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National Program Office
230 South Dearborn Street
Chicago, Illinois 60604

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Green Bay/Fox River Mass Balance Study

Executive Summary

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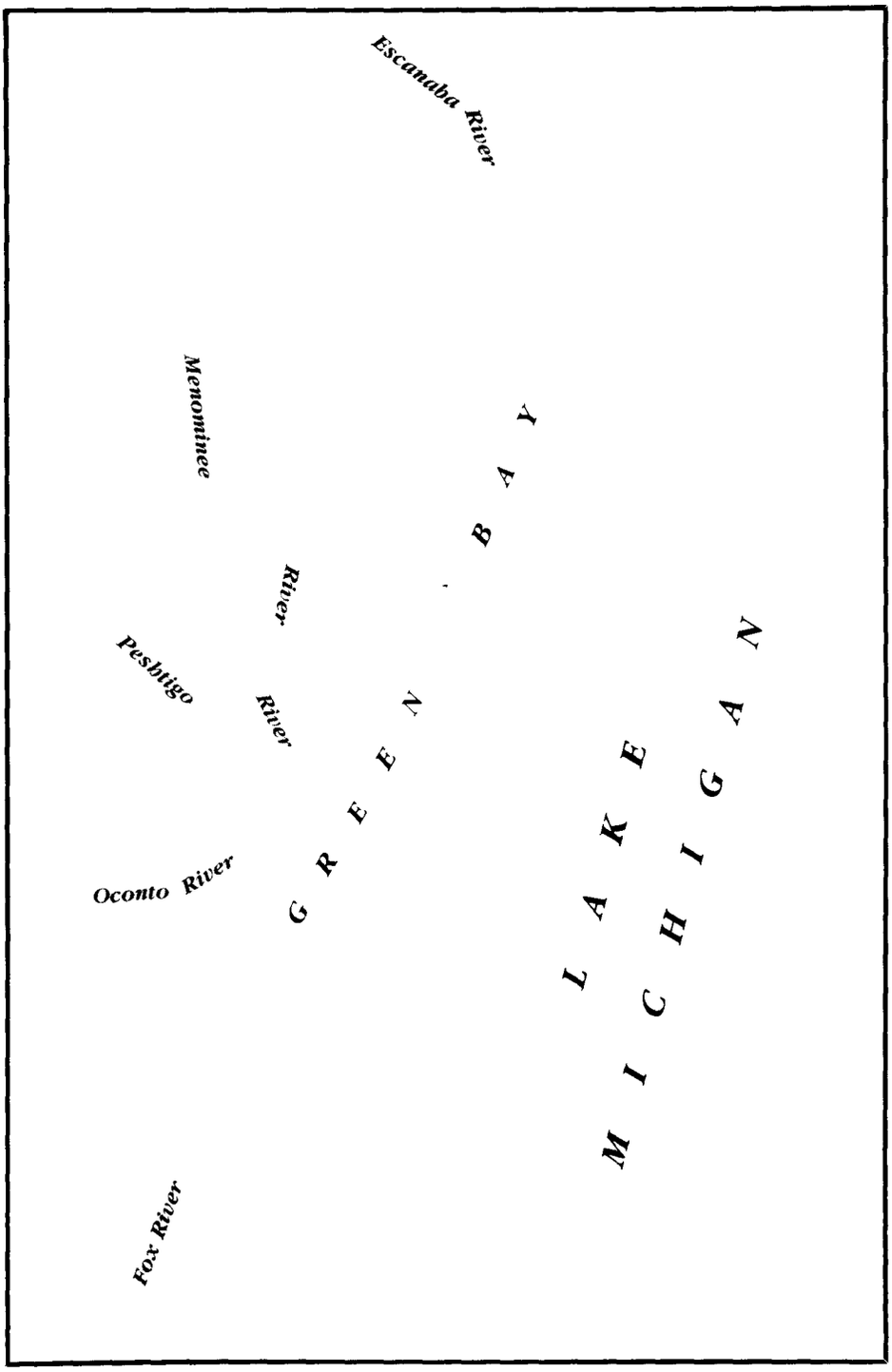

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GREEN BAY/FOX RIVER MASS BALANCE STUDY
EXECUTIVE SUMMARY

November 1988

Prepared for:

U.S. Environmental Protection Agency
Great Lakes National Program Office
230 South Dearborn Street
Chicago, Illinois 60604

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1. INTRODUCTION TO THE GREEN BAY/FOX RIVER MASS BALANCE STUDY

Significant progress has been made on control and reduction of pollution in the Great Lakes. However, accumulation of toxic substances remains a serious problem in each of the lakes as well as in many of the 42 areas designated by the International Joint Commission (IJC) as Areas of Concern. In 1983, the Water Quality Board reported to the IJC that 900 chemicals and heavy metals, potentially dangerous to human health and the biota, have been identified in the Great Lakes.

Concern about potential human health effects of these chemicals has increased with growing evidence of links between the presence of contaminants and tumors in fish, genetic defects in fish-eating birds, and reproductive disorders in biota. Further, possible links have been reported between developmental disorders in human infants and prenatal exposure to contaminants through consumption of certain Great Lakes fish by their mothers.

Traditionally, the management of water quality has focused on control of direct releases of pollutants. Such sources were the easiest to identify, characterize, and control. The regulatory laws to control sources of pollutants are media-specific, with specific laws dealing separately with air, water, and land pollution. For these reasons, restoration and maintenance of water quality were largely tied to control of point sources from which contaminants were discharged directly into the nation's waterways.

Recognition that pollutants are also indirectly introduced to aquatic systems has led to reassessment of the traditional approach to management of Great Lakes water quality. Great Lakes water quality managers have concluded that adequate management of contaminants requires that the total contributions to pollution from all media and all types of sources be quantified, and that a mass balance approach, which allows for evaluation of the relative significance of multiple sources, be used for total load management.

Mass balancing has been successfully applied to the regulation of nutrient loads in the Great Lakes during the past decade; the current concern over toxic substances in the lakes signals the need for a similar approach to

regulation of toxic substances. The sources, pathways, and sinks for toxics, however, are less well understood. It is, therefore, desirable to pilot the mass balance approach for toxics in a smaller ecosystem prior to expansion to all the Great Lakes. The Green Bay/Fox River Mass Balance Study has been designed to serve as such a pilot project.

The purpose of this document is to present the rationale, goals, and anticipated end products of the study, as agreed to by the Green Bay/Fox River Mass Balance Study Management Committee, to describe the management structure of the study, and to outline the study activities.

2. STUDY BACKGROUND AND GOALS

2.1 THE MASS BALANCE APPROACH

In a mass balance, the quantities of contaminants entering the system, minus the quantities stored, transformed, or degraded within the system, must equal the quantity leaving the system. The basic mass balance equation, based on the law of the conservation of mass, is presented below:

INPUT	+	GENERATION	-	CONSUMPTION	-	ACCUMULATION	=	OUTPUT
(enters through system boundaries)		(produced within system)		(transformed or degraded within system)		(buildup within system)		(leaves through system boundaries)

As portrayed in Figure 2-1, an ecosystem can be represented as a series of boxes or compartments (sediments, water, biota, atmosphere, etc.) linked by arrows representing transfer processes. As a result of their physical/chemical properties, many toxic organic contaminants tend to accumulate in the upper levels of the food chain, as illustrated in Figure 2-2. In the Great Lakes ecosystem, these upper levels include large predatory fish and fish-eating birds and mammals. In its simplest form, a mass balance equation can be constructed by measuring the quantities of a contaminant entering the system, the quantities leaving the system, and the quantities present in the system (sediment, water, and biota compartments). The resulting equation, if balanced, provides a quantitative description of the movement of the contaminant through the system. If it is not balanced, it indicates that better understanding of the system dynamics and/or more accurate measurements are required in order to accurately describe the system dynamics.

The ultimate utility of the mass balance approach as a management tool is to prioritize and allocate resources for research, remedial actions, and regulatory efforts. Its usefulness depends on the ability to predict impacts of various management actions on one or more target compartments, e.g., contaminant levels in fish. Mathematical models that describe the interactions among compartments are thus an important component of the mass balance approach.

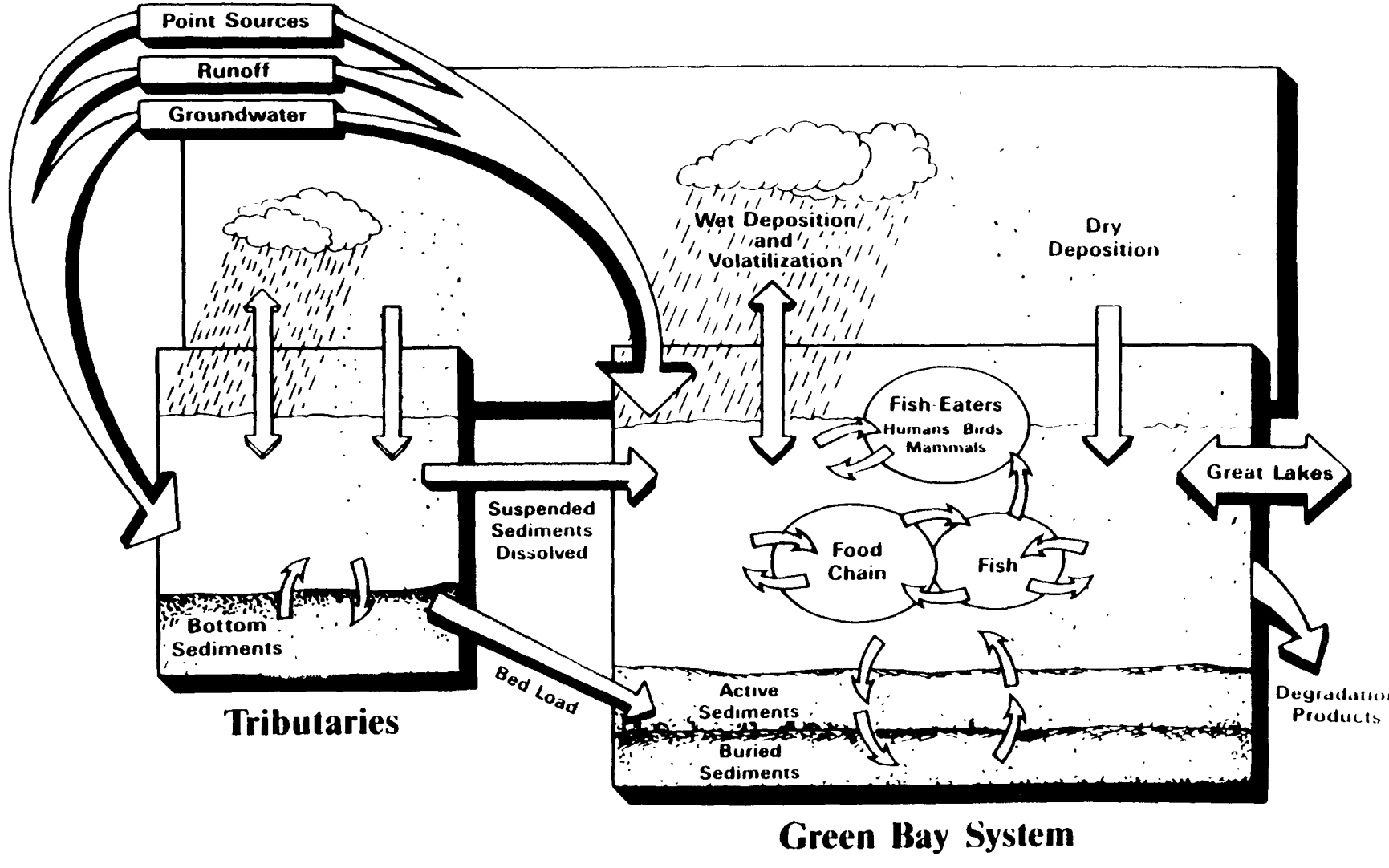

Figure 2-1. Schematic of the Green Bay System: Compartments and Fluxes of Contaminants

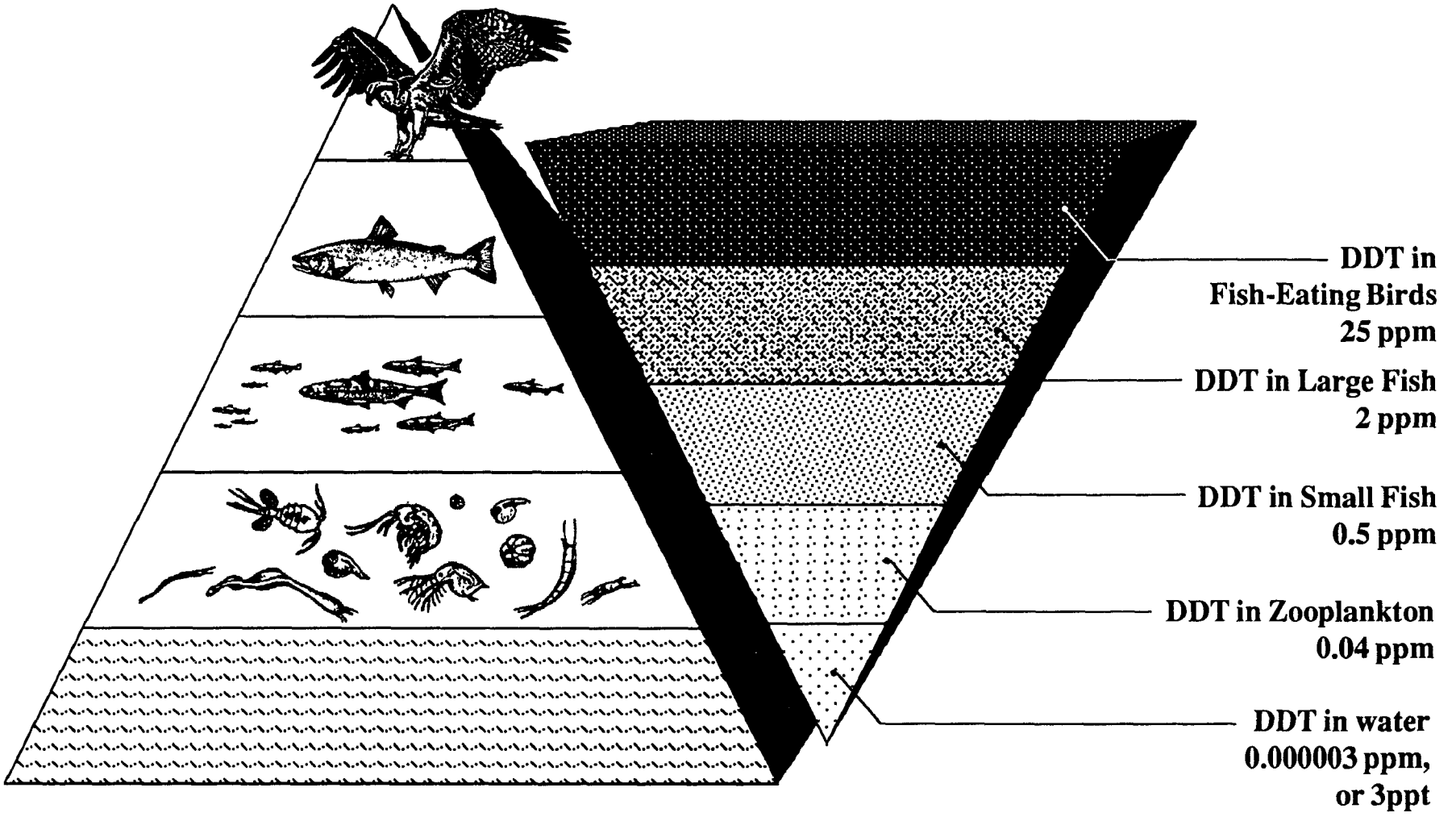

Figure 2-2. Accumulation and Amplification of Organic Contaminants in an Aquatic System

It is also clear that the sophistication of a mass balance approach depends upon the detail to which compartments are defined, the accuracy with which contaminant quantities in the compartments are measured, and the accuracy with which the transfers between compartments are characterized and measured.

2.2 VALUE OF THE MASS BALANCE APPROACH FROM A GREAT LAKES BASIN PERSPECTIVE

The Great Lakes have historically served as a proving ground for exploring solutions to environmental problems. The Great Lakes are deep and have a long retention time; in addition they have been exposed to a wide range of contaminants from industry, agriculture, and municipalities. Consequently, toxic contamination of fish, bioaccumulation of metals, and eutrophication are readily exhibited. Since the lakes are so sensitive to contamination, it has often been incumbent upon the state and federal environmental agencies within the Great Lakes Basin to develop and test innovative solutions to environmental problems.

For example, in the 1970s, severe eutrophication of the lower Great Lakes required immediate binational attention. Several nutrient loading reduction techniques for point and nonpoint sources were developed and implemented, resulting in immediate and long term improvements in lake water quality. Many of these technologies were subsequently adopted by other national and regional agencies to control nutrient problems.

Persistent toxic contaminants in the Great Lakes system are currently a major concern. Although declines of contaminant concentrations in fish flesh have been observed since bans were placed on the use of DDT, PCBs, and dieldrin in the 1970s, the concentrations of these persistent compounds remain at levels which are of concern with respect to human health. The discovery of several hundred other potentially toxic compounds in the Great Lakes further amplifies this concern.

The concept of total load management in the Great Lakes Basin is a fundamental element of the Water Quality Agreement between Canada and the United States, of USEPA's Great Lakes National Program Office Five-Year Strategy, and of the Lake Michigan Toxicant Control Strategy. Great Lakes managers have recognized that addressing toxic contaminants in the Great Lakes system

requires a comprehensive multi-media evaluation of point and nonpoint source loadings to the lakes. This requires going beyond the relatively simple consideration of point and land-based nonpoint source loadings that was used to determine phosphorus loading limits to address eutrophication problems in the 1970s. Current sources of persistent toxics are less likely to be point sources; rather, what needs to be determined is the extent to which there are significant reservoirs of persistent toxic substances in less easily measured media such as air, precipitation, soil, sediments, and groundwater.

The mass balance approach provides a tool with which managers can determine the relative amounts of persistent toxic substances that the various sources contribute to the environment, so that they can determine which environmental control programs should receive greater emphasis. Knowledge about the relative contributions of the different sources of contaminants and the relative costs of their removal or control can lead to more cost-effective approaches for remediation.

There is general agreement among the scientific community that existing mass balance models are rudimentary and require further development at this time in order to meet management needs. Great Lakes studies provide opportunities for testing existing models and developing more sophisticated models. Equally important, the studies promote the development of the improved environmental measurement technologies required for a mass balance approach for toxics.

Last but not least, the mass balance approach provides a valuable framework for the coordination of research activities among the various State and Federal agencies responsible for the protection and greater understanding of the environment. It is a framework for the coordination of environmental research within a given ecosystem by organizations with differing objectives. The information resulting from such a coordinated study is likely to allow conclusions to be drawn that could not have been drawn from any single project by itself.

2.3 GREEN BAY/FOX RIVER STUDY AS NEXT STEP IN DEVELOPMENT OF MASS BALANCE APPROACH

The costs associated with analysis for persistent toxicants, together with the uncertainties as to how best to make the necessary environmental measurements, discourages initiation of a lakewide total load management program at this time. There is still much work to be done to develop sampling designs, models, and analytical capabilities that will allow the data acquistion required by such a program to be undertaken cost-effectively. The approach advocated in the Green Bay/Fox River Study is to develop these capabilities in smaller scale intensive mass balance studies.

Preliminary mass balance studies of river systems for toxics in the Great Lakes basin have previously been undertaken, in particular, in the Niagara River, and the Upper Great Lakes Connecting Channels Studies. In such systems, inputs and outputs were assessed by quantifying the loadings of target chemicals upriver and downriver of the mass balanced system (i.e., the river). The Green Bay/Fox River Mass Balance Study represents a step to not only quantify loadings within a river system but to relate those loadings to the total loadings to a relatively closed system like a Great Lake but smaller (i.e., Green Bay).

Key factors in selecting Green Bay for this step include its relatively closed nature, the wealth of historical and ongoing research projects, the representative range of contaminants found in the system, and the presumed dominance of the Fox River in surface water loadings to the system.

2.4 STUDY GOALS OF THE GREEN BAY/FOX RIVER MASS BALANCE STUDY

The overall goal of the Green Bay/Fox River Study is to test existing modeling frameworks for toxics, to improve our understanding of the sources, transport, and fate of toxic compounds, to evaluate the technological capability to measure multi-media loadings to a system, and ultimately to guide and support regulatory activity. The study will thus serve as a pilot for possible future modeling studies of Great Lakes ecosystems.

3. ORGANIZATION AND MANAGEMENT OF STUDY

3.1 PARTICIPATING AGENCIES

The Green Bay/Fox River Study will engage numerous investigators in project design and budgeting, field collection, analysis and processing of data, quality assurance, data management, and modeling activities. It will require input of expertise and resources from numerous organizations. Participating agencies are listed in Table 3-1.

3.2 MANAGEMENT STRUCTURE

Three levels of management have been created to share responsibility for the various components of the project. An organizational chart depicting the management of the Green Bay Mass Balance Study is presented in Figure 3-1.

Coordination of the many diverse activities that are planned and ongoing, as well as responsibility for obtaining funding commitments and interagency cooperation, rests ultimately with the Management Committee. This committee is comprised of decision makers from the U.S. Environmental Protection Agency (USEPA), the States of Wisconsin and Michigan, and the National Oceanic and Atmospheric Administation (NOAA). A member of the Green Bay Citizen Advisory Committee has observer status with this committee. USEPA/GLNPO and the Wisconsin Department of Natural Resources serve as co-chairs.

As the technical coordinators for the project, USEPA/GLNPO and WDNR co-chair the Technical Coordination Committee, which coordinates the technical activities of the Operational Committees, the Quality Assurance Coordinator, and the Field Coordinator.

Staff from participating agencies form the four Operational Committees. These are the Field and Technical Operations Committee, the Modeling Committee, the Field and Analytical Methods Committee, and the Biota Committee. These committees are comprised of scientists who formulate, review, and evaluate monitoring plans, as well as provide technical expertise to the Management Committee. They are responsible for specifying the monitoring and

TABLE 3-1

AGENCIES PARTICIPATING IN THE GREEN BAY/FOX RIVER MASS BALANCE STUDY

- USEPA - Great Lakes National Program Office
  - Grosse Ile, MI and Duluth, MN Environmental Research Laboratories
  - Region V Water Division
  - Region V Waste Management Division
- Wisconsin Department of Natural Resources
- Michigan Department of Natural Resources
- Wisconsin Sea Grant
- National Oceanic and Atmospheric Administration (NOAA)
- U.S. Fish and Wildlife Service
- U.S. Geological Survey - Madison
- Green Bay Remedial Action Plan Implementation Committee

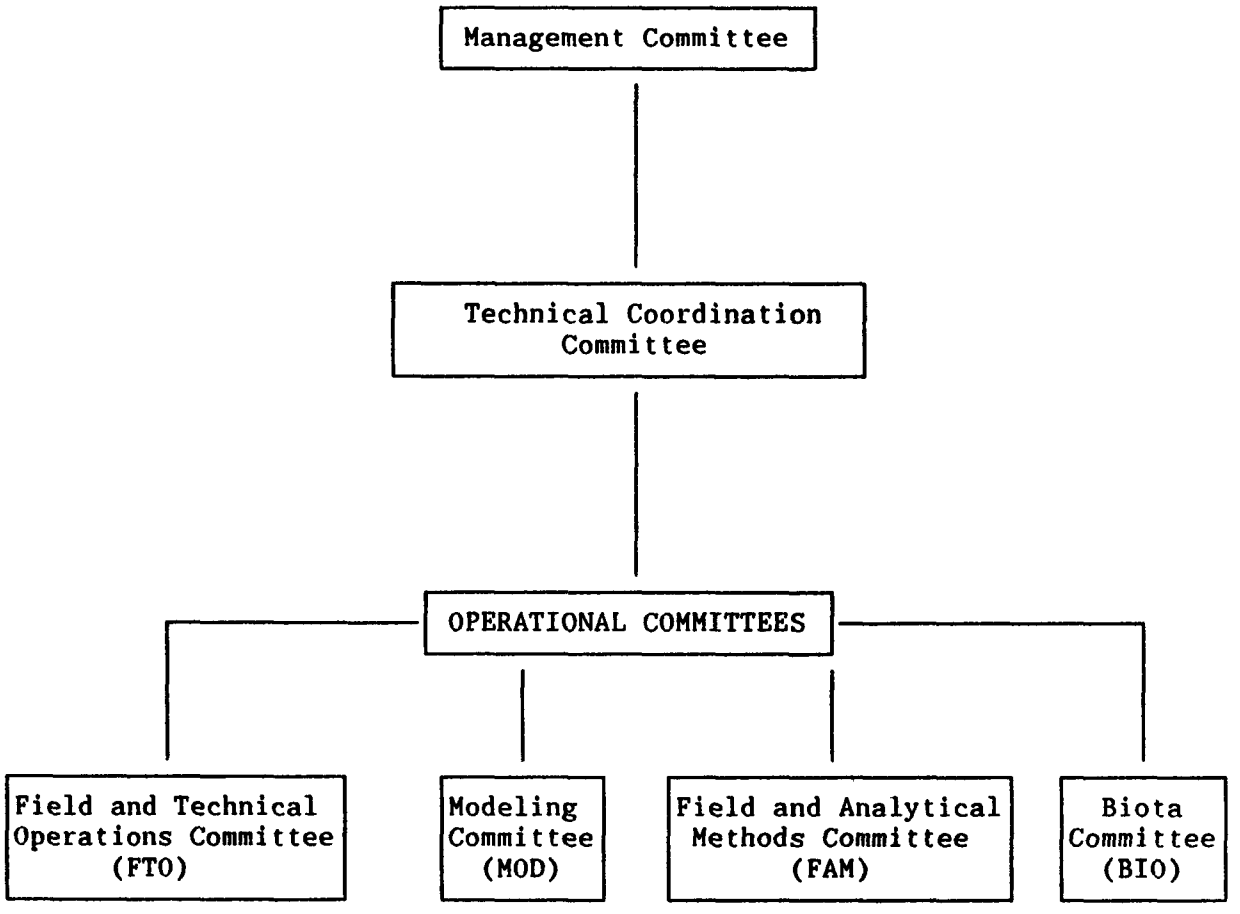

FIGURE 3-1. MANAGEMENT STRUCTURE OF GREEN BAY MASS BALANCE STUDY

modeling requirements for the project, for coordinating field operations, and for providing oversight of the Quality Control (QC) Program.

3.3 PUBLIC INVOLVEMENT

The Mass Balance Study provides an excellent opportunity for increasing public awareness and understanding of the Green Bay ecosystem, and for public input into a project which addresses problems of great concern to the public.

The Management Committee intends to keep the public informed about the study. Brochures detailing the mass balance approach and the roles and responsibilities of the study's many participants are being prepared. Public briefings and news releases are also planned to keep the project visible and highlight its progress. The ship used to collect and analyze water samples from Green Bay, the R/V Roger R. Simons will periodically be open to the public for tours.

A representative from the Green Remedial Action Plan Implementation Advisory Committee, a group formed to facilitate public participation in implementation of a Remedial Action Plan for lower Green Bay and the Fox River, will sit as an observer on the Management Committee of the Mass Balance Study.

4. STUDY SCOPE AND CONTENT

4.1 INTRODUCTION TO GREEN BAY AND THE FOX RIVER

Green Bay can be characterized as a long, relatively shallow extension of northwestern Lake Michigan (Figure 4-1). The Green Bay watershed drains land surfaces in both Wisconsin and Michigan, and contains about one-third of the total Lake Michigan drainage basin. The lower Bay and Fox River have been recognized as a polluted water system, and have been designated by the IJC as a Great Lakes Area of Concern. The Fox River Valley is heavily industrialized and contains the largest concentration of pulp and paper industries in the world.

Presently the Bay ranges from hypereutrophic in the southern portion to mesotrophic-oligotrophic near the Lake Michigan interface. The extreme productivity in the southern Basin results in deposition of organic material and associated hypolimnetic oxygen depletion in the central Bay.

The presence of toxic organic materials in the water, sediment, and biota has adversely impacted both utilization and management of the Bay's fishery. The commercial fisheries in the Bay, with the exception of yellow perch, are closed due to PCB contamination, and consumption advisories have been issued to sports fishermen. Some fish-eating birds have experienced reproductive failure and increased deformities apparently related to toxic contamination.

4.2 GREEN BAY/FOX RIVER STUDY SCOPE

For the Green Bay/Fox River Mass Balance Study, models will be applied to toxicants of interest, including PCBs, dieldrin, cadmium, and lead. The physical/chemical models will be coupled with a food chain model to allow estimation of body burdens in target fish species: carp, brown trout, and walleye. The integrated model will then be used to predict concentrations in the water, sediment, and biota in response to differing regulatory and remedial action scenarios. The predictions will include long-term extrapolation from the short-term calibration.

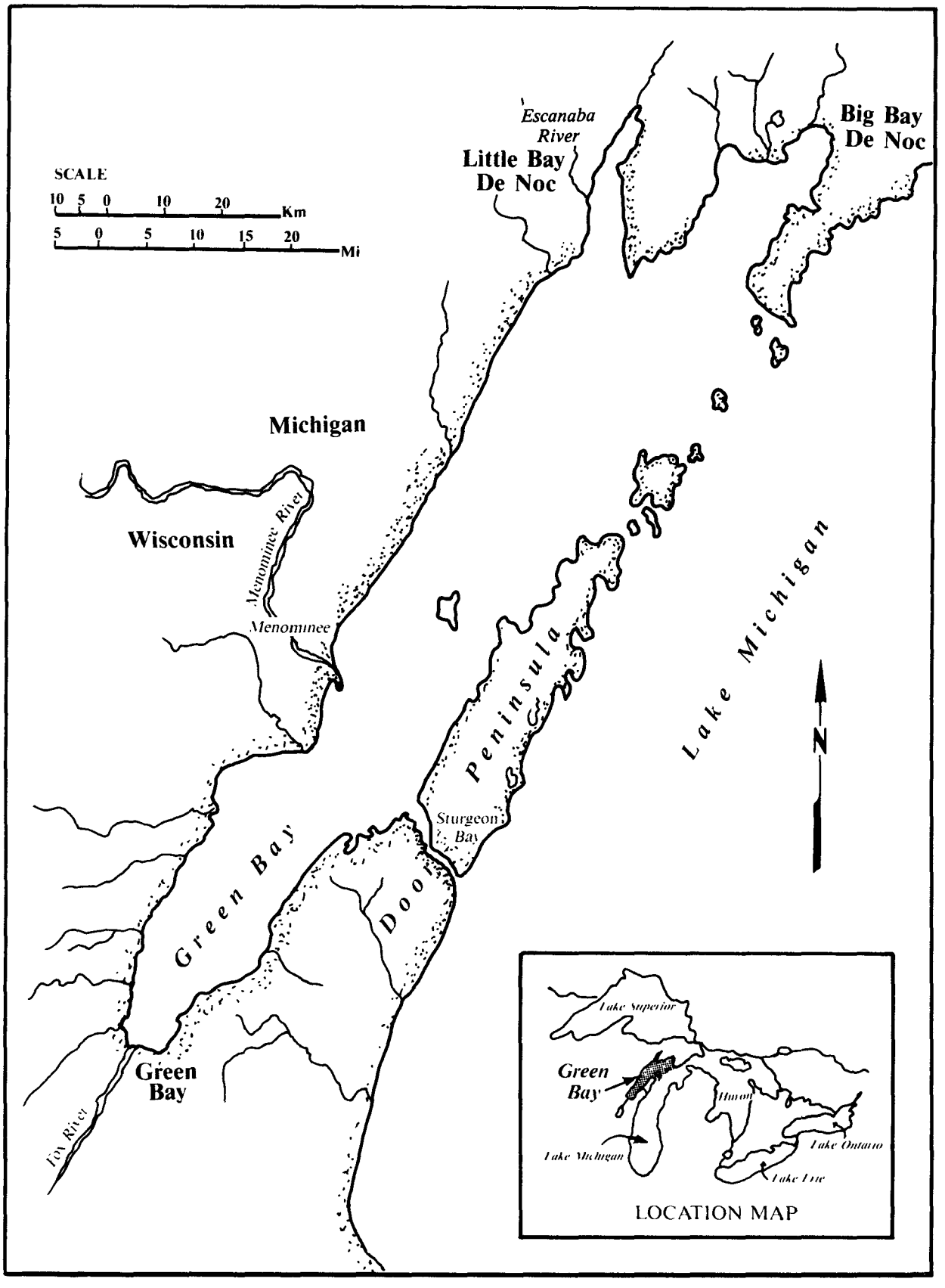

Figure 4-1.
Map of Green Bay and Relation to Lake Michigan and Other Great Lakes

4.3 ANTICIPATED STUDY ACTIVITIES

The Technical Coordination Committee, through the operational committees, has prepared a Study Plan which summarizes the activities required to gather the data needed to construct and drive the mass balance model. These activities will address the following data requirements:

- Inputs
  - Tributaries
  - Contaminated sediments
  - Point sources
  - Atmosphere
  - Dumps and storm sewers
  - Ground water
- Outputs
  - Bay-lake exchange
  - Sedimentation
  - Volatilization
- Active pools and interfaces
  - Bay water column
  - Bay sediments
- Biota
- Modeling

Figure 4-2 identifies sampling stations in the Bay and tributaries, as currently planned. For further details on specific activities, the reader is referred to the Green Bay Mass Balance Study Plan.

4.4 SCHEDULE FOR GREEN BAY/FOX RIVER MASS BALANCE STUDY

Generally, study activities are being conducted during a four-year study period beginning in 1987 and continuing until the end of 1990 with final reporting in 1991. A summary of the anticipated schedule is shown in Table 4-1.

During the first year of the study (FY 87), a monitoring plan was developed, along with a quality assurance program to be used in evaluating analytical and field methods for the project.

During FY '87, field reconnaissance was also done in the Bay and tributaries, and the first atmospheric deposition monitoring stations were established in preparation for the main field season. Modeling tasks were scoped out during this time frame, and assigned to appropriate investigators. Model development will proceed through the duration of the study.

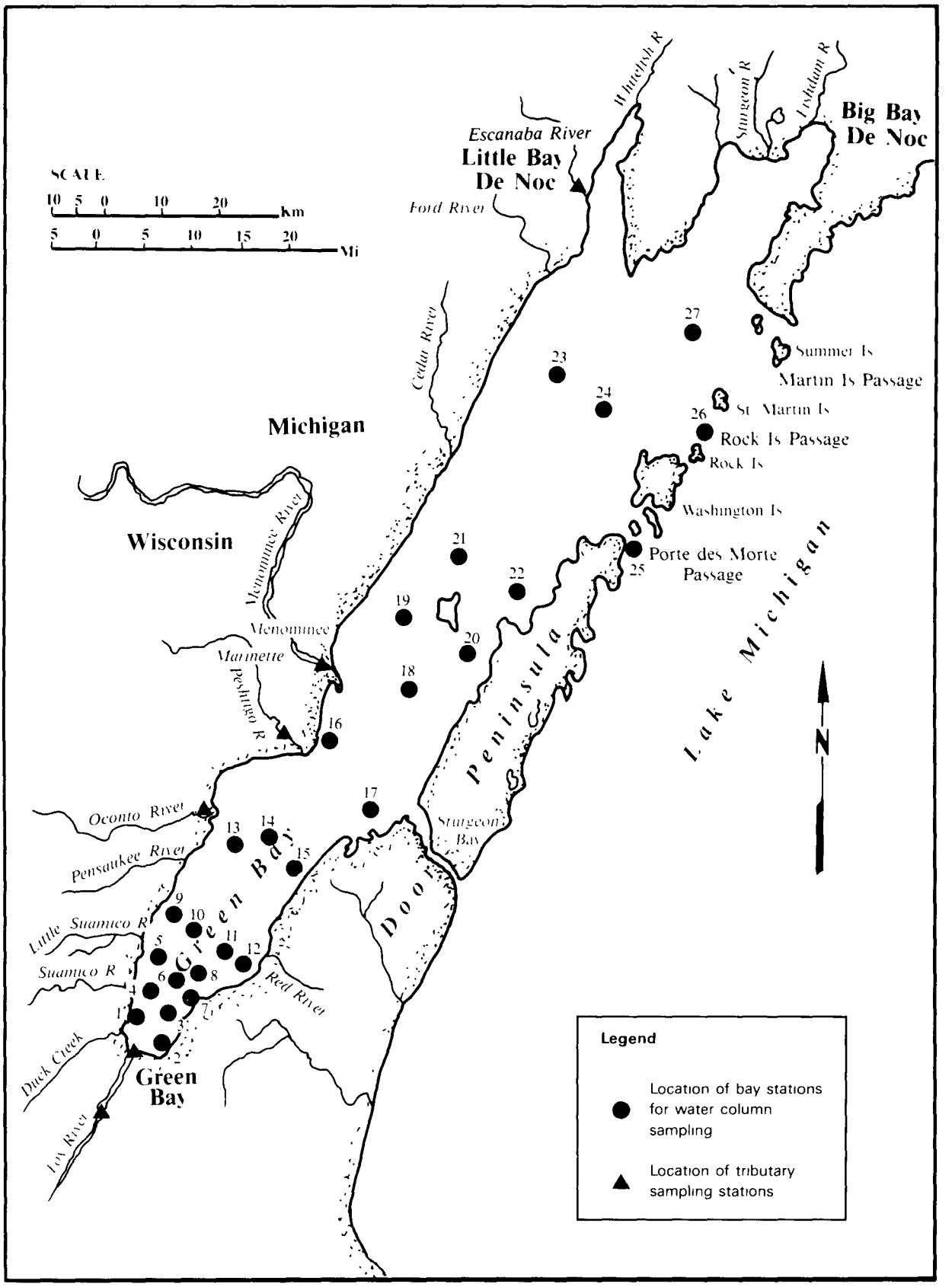

Figure 4-2. Tributary and Water Column Sampling Stations for Green Bay/Fox River Mass Balance Study

TABLE 4-1. SCHEDULE OF ACTIVITIES FOR THE GREEN BAY/FOX RIVER MASS BALANCE STUDY

	FY '87	FY '88	FY '89	FY '90	FY '91
Study Plan	X	X			
Quality Assurance	X	X	X	X	X
Field Reconnaissance	X	X			
Modeling	X	X	X	X	X
Monitoring		X	X	X*	
Sample Analysis		X	X	X	
Interim Reports		X	X	X	
Data Evaluation	X	X	X	X	
Final Reports					X

*Additional monitoring as required

Measuring bottom sediments, Bay-lake exchange, atmospheric deposition, water and suspended sediments, tributary loads, point and nonpoint sources, groundwater, and biota is a resource-intensive effort that must be accomplished within a limited timeframe and yet provide high-quality data for use in modeling. The main field season for sample collection is August 1988 through September 1989. Once the samples are collected, analysis will be conducted from August 1988 through June 1990. During this time additional field work may be identified as the raw data are analyzed.

Reports on the results of the monitoring activities will become available as the data are analyzed. Final reports of all monitoring results are scheduled for September 1991 along with the issuance of a PC-compatible mass balance model.

5. ANTICIPATED STUDY OUTCOME

The Green Bay/Fox River Mass Balance Study, as outlined in this document, will provide baseline information about the relative contributions of sources of target chemicals to Green Bay. Every major loading of target chemicals to Green Bay will be identified, and, to the greatest extent possible, will be quantified, the fate and transport of the target chemicals in the Bay system will be examined, and the outputs from the Bay will be addressed.

At a minimum, it is expected that the study will provide:

- An approximation of the relative contributions of target chemicals from each source
- An information data base collected over the same time period, using comparable methods, for use by the public, regulators, and scientists
- Some improvements in technologies for environmental measurements needed for a mass balance approach
- A first attempt to quantify atmospheric deposition for toxics to a specified system
- An understanding of where research and development funds should be invested for future mass balance projects.

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15. SUPPLEMENTARY NOTES

Sarah Pavlovic, Project Officer

16. ABSTRACT

Mass balancing of all direct & indirect multiple sources, pathways, and sinks of toxic contaminants can provide a knowledge base for adequate control and management of the Great Lakes Basin. The Green Bay/Fox River Mass Balance Study is a major coordination of environmental research activities among some elven State and Federal agencies to measure major loads and the fate and movements of PCBs, dieldrin, cadmium, and lead in and out of the Green Bay/Fox River ecosystem.

In the period between August 1988 and September 1989, measurements of bottom sediments, Bay-Lake exchange, atmoshperic deposition, tributary loads, biota, etc., will be made; analysis will be carried out through June 1990, with the final report scheduled of September 1991.

17. KEY WORDS AND DOCUMENT ANALYSIS

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