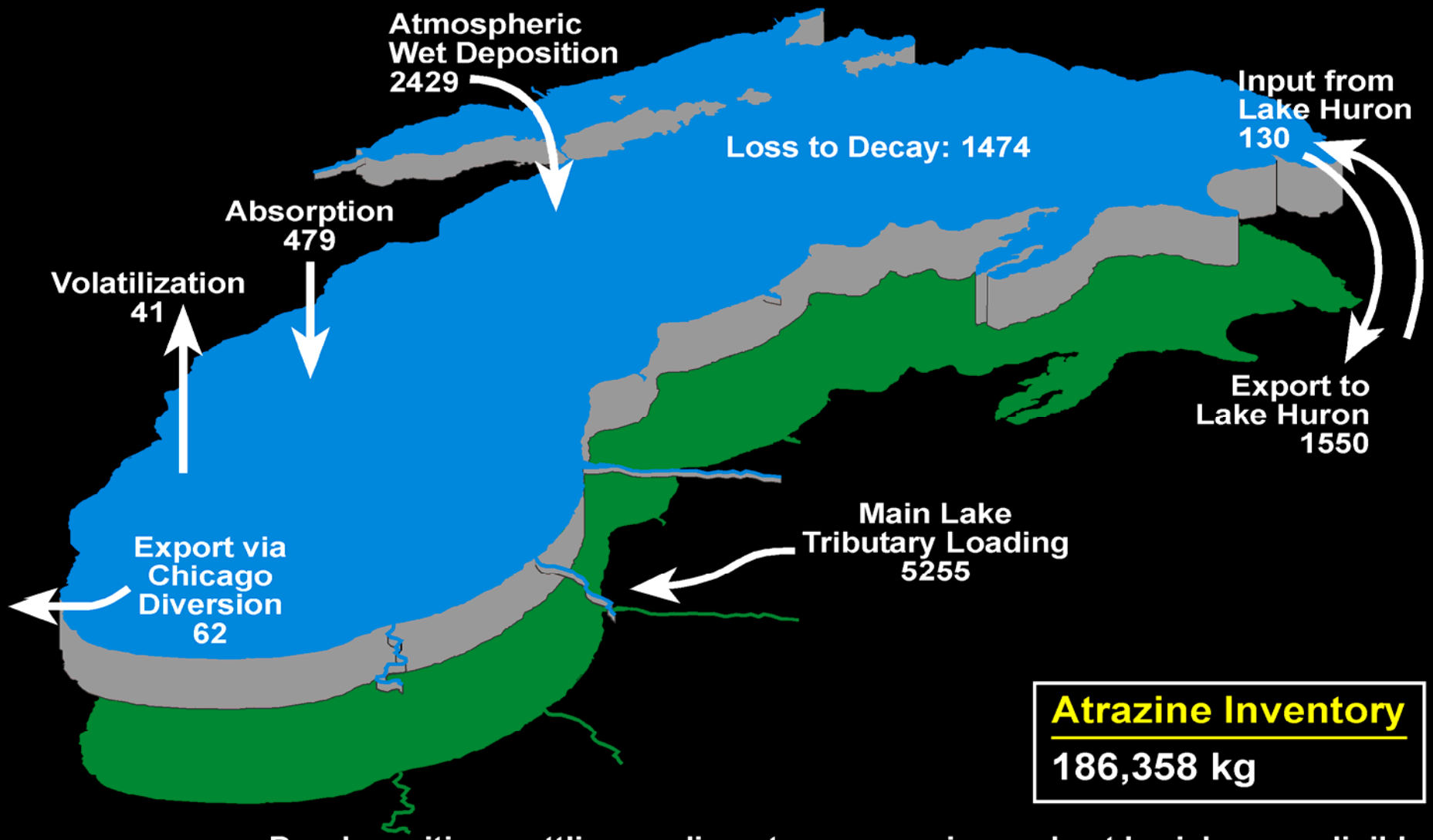
Total Unmonitored Loadings : 31

Concentration of PCBs in Lake Michigan Water 4/24/94 - 5/11/94



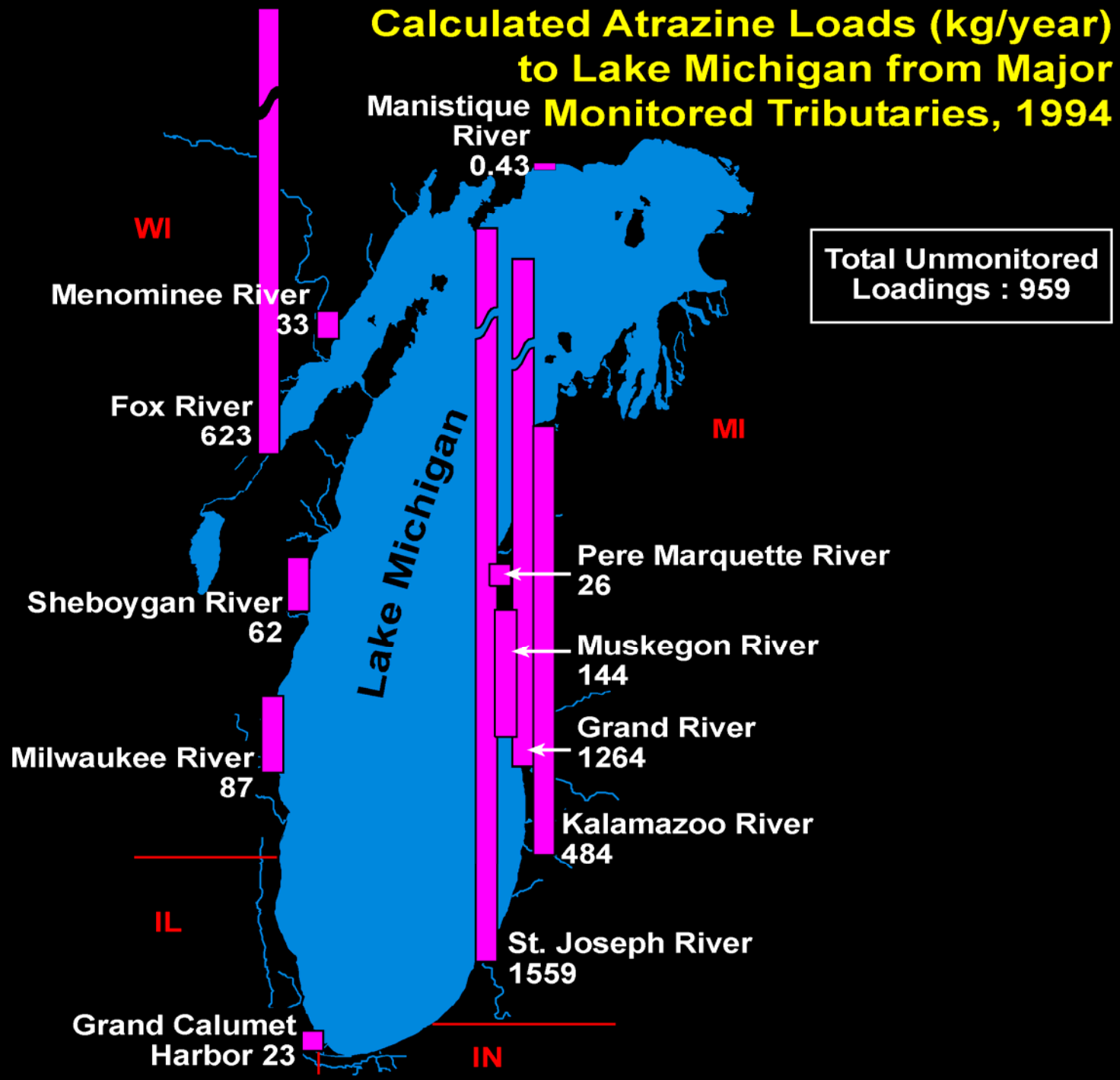
distance square inverse interpolation

1994 Average Lake Michigan Atrazine Fluxes (kg/year)



Dry deposition, settling, sediment resuspension and net burial are negligible

Calculated Atrazine Loads (kg/year) to Lake Michigan from Major Monitored Tributaries, 1994



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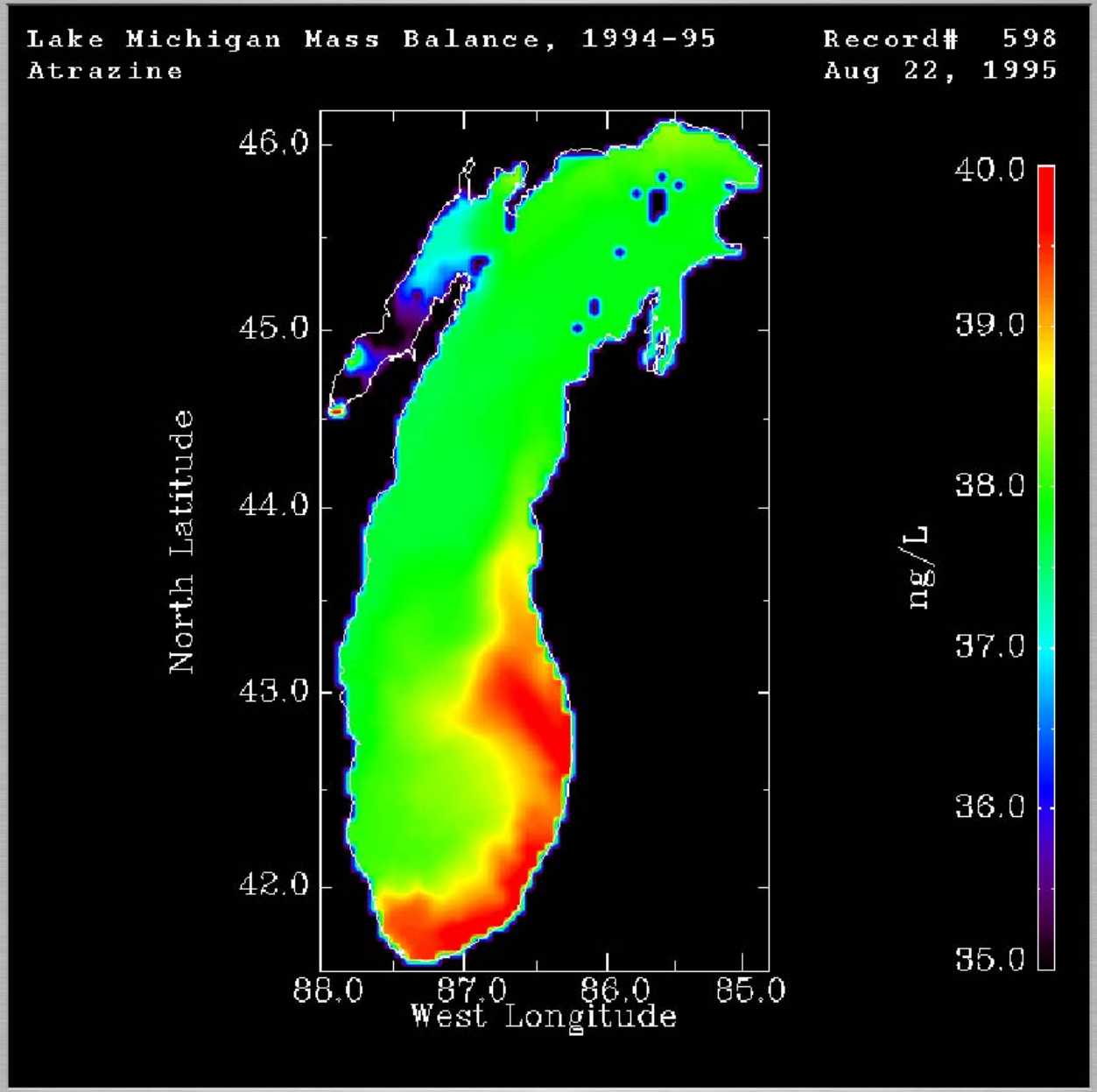

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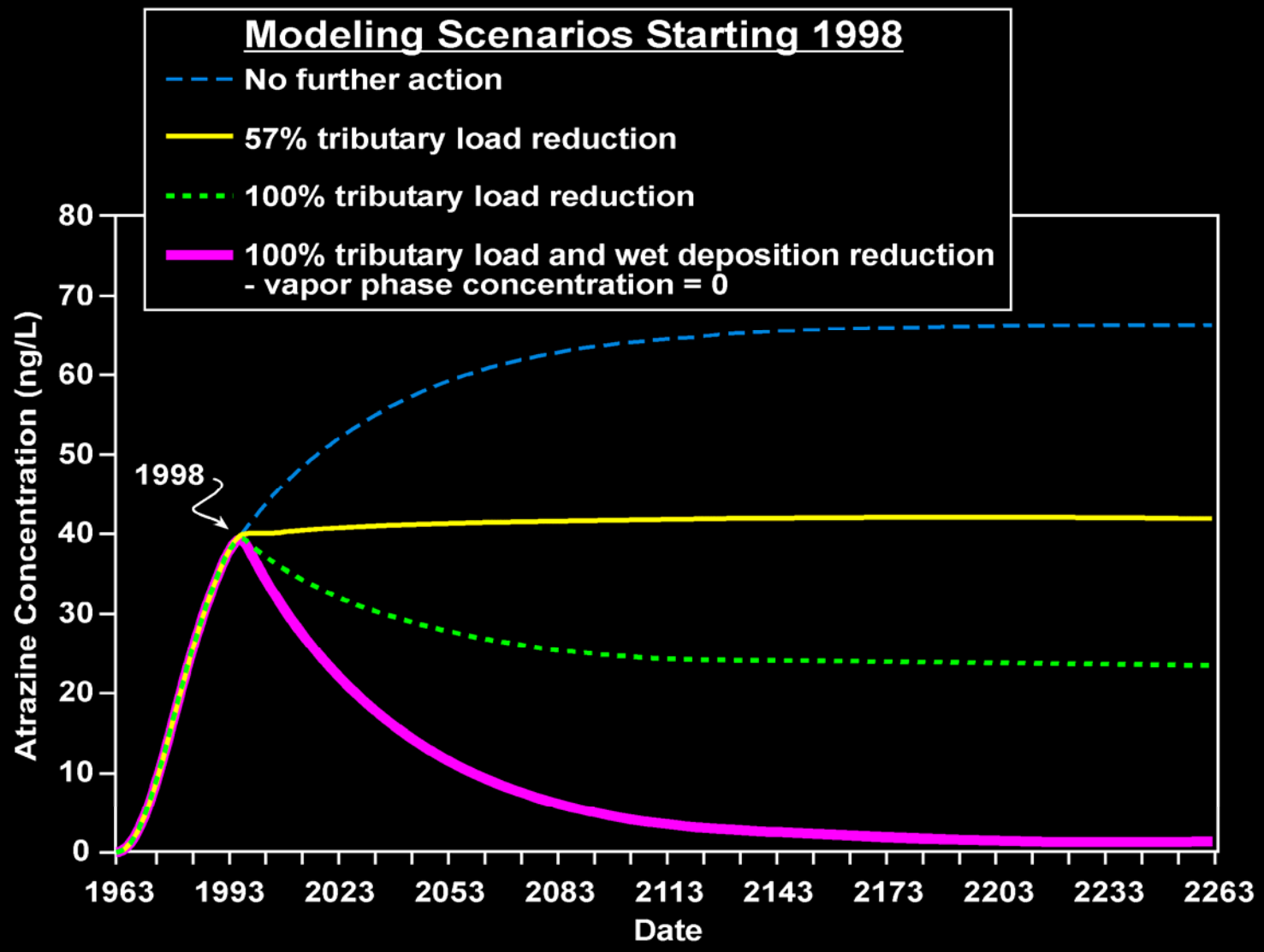
Lakewide Atrazine Concentration Forecasts (Lake Michigan 41 Segment Model)