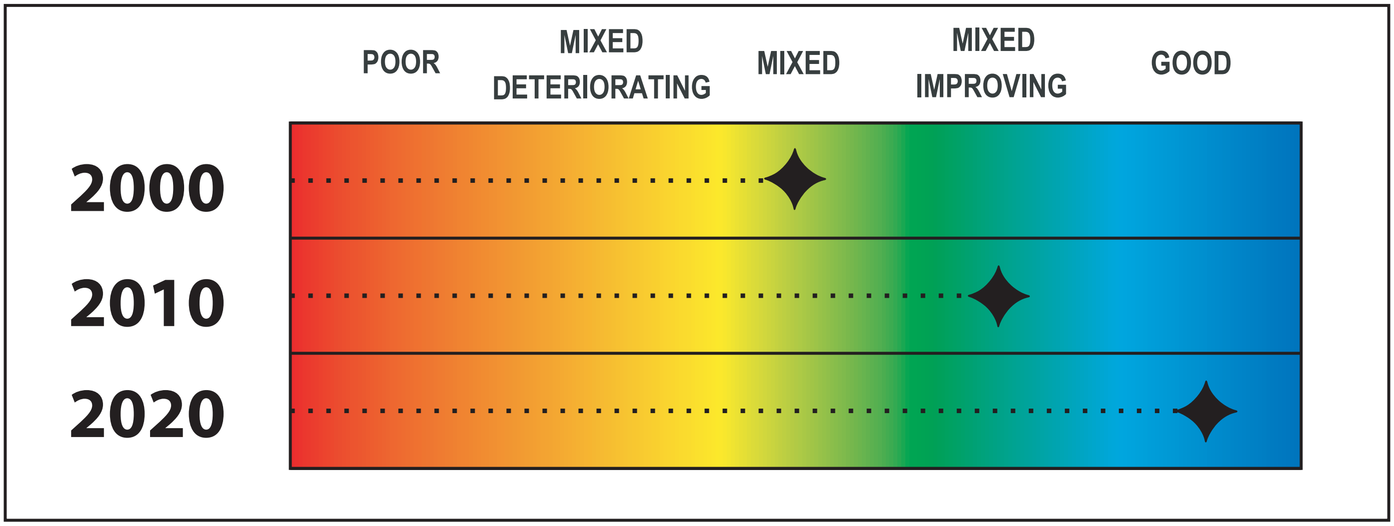
Subgoal 7
Are sediments, air, land, and water sources or pathways of contamination that affect the integrity of the ecosystem?



Status

Sediments, air, land, and water continue to be sources or pathways of contamination that affect the integrity of the Lake Michigan ecosystem. While regulatory and remediation programs reduce pollutant sources, ongoing releases and the region's legacy of contamination continue to serve as sources of pollutants. As a result, the status of this goal is mixed. There has been significant activity that will assist in changing the status to mixed/ improving over the next decade. In particular, the findings of the Lake Michigan Mass Balance Study will allow decision-makers to better understand pollution pathways so that they can develop more effective policies to deal with pollution issues and pathways.

The following section presents recent findings regarding pollution pathways and predictions of future levels of PCBs in lake trout fish

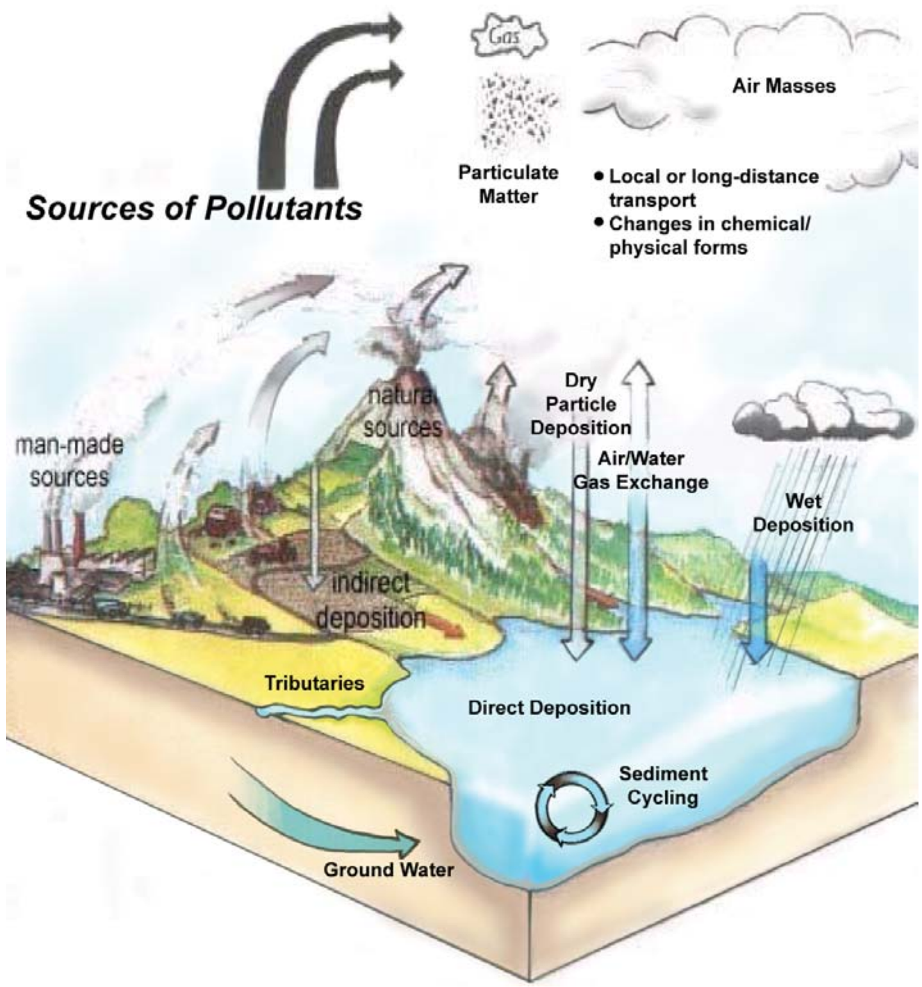


Figure 5 Pollutants enter Lake Michigan through several pathways
Source: EPA (http://www.epa.gov/owow/oceans/airdep)
Augmented by Joseph F. Abboreno, Tetra Tech EM, Inc.

Lake Michigan Mass Balance Study Findings

- Present concentrations of PCBs in Lake Michigan water and biota are dominated by historical loadings as represented by the large reservoir of PCBs present in bottom sediments. As sediments are resuspended, PCBs are released to the water column where they are subsequently volatilized to the atmosphere.

- Once the sediment reservoir of PCBs is depleted, the most important remaining sources will become atmospheric absorption, tributary loadings, and atmospheric deposition (wet and dry). Gaseous exchange is an important mechanism and together with vapor phase concentrations, govern the movement of PCBs into and out of Lake Michigan via the air.

- Chicago is an important contributor of atmospheric inputs to the lake. Levels of PCBs tend to be higher in the Chicago area than at offshore and rural sites. High concentrations of PCBs occur over the lake when the winds are from the southwest (Chicago-Gary region) and during warm months.

- Approximately 70 percent of the atrazine loading to the lake comes from tributaries, with the remaining 30 percent of the load coming primarily from precipitation.

- Trans-nonachlor concentrations in Lake Michigan rivers are relatively low in all cases. However, the concentrations in rivers draining agricultural watersheds are usually higher. The Kalamazoo, Milwaukee, and Sheboygan Rivers, and Indiana Harbor have slightly lower trans-nonachlor levels than other Lake Michigan tributaries, but are still of similar magnitude (Figure 6).

- Mercury is transported into Lake Michigan from a variety of sources, including tributary rivers (Figure 7). Transport of mercury from some tributaries to Lake Michigan increases with summer and fall storm events, particularly in more freely flowing rivers with mercury-contaminated sediments.

Additional information on the study is available at *http://www.epa.gov/glnpo/monitor.html.*

References and figures see Appendix C.

tissue and atrazine in the waters of Lake Michigan. The section concludes with an overview of specific pathways that continue to serve as sources of pollutant load to Lake Michigan.

Challenges

(1) To gather data on sources and pathways of contaminants in Lake Michigan.

(2) To develop a better understanding of the natural dynamics that affect pollutant distribution in the Lake Michigan ecosystem.

(3) To reduce pollutant loads with effective control and pollution control measures

(4) To develop coordinated monitoring in 2004 or 2005 and to develop a 10-year trend analysis based on the 1994 mass balance project for the lake.

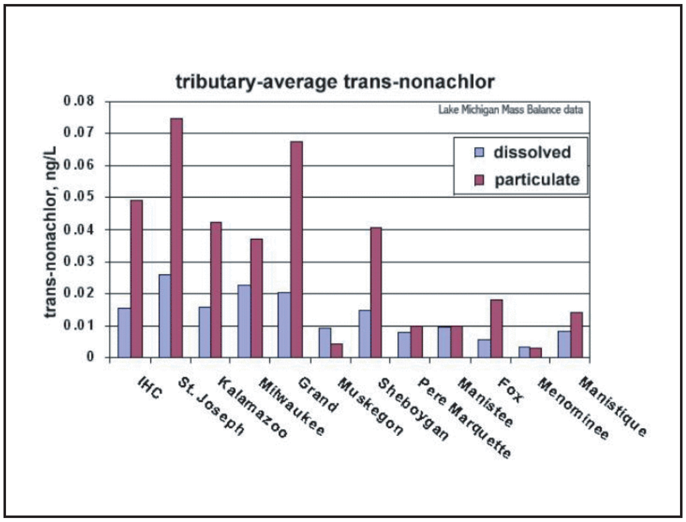


Figure 6: Average Tributary trans-nonachlor Concentrations
Source: EPA GLNPO

Lake Michigan Mass Balance Project

The Lake Michigan Mass Balance (LMMB) Project is an enhanced monitoring and modeling project that is working to develop a scientific base of information to inform LaMP policy decisions and better understand the science of pollutants within an ecosystem. The LMMB Project's specific objectives are:

(1) To identify relative loading rates of four categories of pollutants (PCBs, mercury, transnonachlor, and atrazine) entering Lake

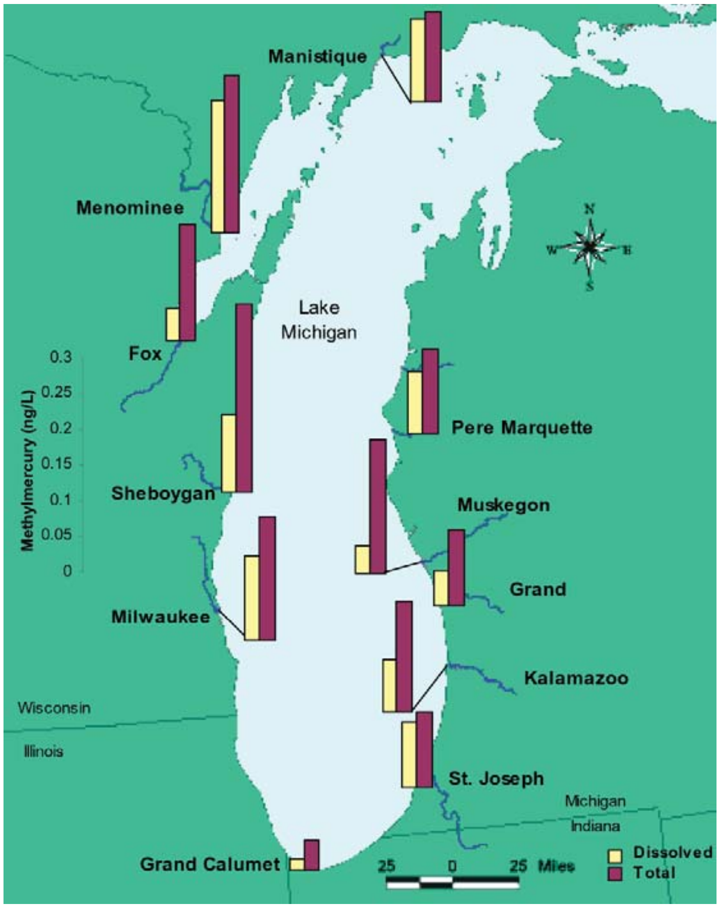


Figure 7: Lake Michigan Mass Balance Findings: Methylmercury in Lake Michgan Tributaries (mg/L)

Michigan from major media (air, tributaries, and sediments);

(2) To establish baseline loading estimates in 1994-1995 against which to gauge future progress;

(3) To develop the predictive ability to determine the environmental benefits of specific load reduction scenarios for toxic substances and the time required to realize those benefits through the use of models; and

(4) To improve our understanding of key environmental processes governing the movement of pollutants through the lake (cycling) and fish and plant life (bioavailability) within relatively closed ecosystems.

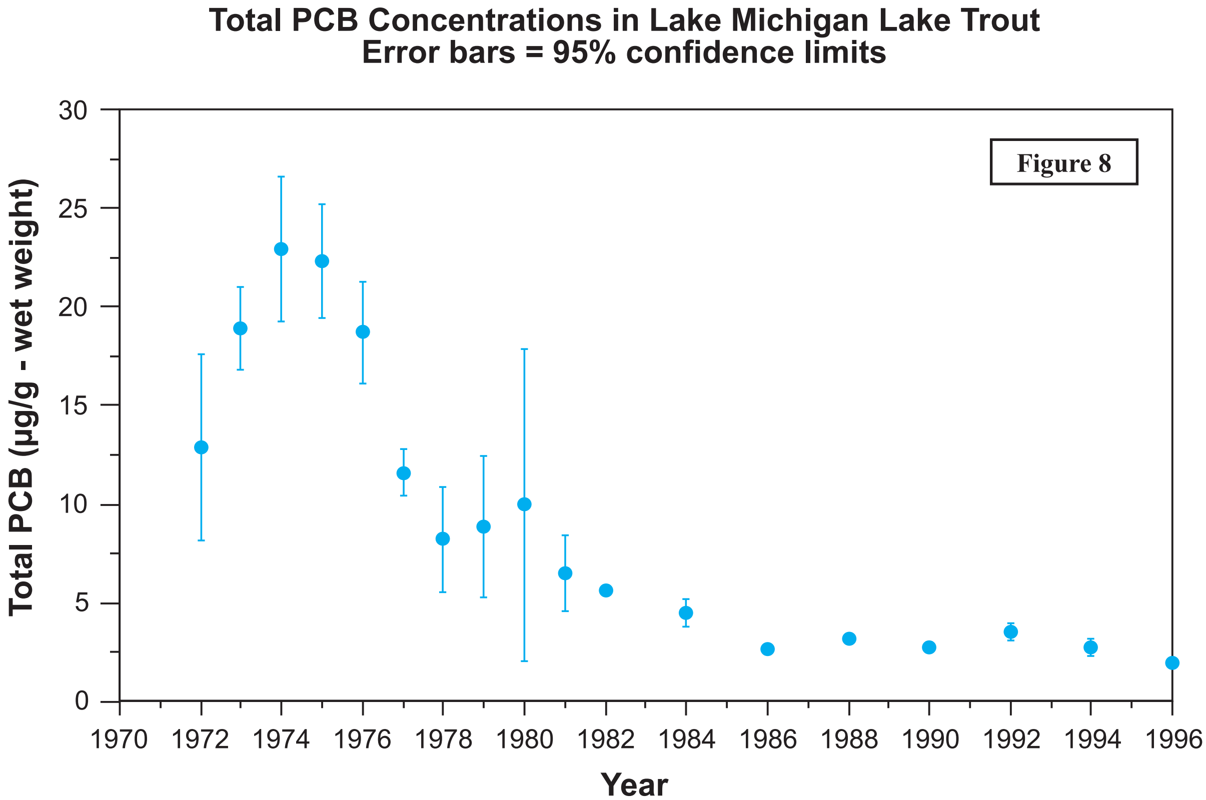
The LMMB Project focused on constructing mass balance models for a limited group of pollutants. Polychlorinated biphenyls (PCBs), trans-nonachlor, atrazine, and mercury were selected for inclusion in the LMMB Project because these pollutants currently or potentially pose a risk to aquatic and terrestrial organisms (including humans) in the Lake Michigan ecosystem. These pollutants were also selected to cover a wide range of chemical and physical properties and represent other classes of compounds which pose current or potential problems. Once a mass budget for selected pollutants is established and a mass balance model calibrated, additional contaminants can be modeled with limited data.

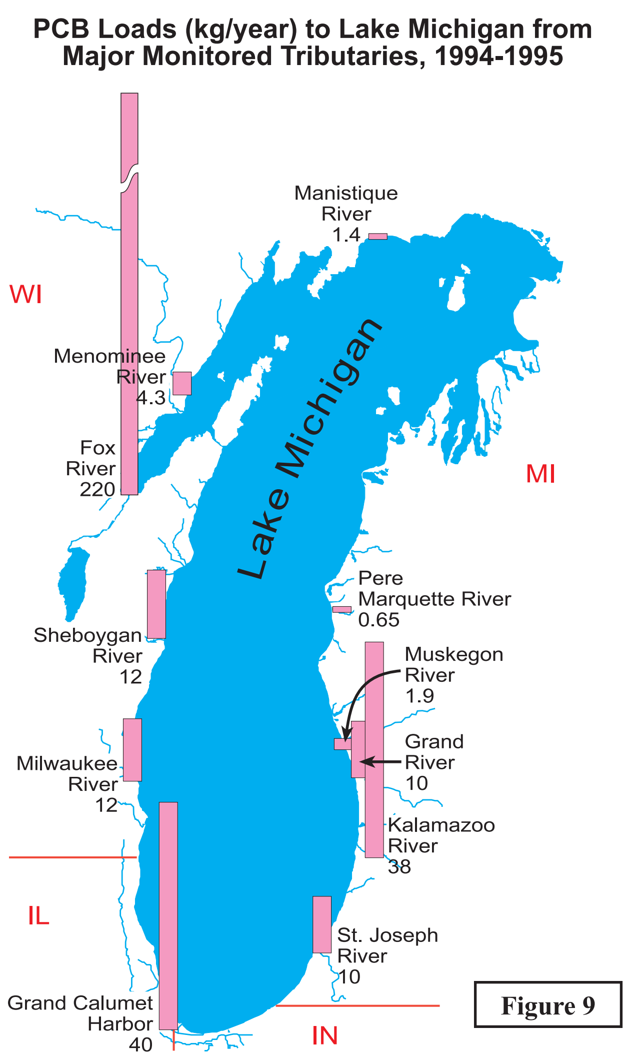
The LMMB Project used a mass balance approach to evaluate the sources, transport, and fate of contaminants in the Lake Michigan ecosystem. The mass balance approach is based on the law of conservation of mass, which states that the mass of a chemical contained in the lake is equal to the amount entering the system, less the amount leaving and chemically changed in the system. In the Lake Michigan system, pollutant inputs may come from atmospheric deposition, tributary loads, or sediments. Pollutants may leave the system through burial in bottom sediments, volatilization to the atmosphere, or discharge through the Straits of Mackinac. Pollutants within the system may be transformed through degradation or stored in ecosystem compartments such as the sediments, water column, or biota, including humans.

Data reports and preliminary modeling results are now being released by LMMB researchers. Although a suite of models is still being developed, modified, calibrated, and applied, preliminary model results have been used to conduct these initial assessments. The initial model results have focused on PCBs and atrazine. Mercury and trans-nonachlor model results will be published in the next 2 years. A few highlights of these results are summarized below.

PCB Prognosis for Lake Michigan: Modeling Future PCB Levels in Lake Trout

PCB concentrations in fish over the past 30 years show a downward trend from peak levels in the 1970s (Figure 8). However, the most recent data indicate that concentrations may be achieving equilibrium above desired levels in lake trout. Similar trends may be occurring in other species. The LMMB Project was undertaken, in part, to





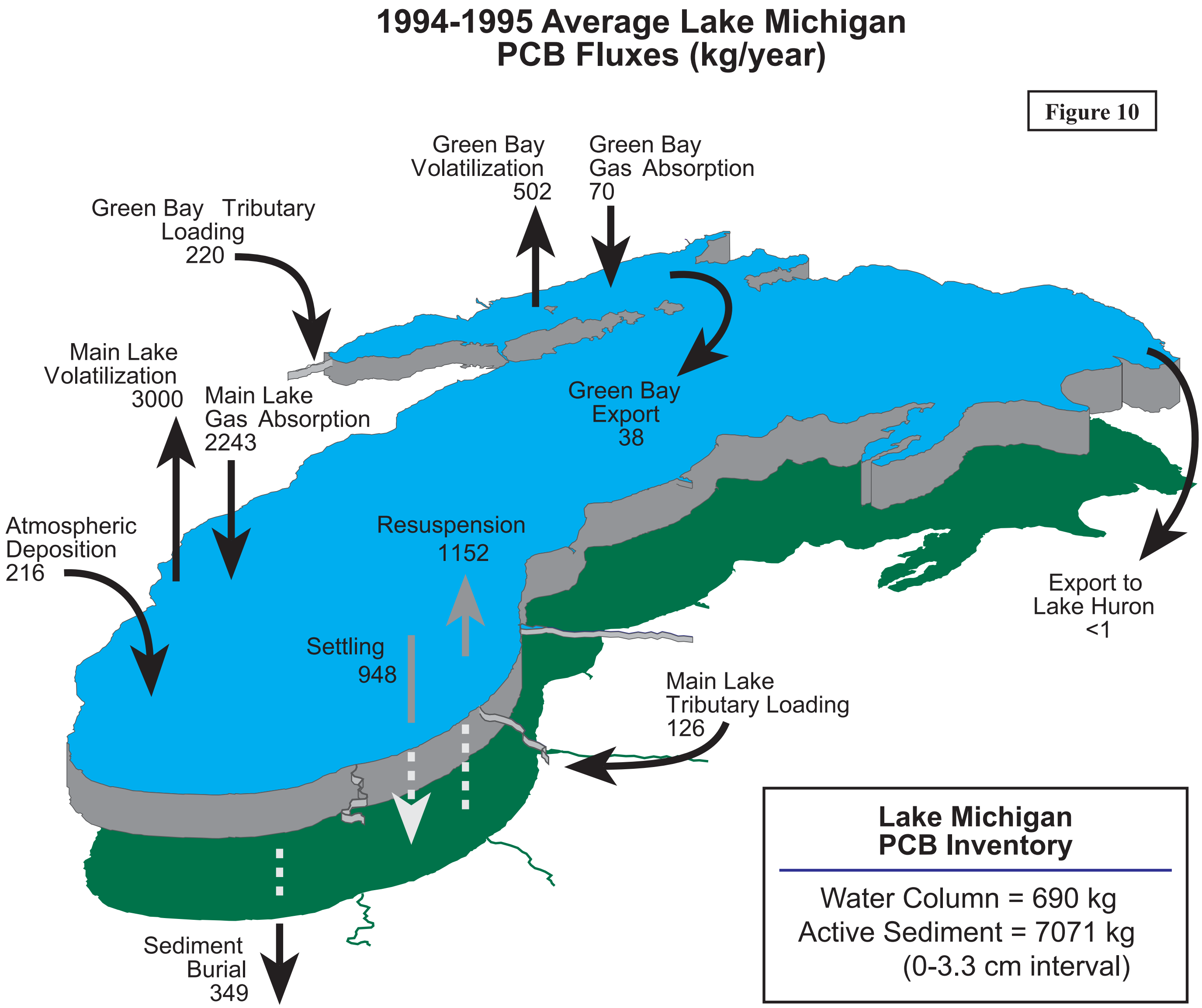
investigate this problem in detail and to develop mathematical models that could be used to project future concentrations in water, sediment, and biota, with and without further remedial and/or regulatory efforts.

These interim results provide several insights into the sources, fate, and effects of PCBs in Lake Michigan and the continuing need for reduction.

Figure 9 shows a summary of PCB loads from tributaries in 1994-1995. The relative importance of sources and losses of PCBs in the entire system is provided in Figure 10.

Table 2 outlines three scenarios evaluated using the MICHTOX model. The scenarios evaluate a range of management alternatives from taking no action to reduce PCB loads to eliminating 50 percent of loads to eliminating all PCB loads from tributaries, atmospheric deposition, and the vapor phase. The scenarios were evaluated to determine whether they would achieve reductions in fish tissue PCB levels.

Under Scenario A, PCBs should continue to decline over time even with no further controls (Figure 11) Under this scenario, PCBs should decline naturally over time, but once the sediment reservoir is depleted, further reductions will depend on the



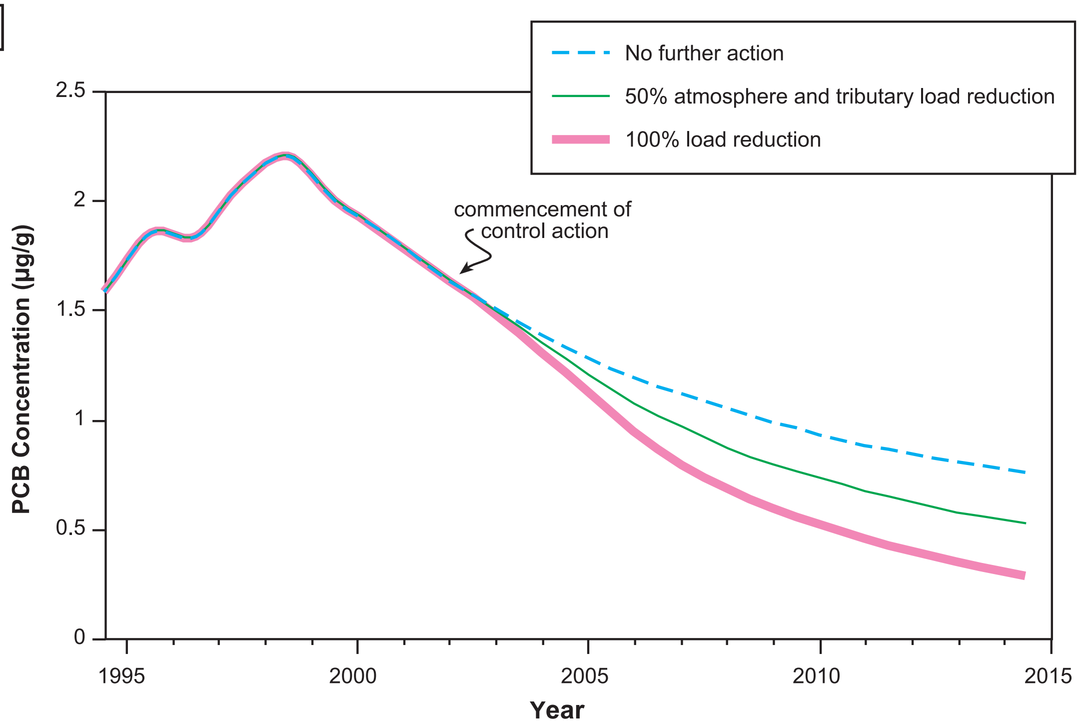
control of the tributary and atmospheric sources. Under Scenario B, in order to further reduce fish consumption advisories by 2020, a 50 percent reduction of PCB loads needs to occur. Under Scenario C (hypothetical virtual elimination or 100 percent reduction of PCB loads), fish tissue levels would be approaching advisory levels by approximately 2020. However, this virtual elimination scenario is hypothetical, because PCBs presently found in the environment make virtual elimination unfeasible.

Table 2. PCB Load Reduction Scenarios

Scenario	Description	Tributary Loads	Atmospheric Deposition	Vapor Phase Concentration
A	No Change	Constant	Constant	Constant
B	50% Reduction	50% Reduction	50% Reduction	50% Reduction
C	Virtual Elimination	100% Reduction	100% Reduction	100% Reduction

Toxic Chemical Management Alternative Comparison of Forecast Simulations for Age 7 Lake Trout in Southern Lake Michigan

Figure 11



Atrazine Prognosis in the Open Waters of Lake Michigan

Unlike PCBs and mercury, the herbicide atrazine does not bioaccumulate in organisms but does remain in the water column. The two single-most important atrazine loads to Lake Michigan include tributaries and wet deposition (rain and snow). Historical loading estimates of atrazine from both tributaries and wet deposition to Lake Michigan are depicted in Figure 12. Decreases in loadings from the tributaries is evident starting in 1985. A decreasing trend of loadings from the atmosphere in the form of wet deposition is not as evident.

Atmospheric loadings to the lake are higher in the southern portions than in the northern areas. The higher loadings in the south are likely due to the close proximity of this area to corn growing regions in the southern basin. Most of the atrazine loadings

Integrated Atmospheric Deposition Network (IADN)

IADN has been operating since 1990 through a partnership between Environment Canada and the U.S. EPA's Great Lakes National Program Office. IADN consists of a system of 5 master monitoring stations (one located on each of five Great Lakes) and several satellite stations (see figure). IADN measures concentrations of PCBs, PAHs, organochloride pesticides, and trace metals in the air and precipitation around the Great Lakes. One of the goals of IADN is to calculate atmospheric loadings of these pollutants to the Lakes and examine trends in atmospheric concentrations at the different stations over time. The latest IADN loadings report, using more recent data, is consistent with the LMMB findings. The IADN findings include:

- PCB levels and loadings are generally decreasing at IADN master stations; however, available data for Chicago suggests that PCB concentrations are holding steady over time.
- Loadings of banned pesticides to the Great Lakes are generally decreasing over time. Loadings of in-use pesticides are generally twice as high as banned pesticides.
- Regional loadings of DDT and DDD have been consistently positive (into the Great Lakes) over time. This finding indicates that the Great Lakes basin is still acting as a sink for chemicals that have been banned from use in the United States and Canada for over 20 years.

For more information on IADN, please refer to *http://www.msc.ec.gc.ca/IADN*

Atrazine Reassessment

Atrazine is regulated as a pesticide and EPA has set a maximum contaminant level (MCL) for drinking water. The MCL is most important for groundwater sources as Lake Michigan provides a large dilution factor. EPA's Office of Pesticide Programs (OPP) has released the preliminary ecological risk assessment for atrazine, a pesticide undergoing re-registration and tolerance reassessment. The atrazine risk assessment and related documents are available at: http://www.epa.gov/pesticides/reregistration/status.htm.

Concurrently, EPA's Office of Water has released the Draft Aquatic Life Criteria Document for Atrazine, which provides recommendations to states and tribes for their use in establishing water quality standards as regulations. The associated Federal Register notices are available on EPA's web site at http://www.epa.gov/fedrgstr. The comment periods for these documents ended in 2001.

EPA's preliminary ecological risk assessment for atrazine indicates that risk quotients exceeded levels of concern for chronic effects on mammals, birds, fish, aquatic invertebrates, and non-target plants at maximum and in some cases at typical use rates. A refined risk assessment for atrazine focusing on the aquatic environment and using the extensive ecosystem exposure monitoring data as well as additional ecotoxicological data found in the open literature, resulted in concerns for adverse toxicological effects on freshwater and estuarine plants and their communities as well as indirect adverse effects on aquatic invertebrate and fish populations at monitored atrazine levels in surface waters. For more information on the preliminary ecological risk assessment, see http://www.epa.gov/oppsrrd1/reregistration/atrazine/atrazine_eco_assessment.pdf.

from the atmosphere to the lake are associated with wet deposition.

In water, atrazine is primarily in the dissolved state and, therefore, any processes that involve sediment or suspended particle interactions are probably of minor significance (Rygwelski et al. 1999).

Tributaries are the most significant source of atrazine to the lake. Figure 13 illustrates atrazine loadings from the eleven rivers monitored under the LMMB Project. Estimates of these tributary loads were made in 1994 and 1995 using two methods: (1) monitoring estimates by USGS and (2) estimates based on the amounts of atrazine applied in these river basins and the amounts historically exported from these types of watersheds. As depicted in Figure 13, both methods for calculating loads indicate that the tributary carrying the largest load

Historical Tributary and Wet Deposition Atrazine Loadings to Lake Michigan

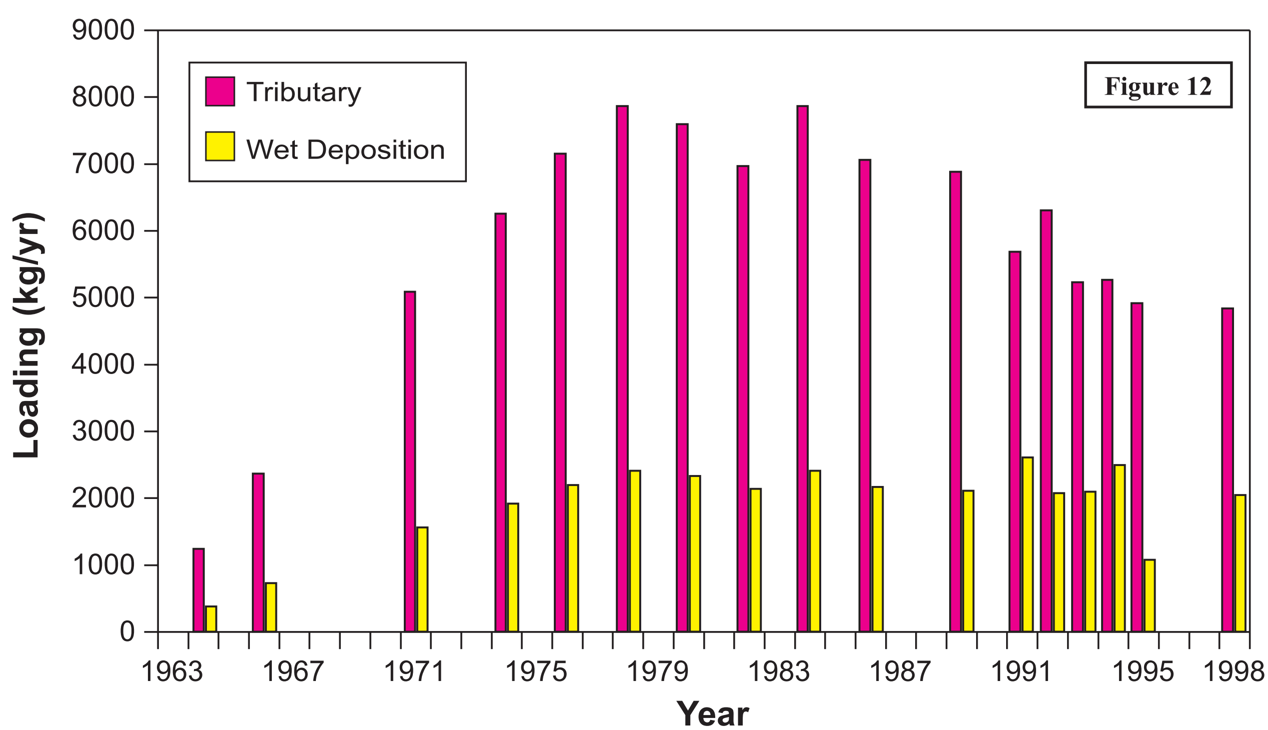
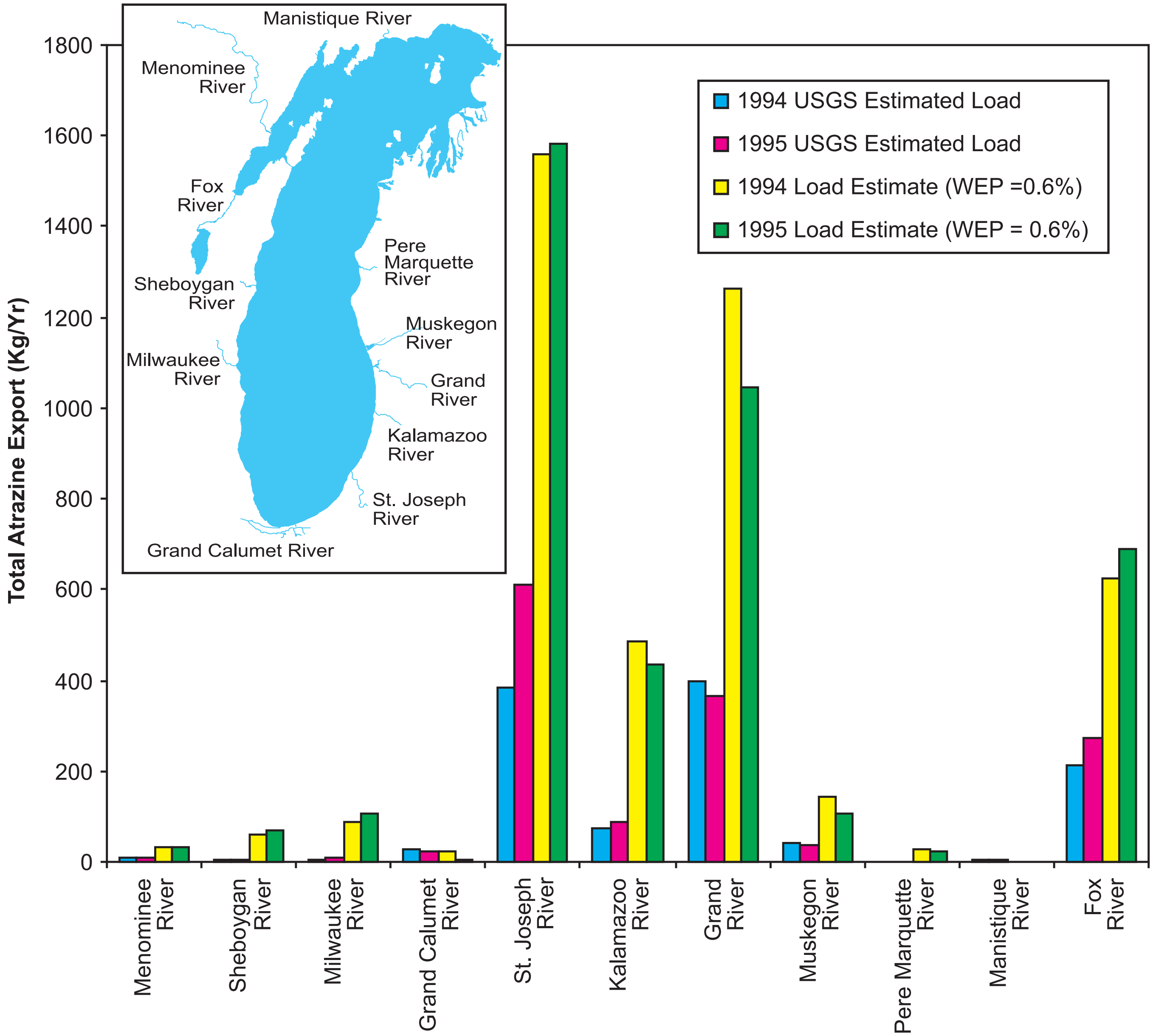


Figure 13

Atrazine Loadings from Tributaries to Lake Michigan



of atrazine to the lake in 1994 and 1995 was the St. Joseph River followed by the Grand River.

In order to understand the impact of the atrazine loadings to Lake Michigan, a mass balance model was developed for the lake. From these model results, one can note that of the fluxes out of the system, gross export out of the Straits of Mackinac is largest at 1,550 kg/year (Figure 14). Net absorption less volatilization is estimated to be a flux of 438 kg/year into the lake; however, if the vapor phase concentration were assumed to be zero throughout the model simulation, this number would be negative indicating that there would be a net flux out of the lake through volatilization.

The results from the modeling exercises indicate that atrazine in Lake Michigan water is decaying only at an estimated rate of 0.8 percent per year. This translates into a half-life of approximately 87 years due to loss through decay. The literature suggests that atrazine decay is enhanced in shallow, warm freshwater systems that have high suspended solids, high dissolved organic carbon, low pH, and high concentrations of nitrate ions (Rygwelski et al. 1999). The cold, deep, high pH, oligotrophic

Toxic Air Emissions Inventory

On January 16, 2002 the Great Lakes Commission released the 1998 Inventory of Toxic Air Emissions, presenting a multijurisdictional inventory of point, area, and mobile (onroad and nonroad) sources for 82 toxic contaminants released in the Great Lakes Basin. (Emissions data were available for 78 of the 82 targeted contaminants.) This is an ongoing project in which the air quality departments in each of the Great Lakes states and the province of Ontario perform the inventory work, which is coordinated by the Great Lakes Commission. The emissions inventory is just that: an inventory of recorded emissions of the targeted contaminants. The results are not a trend analysis of emissions. Differences between years are mainly due to an expansion of area sources for some states and improvements of emission estimation methods, emission factors, and activity data. The 1999 inventory will include all 188 hazardous air pollutants identified in Section 112(b) of the Clean Air Act for point, area, and mobile sources.

The 1998 emissions inventory includes emissions from 672 distinct source categories and 1,532 distinct processes. Point sources emitted all 78 pollutants, while area, onroad, and nonroad mobile sources emitted subsets of these pollutants. Toluene was estimated to have the highest overall emissions (631,177,350 lbs.) and parathion emissions were estimated to be the lowest (0.58 lbs.). Additional inventory results and information, as well as state-by-state emissions data may be found at *www.glc.org/air/air3.html*

waters of Lake Michigan do not appear to support considerable decay of atrazine.

Long-term simulations under various loading scenarios are depicted in Figure 15. The no action scenario fixes current loadings at rates estimated for 1998 and holds them constant. The resultant lakewide concentration increases to approximately 67 ng/L. To maintain the lake concentration at levels observed in 1994 (no further degradation scenario), a tributary load reduction of approximately 57 percent would be needed. A 100 percent tributary load reduction results in an ultimate concentration of approximately 24 ng/L. The modeled scenario yielding the most rapid decline in lake-wide concentrations is achieved if all external loads were shut off including tributary loads, wet deposition, and load input from the vapor phase.

1994 Average Lake Michigan Atrazine Fluxes (kg/year)

Figure 14