Lake Michigan Mass Balance Project: Atrazine Results

Large Lakes Research Station
(U.S. EPA/ORD/NHEERL/MED)
with
U.S. EPA Great Lakes National Program Office

Goals

Quantify historical loads of atrazine to Lake Michigan and determine transport and fate in the lake using mass balance models.

Forecast concentrations of atrazine in the lake under various loading scenarios.

Assess the potential for exceeding aquatic biological effects thresholds using model forecasts.

Major Findings

Observed and forecasted lake-averaged concentrations of atrazine are well below EPA biological effects thresholds.

Tributaries are the major source of atrazine to the lake.

Atrazine is very persistent in Lake Michigan – decay is estimated at less than 1% per year.

Atrazine concentrations are forecasted to increase in the lake under present loads (1994-1995 constant load).

Atrazine Background

Registered in 1958. EPA re-registration expected in 2006. Classified as a Restricted Use Pesticide.

One of the most widely used pesticides in the U.S. (29 – 33 million kg applied annually).

In the Lake Michigan basin, atrazine is usually applied to corn fields in the spring to control broadleaf and some grassy weeds.

Approximately 850,000 kg applied annually in the Lake Michigan basin.

Included on the pollutant watch list in the Lake Michigan LaMP 2002 supplement.

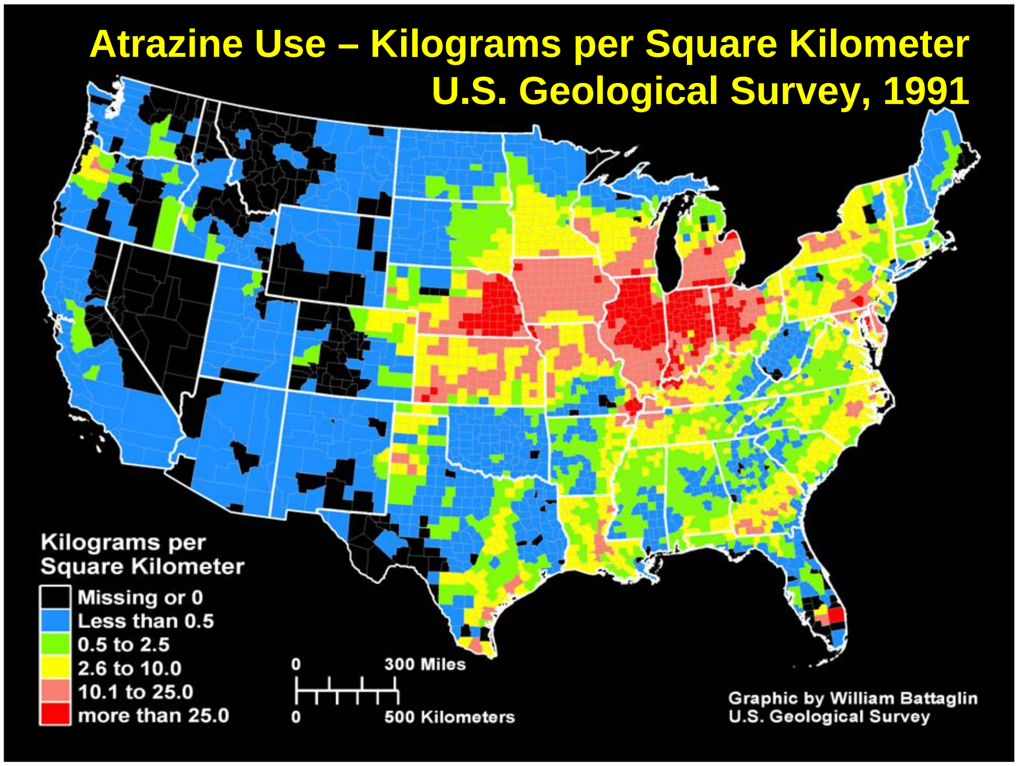
Atrazine Properties

Inhibits photosynthesis

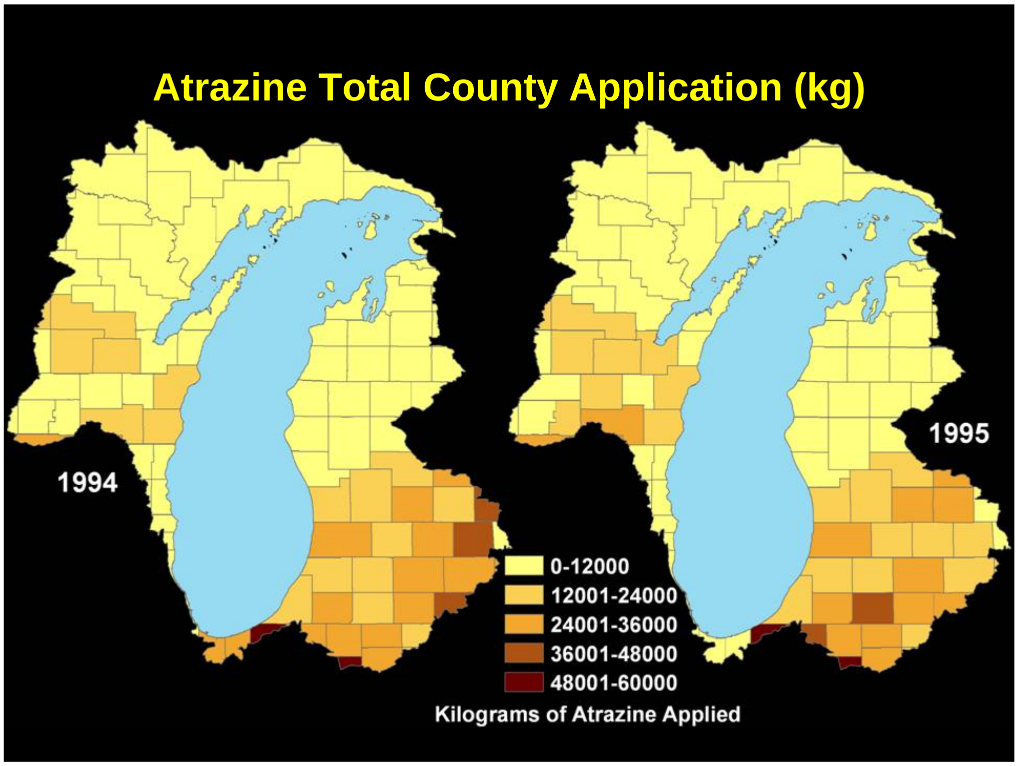
Biodegradable in soil but slow to decay in aquatic systems

Properties in aquatic systems:

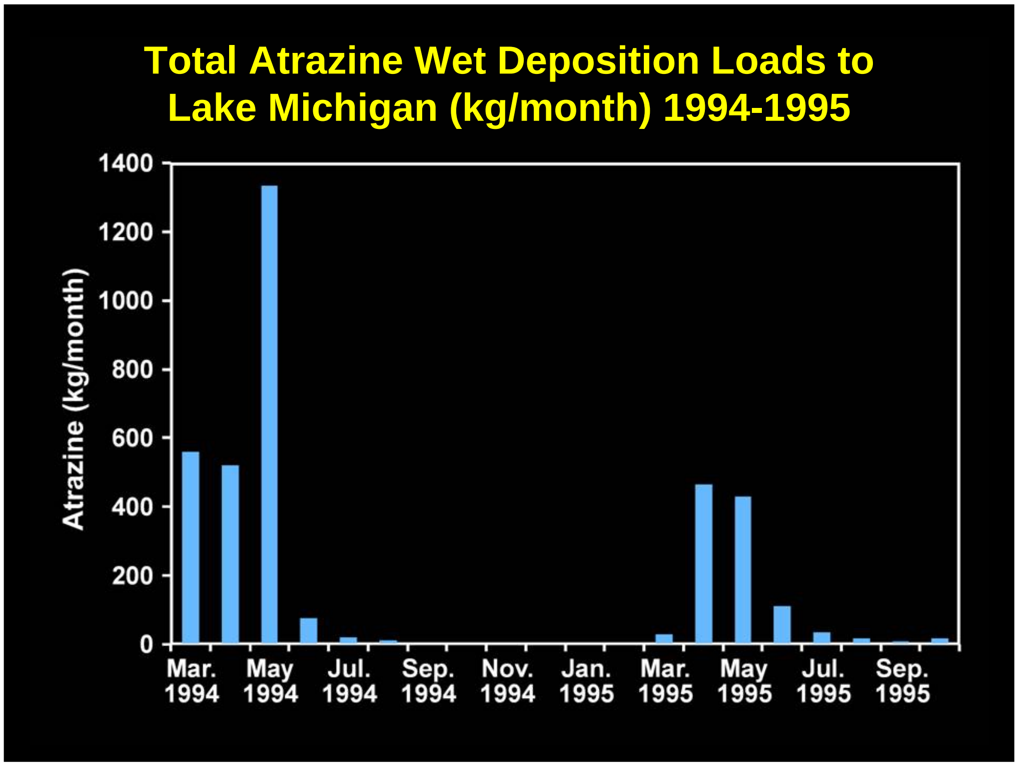
- not significantly bioaccumulative
- not strongly associated with particles or sediments
- water soluble
- low volatility



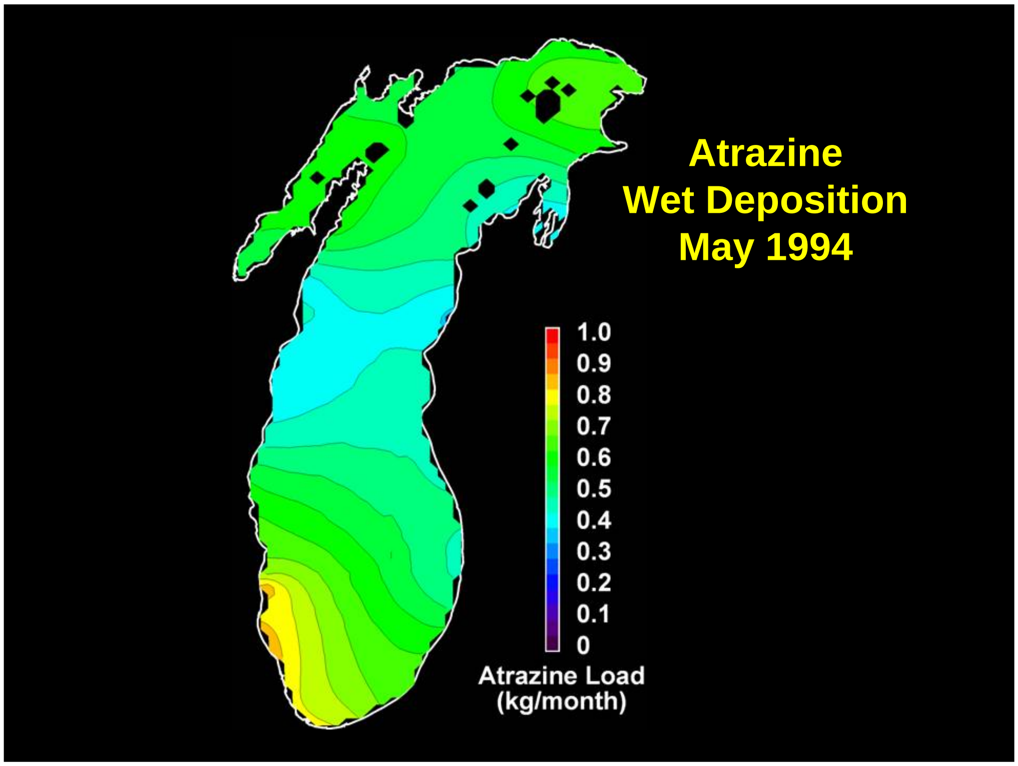
Usage in Illinois and Indiana is relatively high, but except for the northern-most part of Indiana, most of drainage and associated load from these states discharges into the Mississippi watershed. However, the proximity of these high-use areas to Lake Michigan can have an impact on the atmospheric loading to the southern part of Lake Michigan.



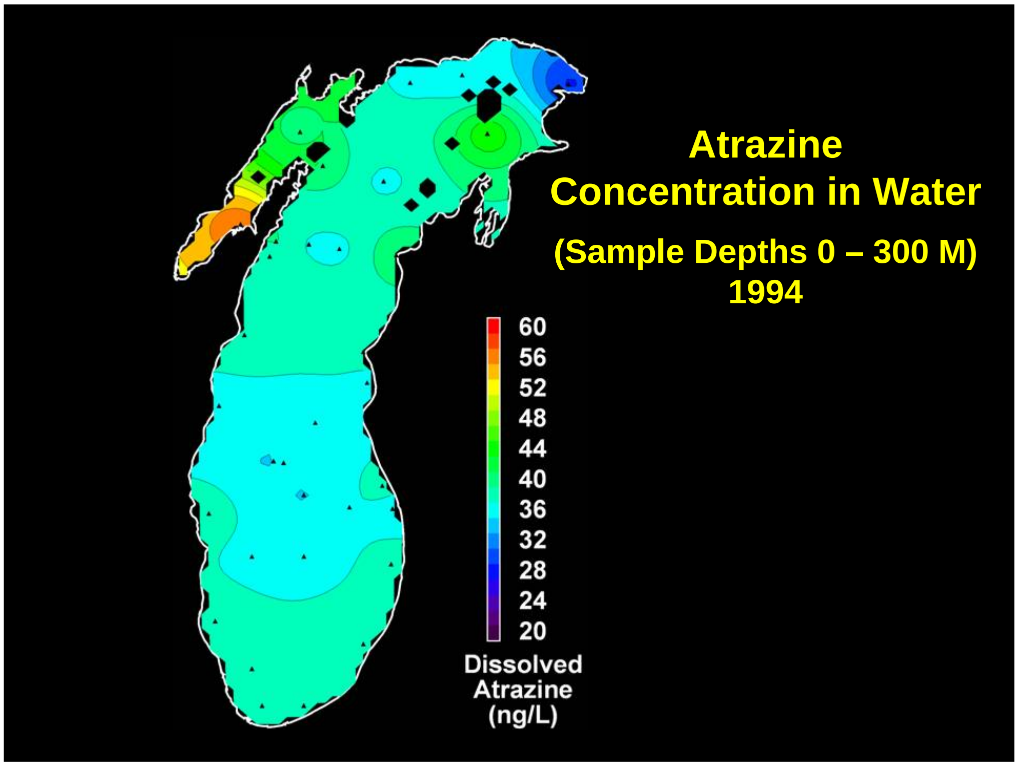
This is a close-up of the Lake Michigan basin showing total atrazine application for 1994 and 1995. Note the highest use region is in the southwestern part of Michigan and the northern part of Indiana.



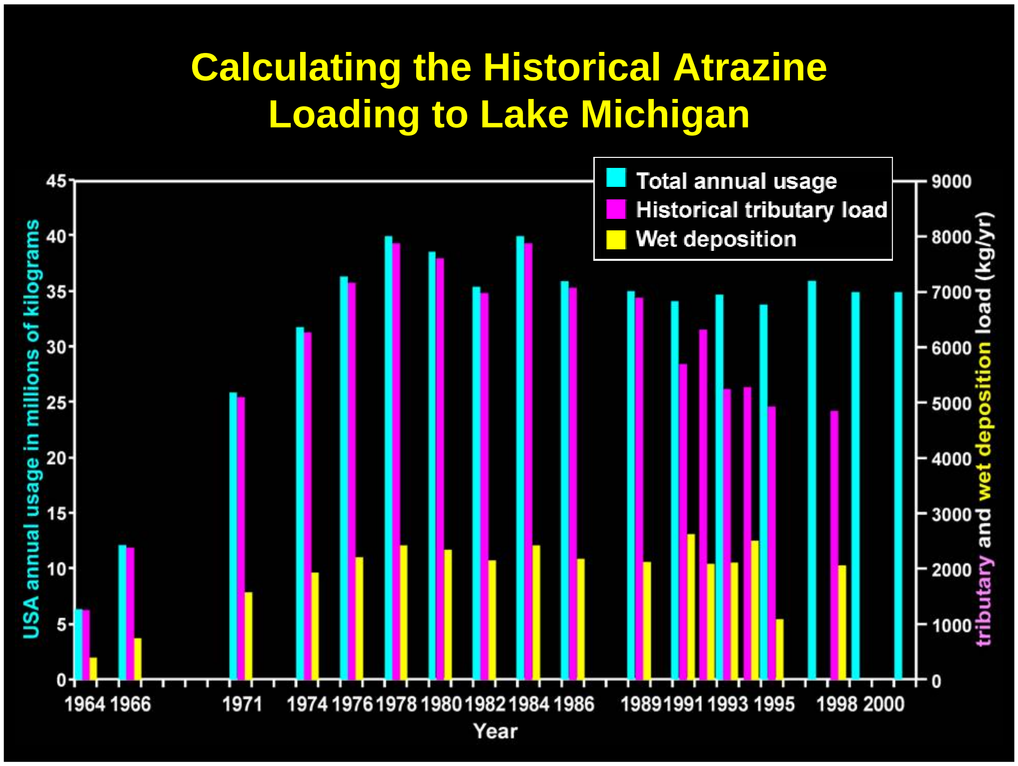
This graphic shows the seasonality of the atrazine wet deposition loading to Lake Michigan. Note the high loadings occur in the early spring months. This pattern is also observed for tributary loadings. These loading patterns are related to the spring application of atrazine.



This contour map shows the gradient of atrazine in the wet deposition loadings over Lake Michigan for May 1994.



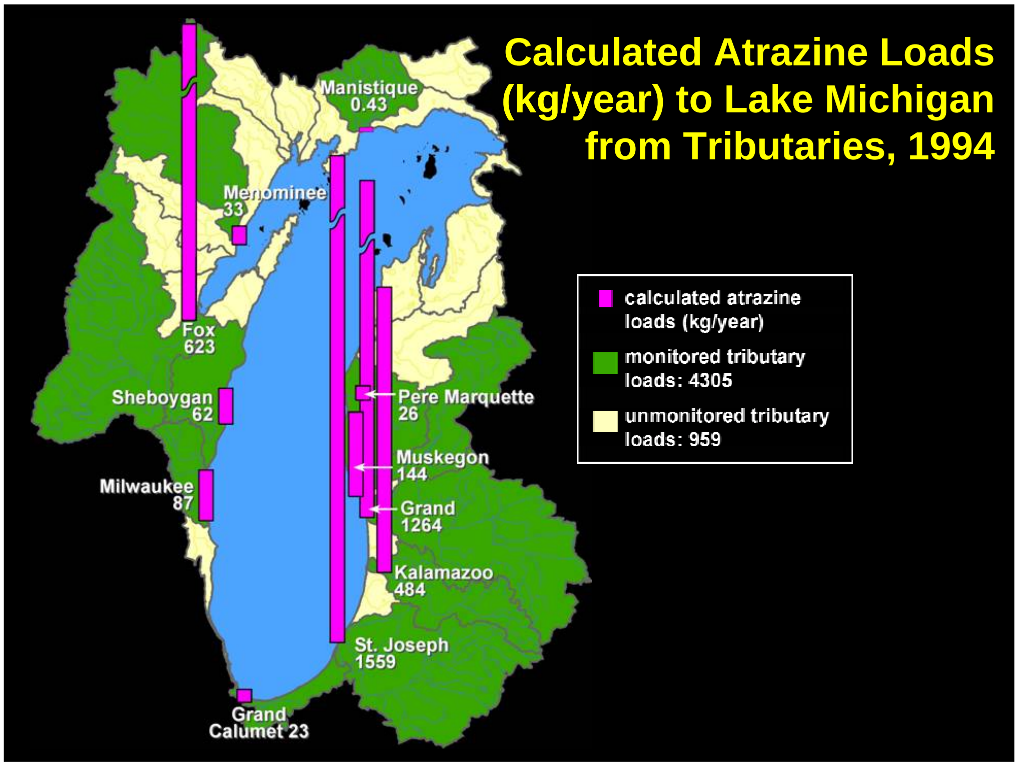
This figure shows atrazine concentrations in Lake Michigan water. You can note the higher concentrations in the lower part of Green Bay. The gradient noted in Green Bay is persistent throughout the year.



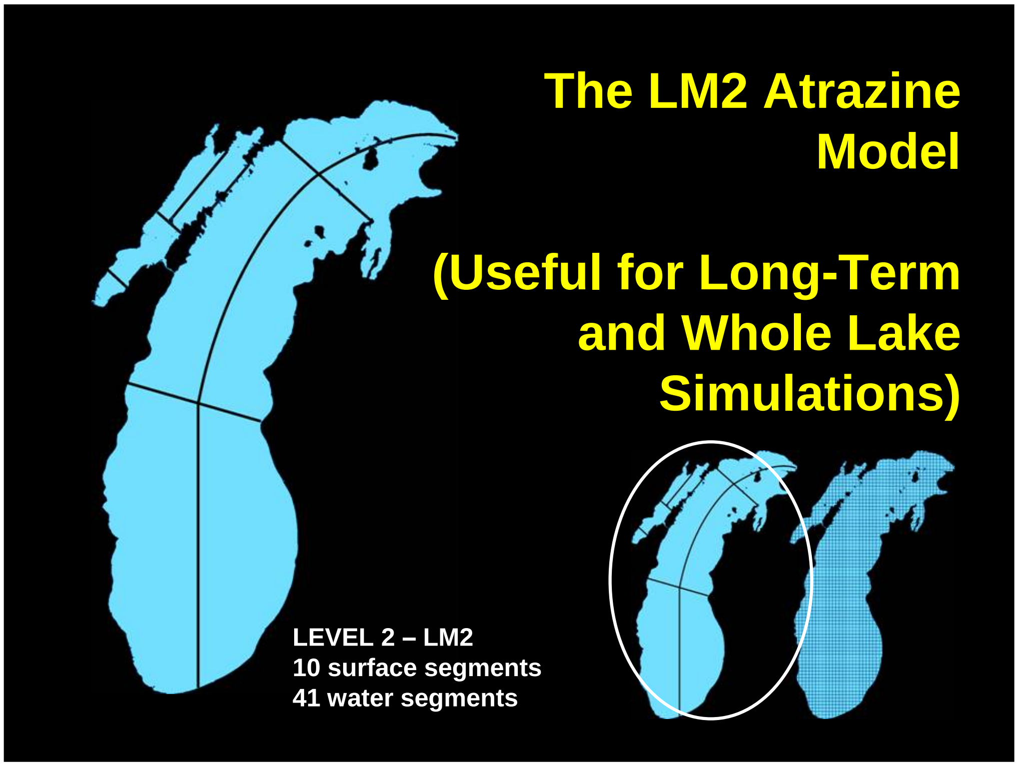
Total annual usage of atrazine in the USA was obtained from U.S. EPA Office of Pesticides Program. The usage peaked in approximately 1978, and has shown a slow decline since then.

There is a notable decline in tributary loadings in the 1990's relative to total annual usage. This decline may be attributable, in part, to label changes related to application and the Wisconsin Atrazine Management Plan (1991).

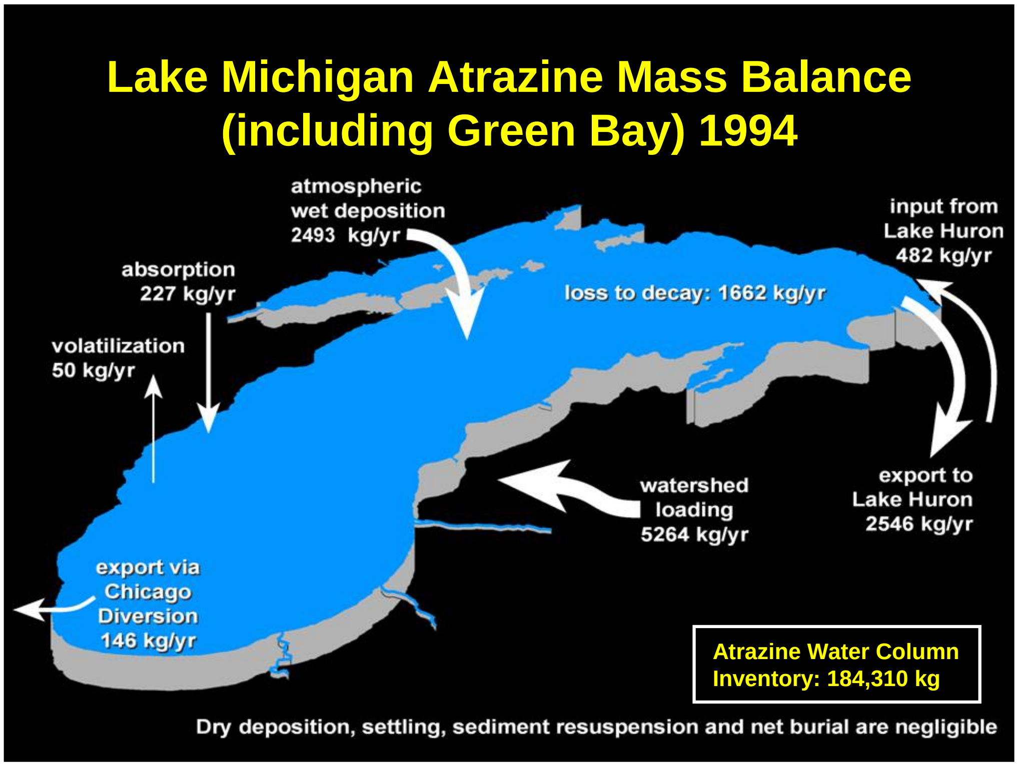
The precipitation loadings for 1995 show an unusual drop. A possible explanation is that the spring of 1995 was cold and wet in the prime corn growing regions of the country. Runoff of the chemical into streams, lakes, and reservoirs would reduce volatilization compared to that which would be expected if it had remained on the fields. Also, the colder temperatures limit volatilization.



Some of the larger loads are from the St. Joseph, Grand, and the Fox rivers. The total load from the southwest part of the state of Michigan represented by St. Joseph, Kalamazoo, and Grand represents about 63% of the total watershed load into Lake MI. Most of the loading occurs in early spring.



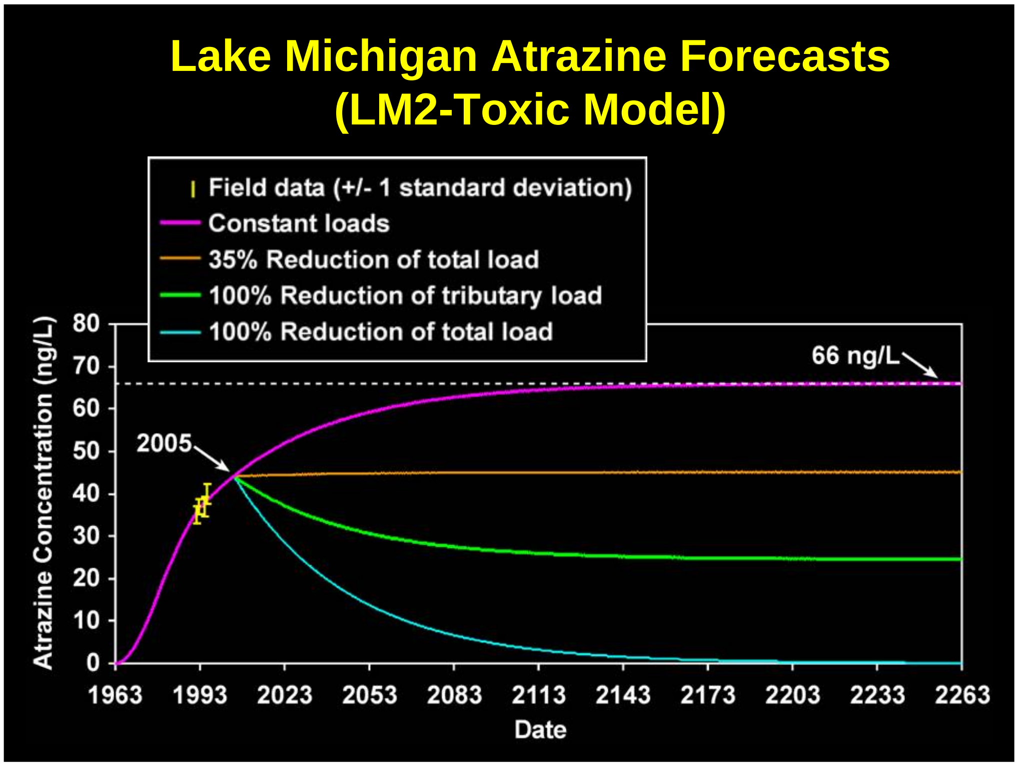
The LM2 Atrazine Model
(Useful for Long-Term and Whole Lake Simulations)
LEVEL 2 – LM2
10 surface segments
41 water segments



This is a snapshot of what the mass balance for atrazine in the lake looked like in the year 1994. Mass loadings into the lake are higher than those leaving the system. The system is not at steady state.

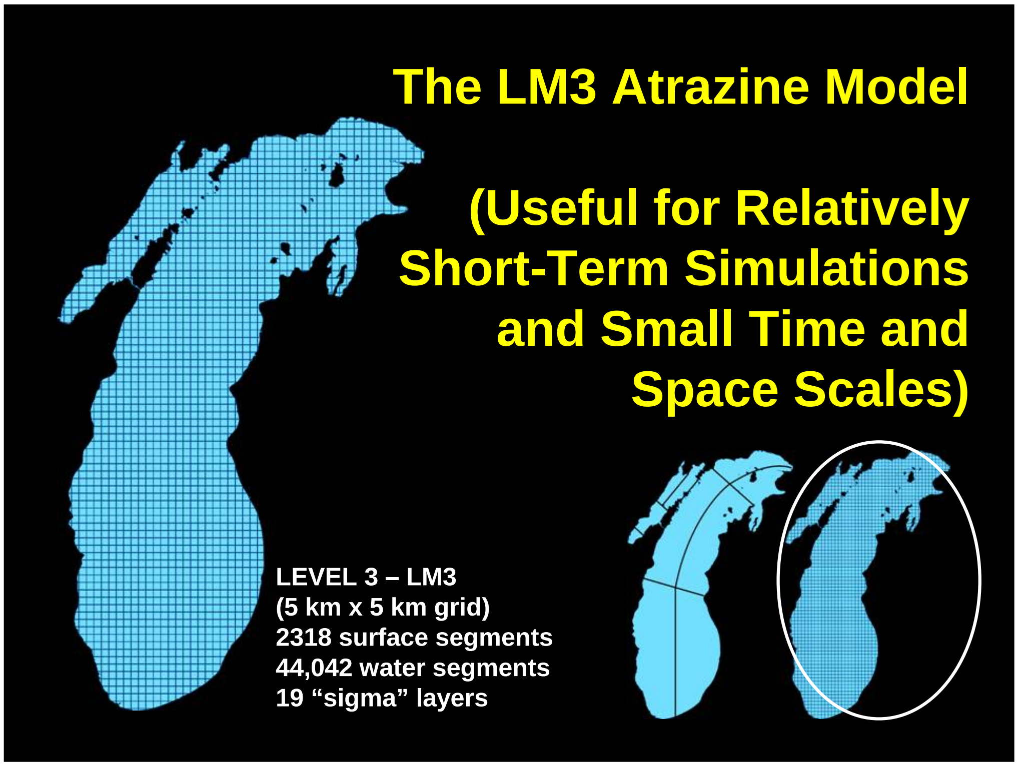
Watershed loading is the highest load to the lake and represents about 68% of the total loading to the lake. Atmospheric wet deposition is the second highest. The third largest load to the lake is that which is transported in from Lake Huron. Finally, absorption is the smallest load to the lake.

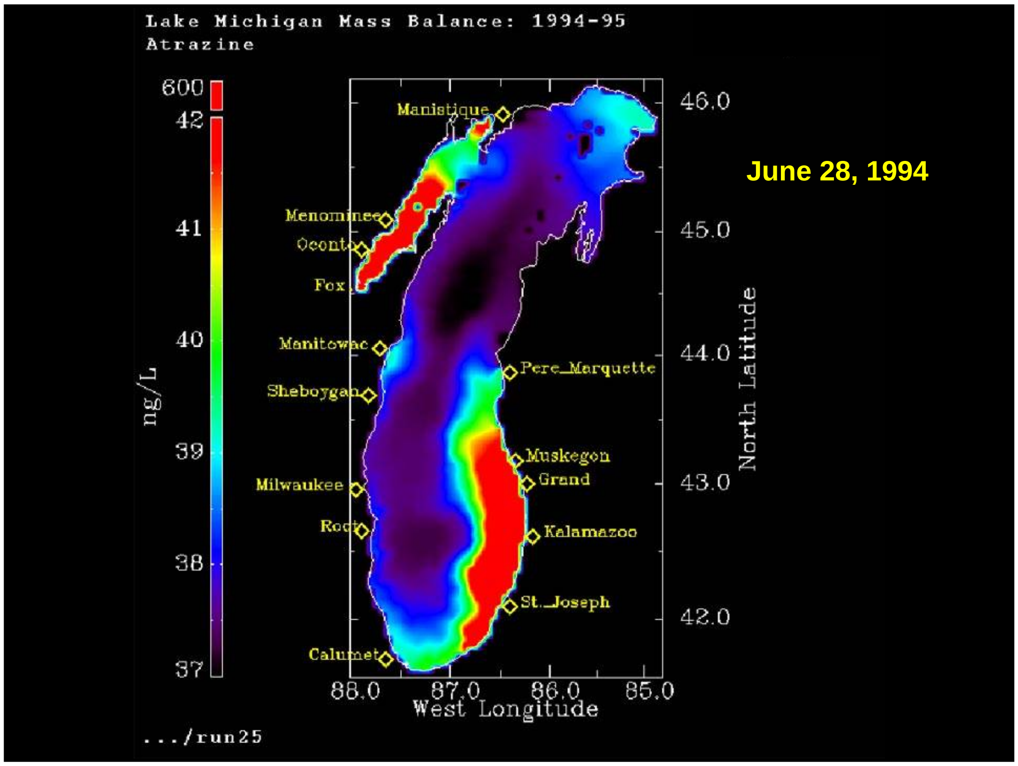
The export to Lake Huron is the largest loss of atrazine from the system. Loss to in-situ decay is the second highest loss. The rest of the losses are small (volatilization and export via the Chicago Diversion).



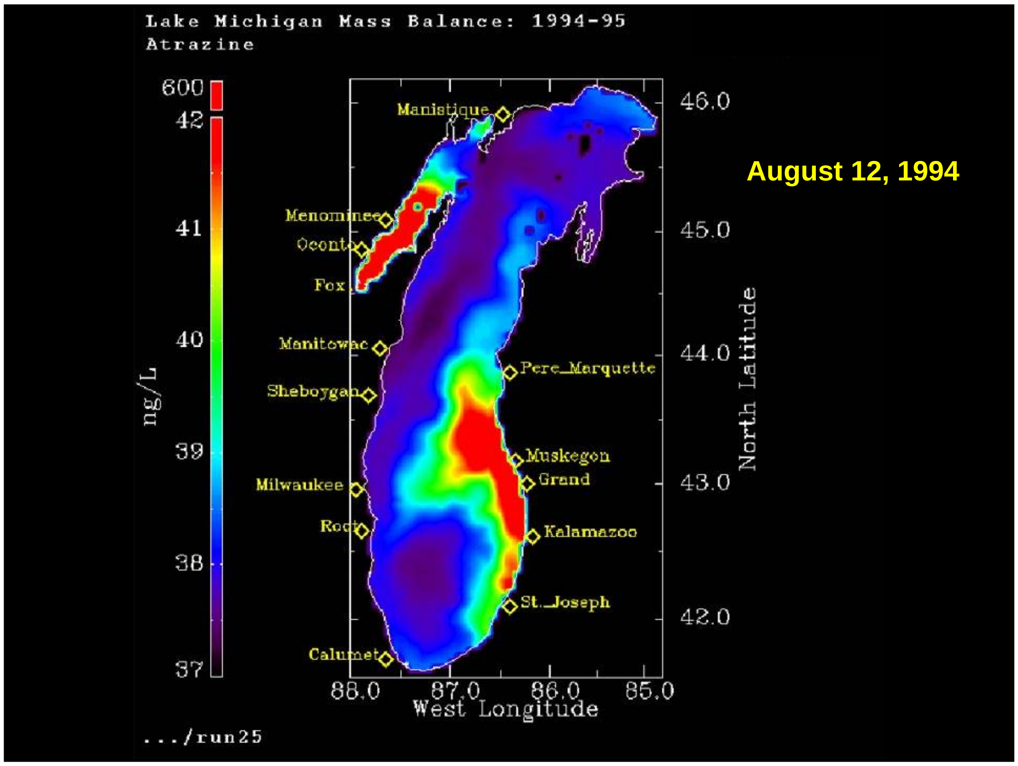
The lake data are shown here in yellow. If the loadings are the same as they were in the late 1990's, the model predictions are expected to follow the pink line. A maximum concentration of about 66 ng/l is reached in 2263.

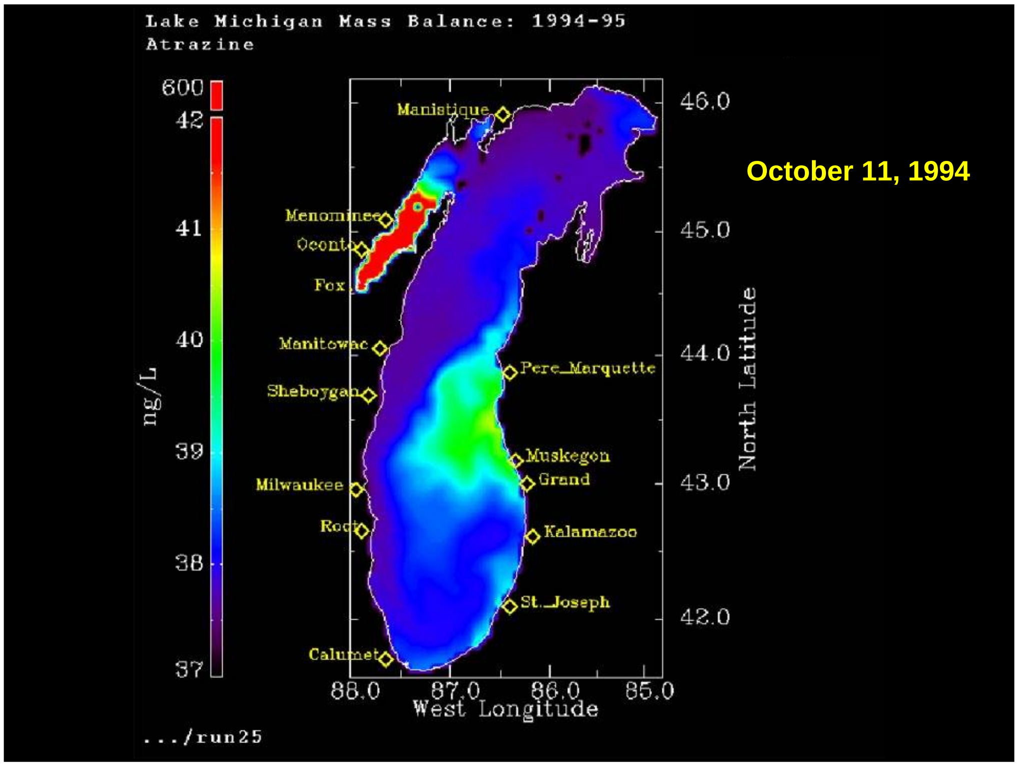
The model can be easily used to perform a back calculation to make an estimate of what loading would be necessary for the lake to show no further increase in concentration of atrazine. This amount is 35%, determined by trial and error. The green line shows the model prediction if tributary loads were cut off and the blue line shows the model prediction if all loads were cut off.

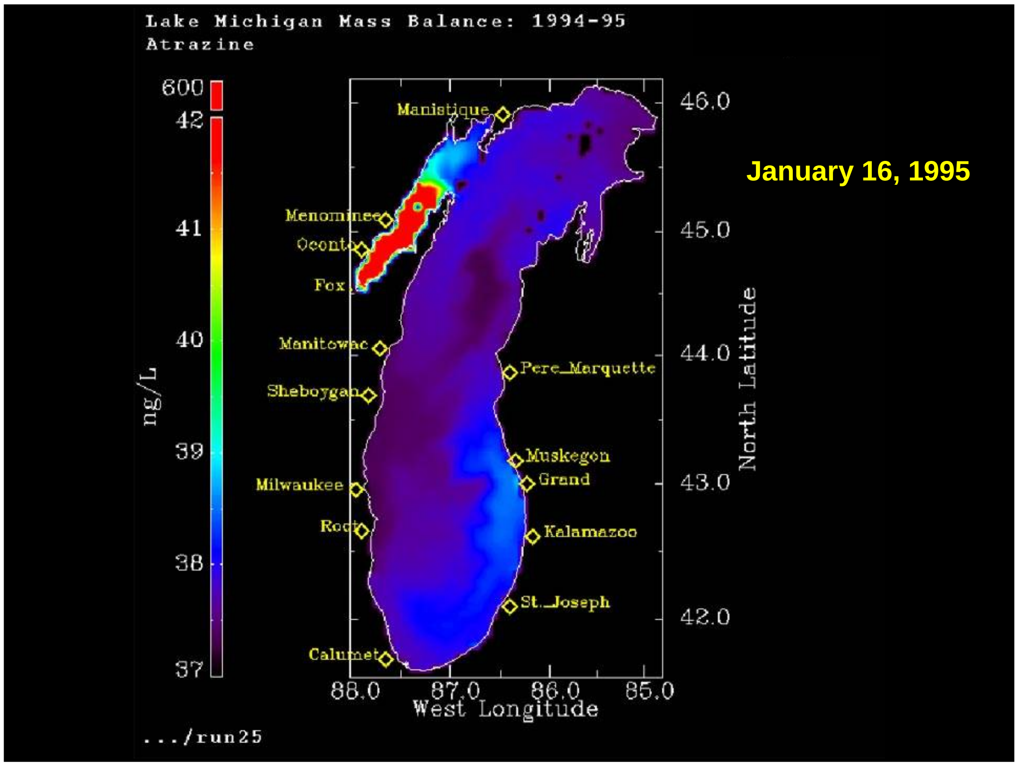

The LM3 Atrazine Model
(Useful for Relatively Short-Term Simulations and Small Time and Space Scales)
LEVEL 3 – LM3
(5 km x 5 km grid)
2318 surface segments
44,042 water segments
19 "sigma" layers

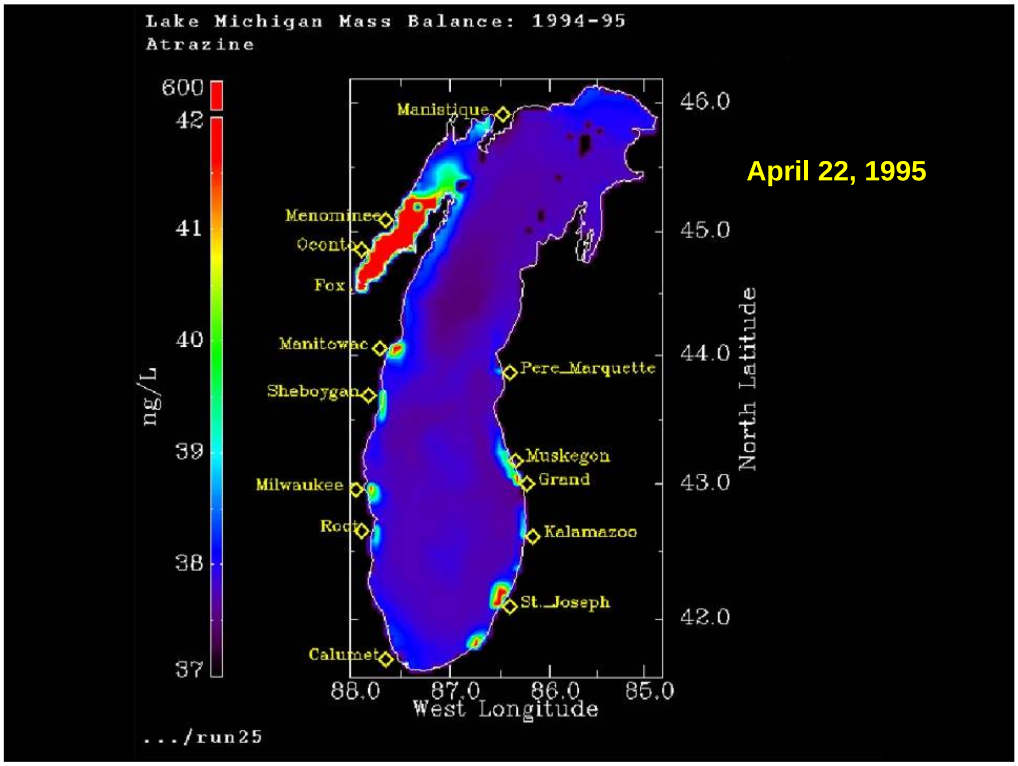


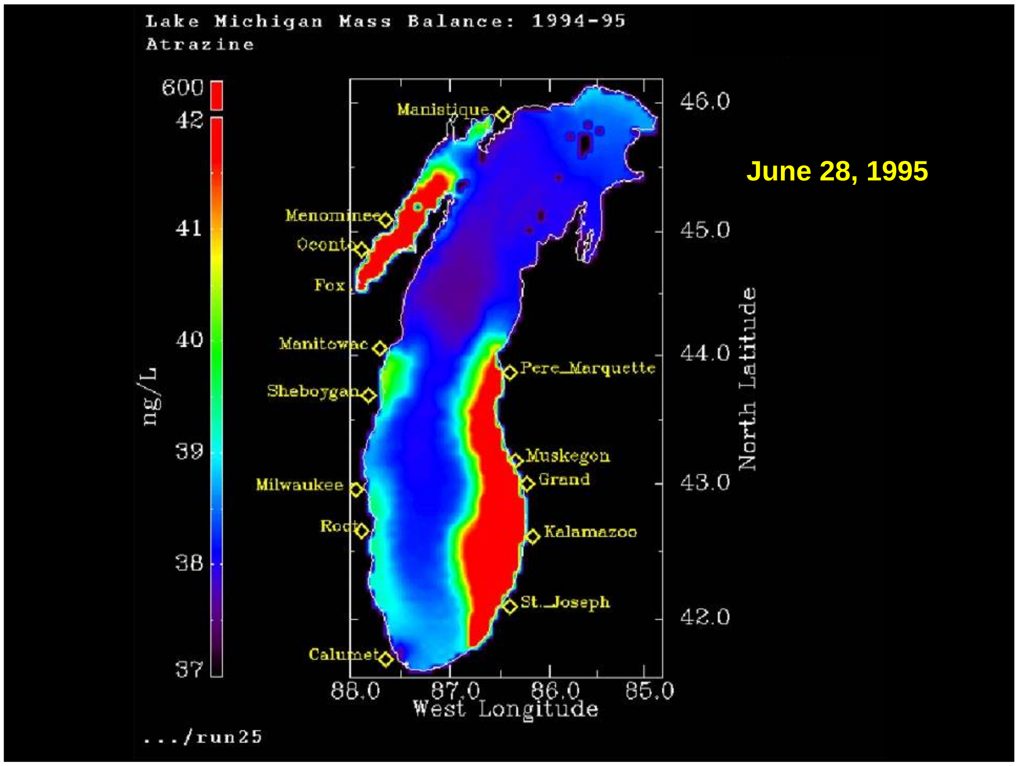
This graphic, and those that follow, depict concentrations of atrazine in the water. Output is from the high resolution LM3 Atrazine model.


Lake Michigan Mass Balance: 1994-95
Atrazine
August 12, 1994
600
42
41
40
39
38
37
ng/L
Manistique
Menominee
Oconto
Fox
Manitowac
Sheboygan
Milwaukee
Root
Calumet
Pere_Marquette
Muskegon
Grand
Kalamazoo
St._Joseph
46.0
45.0
44.0
43.0
42.0
North Latitude
88.0
87.0
86.0
85.0
West Longitude
.../run25

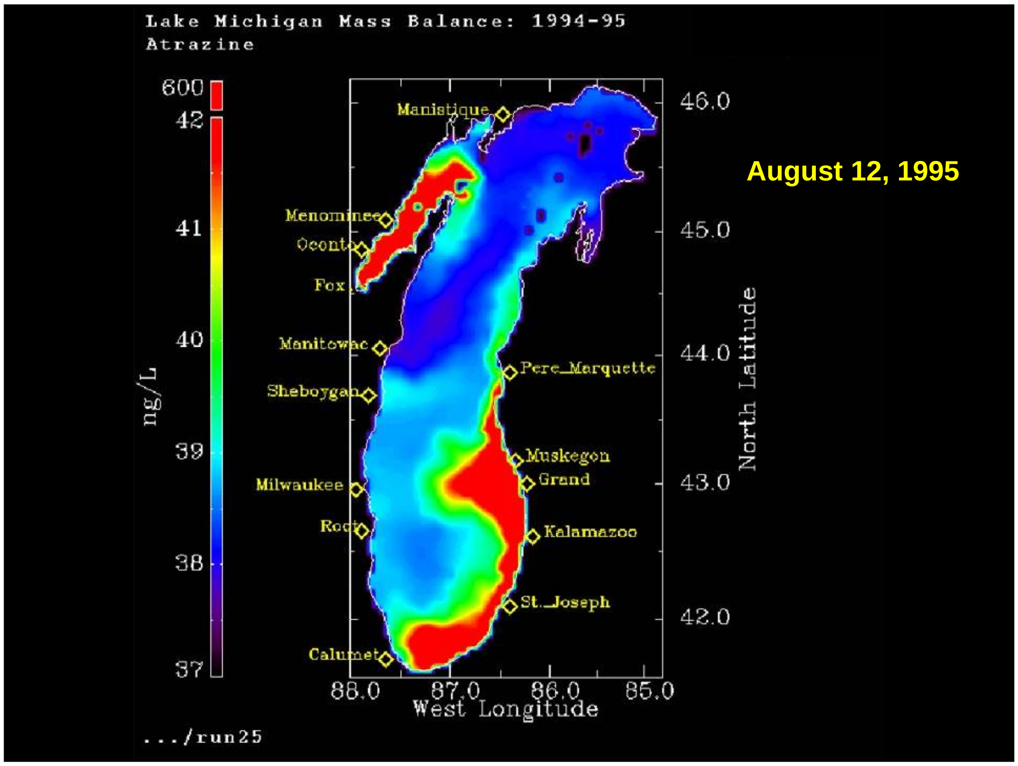

Lake Michigan Mass Balance: 1994-95
Atrazine
October 11, 1994
600
42
41
40
39
38
37
ng/L
Manistique
Menominee
Oconto
Fox
Manitowoc
Sheboygan
Milwaukee
Root
Calumet
Pere_Marquette
Muskegon
Grand
Kalamazoo
St._Joseph
46.0
45.0
44.0
43.0
42.0
North Latitude
88.0
87.0
86.0
85.0
West Longitude
.../run25

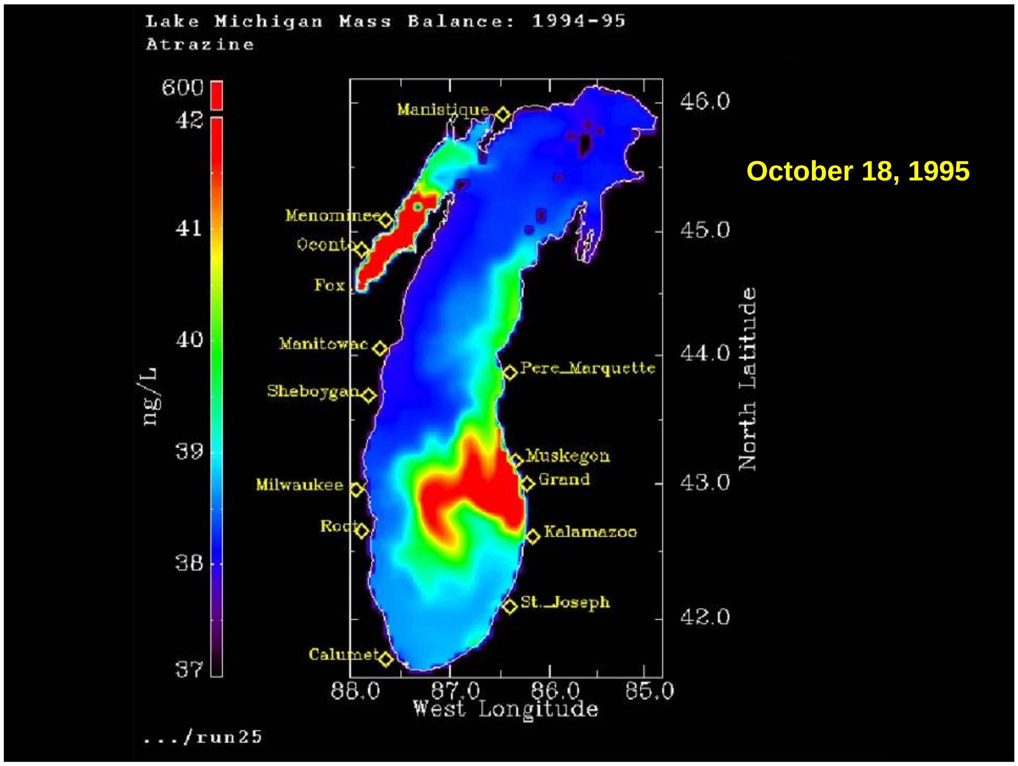

Lake Michigan Mass Balance: 1994-95
Atrazine
January 16, 1995
600
42
41
40
39
38
37
ng/L
Manistique
Menominee
Oconto
Fox
Manitowac
Sheboygan
Milwaukee
Rock
Calumet
Pere_Marquette
Muskegon
Grand
Kalamazoo
St._Joseph
46.0
45.0
44.0
43.0
42.0
North Latitude
88.0
87.0
86.0
85.0
West Longitude
.../run25

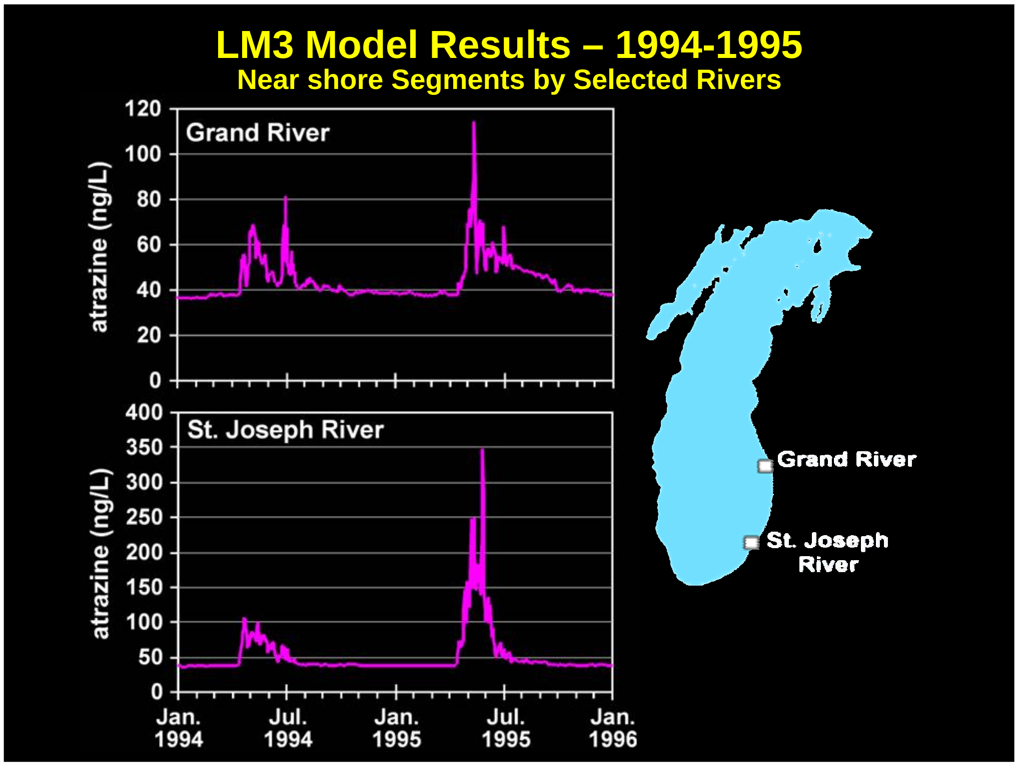

Lake Michigan Mass Balance: 1994-95
Atrazine
April 22, 1995
600
42
41
40
39
38
37
ng/L
Manistique
Menominee
Oconto
Fox
Manitowac
Sheboygan
Milwaukee
Root
Calumet
Pere_Marquette
Muskegon
Grand
Kalamazoo
St._Joseph
46.0
45.0
44.0
43.0
42.0
North Latitude
88.0
87.0
86.0
85.0
West Longitude
.../run25



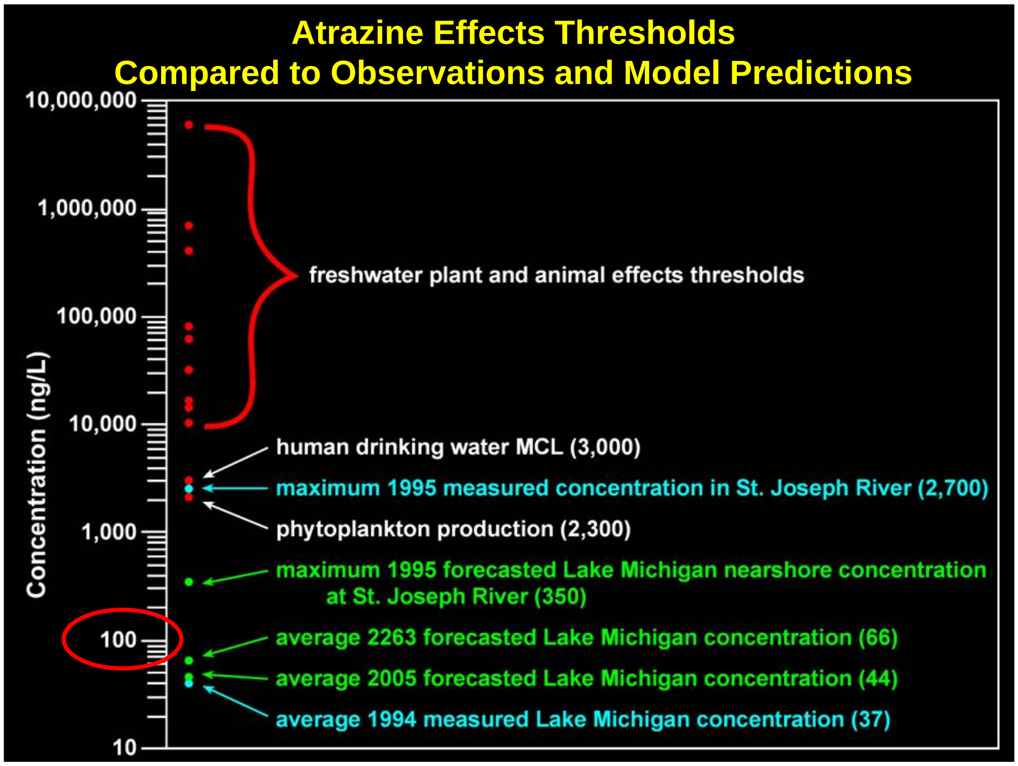
Lake Michigan Mass Balance: 1994-95
Atrazine
June 28, 1995
600
42
41
40
39
38
37
ng/L
Manistique
Menominee
Oconto
Fox
Manitowac
Sheboygan
Milwaukee
Root
Calumet
Pere_Marquette
Muskegon
Grand
Kalamazoo
St._Joseph
46.0
45.0
44.0
43.0
42.0
North Latitude
88.0
87.0
86.0
85.0
West Longitude
.../run25


Lake Michigan Mass Balance: 1994-95
Atrazine
August 12, 1995
ng/L
600
42
41
40
39
38
37
Manistique
Menominee
Oconto
Fox
Manitowoc
Sheboygan
Milwaukee
Root
Calumet
Pere_Marquette
Muskegon
Grand
Kalamazoo
St._Joseph
46.0
45.0
44.0
43.0
42.0
North Latitude
88.0
87.0
86.0
85.0
West Longitude
.../run25


Lake Michigan Mass Balance: 1994-95
Atrazine
October 18, 1995
600
42
41
40
39
38
37
ng/L
Manistique
Menominee
Oconto
Fox
Manitowoc
Sheboygan
Milwaukee
Root
Calumet
Pere_Marquette
Muskegon
Grand
Kalamazoo
St._Joseph
46.0
45.0
44.0
43.0
42.0
North Latitude
88.0
87.0
86.0
85.0
West Longitude
.../run25



This graphic represents LM3 model predictions of atrazine in a near-shore lake cell, near the discharge of the Grand and St. Joseph Rivers. Note the high loadings in the spring-time are causing seasonally elevated near-shore lake concentrations.



So, how do the data and model predictions compare to known biological effects criteria? The blue text indicates measured values and the green text shows the model-predicted open lake stations averages and the highest near-shore concentration in a lake segment located near the discharge of the St. Joseph River. Lake concentrations (both measured and model-predicted) are below all accepted effects thresholds.

The 100 ng/L effect threshold is thought to impact early life stage frog *(Xenopus laevis*) development by Tyrone Hayes *et al*., 2002, Proceedings of the National Academy of Sciences, 99 (8); however, this conclusion has not been widely accepted in the research community. EPA has decided that there is sufficient evidence in the literature to formulate a hypothesis that atrazine may affect amphibian development, but a definitive conclusion cannot be reached at this time. The pesticide registrant, Syngenta, has been asked to do additional research in this area and report on results, expected in spring 2006.

Summary

Observed and forecasted lake-averaged concentrations of atrazine are well below EPA biological effects thresholds (2300 ng/L for phytoplankton production).

Approximately 68% of the total atrazine loading to the lake is from tributaries.

Atrazine is very persistent in Lake Michigan – decay is estimated at less than 1% per year.

Atrazine concentrations are forecasted to increase in the lake under present loads.

Next Steps

Prepare a detailed U.S. EPA Office of Research and Development project report

Additional forecasts?

Publish in a peer-reviewed journal

Analyze Lake Michigan water samples collected in 2005 (open lake) to confirm model-predicted concentration 44 ng/L