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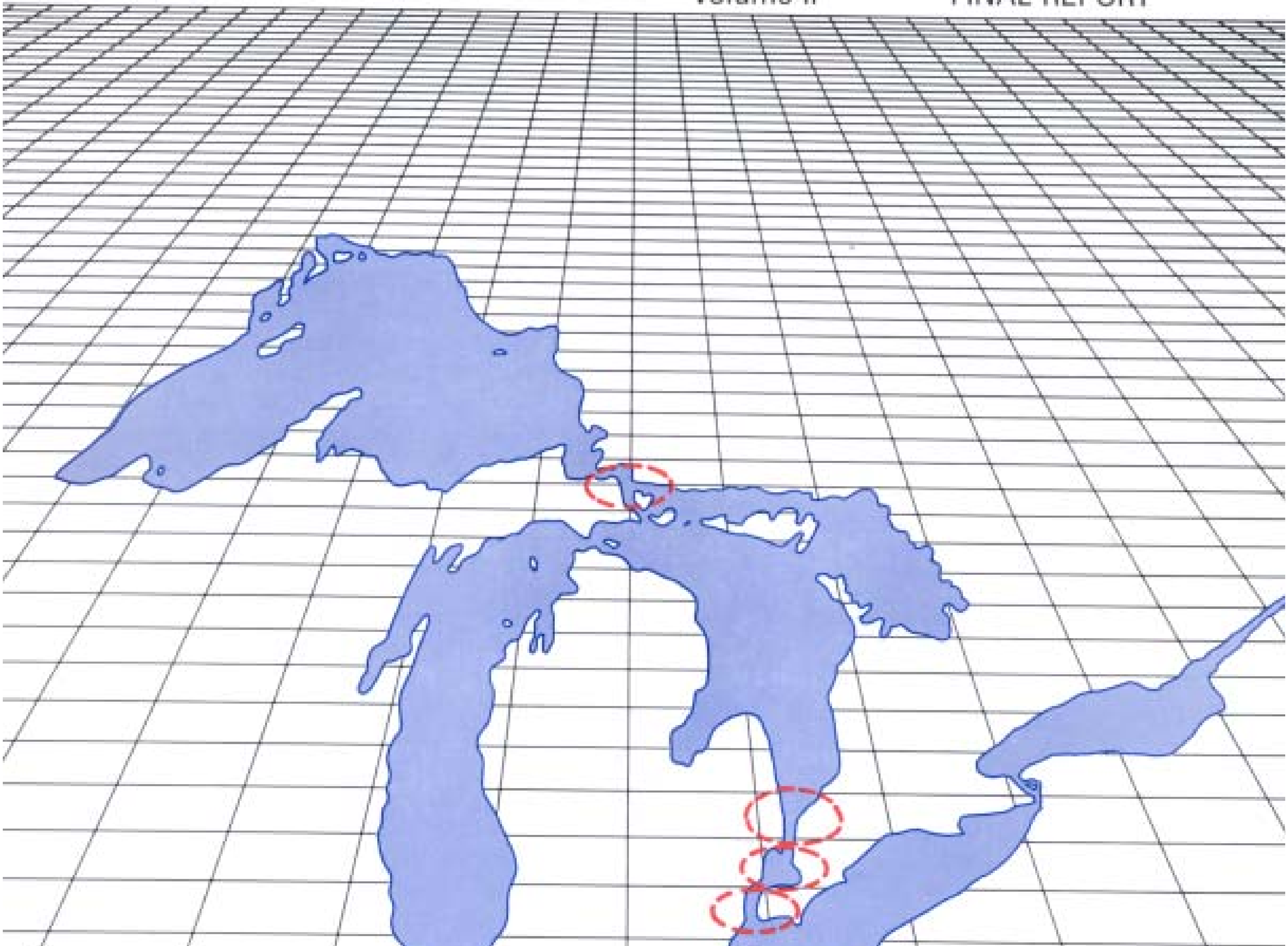
UPPER GREAT LAKES CONNECTING CHANNELS STUDY

Volume II FINAL REPORT



FINAL REPORT

of the

UPPER GREAT LAKES CONNECTING CHANNELS STUDY

VOLUME II

DECEMBER 1988

Environment Ontario
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On behalf of the Management Committee we are pleased to submit the final report and executive summary of the Upper Great Lakes Connecting Channels Study. The report is a comprehensive and detailed review of the project studies and their results.

Respectfully submitted, February 1989.

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ACKNOWLEDGEMENTS

Many people contributed to the completion of this document. There were over a hundred principal investigators and associated staff who contributed the most essential ingredient to the study - the data and preliminary interpretations. Although too numerous to mention, the Management Committee of the Upper Great Lakes Connecting Channels Study extends thanks to all.

Members of the numerous committee, workgroup, task force and synthesis writing teams are listed in Appendix I. The Management Committee would especially like to acknowledge the members of the Activities Integration Committee. This committee co-ordinated the technical studies, chaired individual workgroups, and assisted with and directed the writing of the final report. These people include: Daryl Cowell (Canadian Co-chair), Vacys Saulys (U.S. Co-chair), A.S.Y. Chau, Tom Edsall, Yousry Hamdy, Tom Fontaine, John Moore, Paul Horvatin, Griff Sherbin, Rick Lundgren, Don Williams, Keith Rodgers, Wayne Wager and Bill Richardson (Appendix I).

The principal writers of the final report are: Yousry Hamdy, Diana Klemens, Barry Oliver, Pranas Pranckevicius, Paul Bertram, Paul Hamblin, David Kenaga, Cynthia Fuller, Daryl Cowell, Vacys Saulys and Wayne Wager. The overall editing of the final report was conducted by the Activities Integration Committee. The primary editor was Daryl Cowell with the assistance of Wayne Wager and Vacys Saulys. Again, the Management Committee extends their appreciation.

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PREFACE

This Report provides the major findings and recommendations of the Upper Great Lakes Connecting Channels Study (UGLCCS). The study was first announced as a U.S. Program in November, 1983 by then United States Environmental Protection Agency (U.S.EPA) Administrator, William Ruckelshaus. In July, 1984 it became a multi-agency U.S./Canada investigation of toxic chemicals and other environmental concerns in the Upper Great Lakes Connecting Channels. The study area included the Detroit, St. Clair and St. Marys Rivers and Lake St. Clair. The principal agencies involved were the U.S.EPA, Environment Canada, the Ontario Ministry of the Environment, Michigan Department of Natural Resources, U.S. Fish and Wildlife Service, U.S. Geological Survey, National Oceanic and Atmospheric Administration, U.S. Army Corp of Engineers, the City of Detroit, Fisheries and Oceans Canada and the Ontario Ministry of Natural Resources.

The UGLCC Study was organized such that the participating agencies could focus and co-ordinate their on-going studies in the four areas and identify priorities for new studies. All programs and individuals benefited from working together and sharing their individual strengths. The total cost of this study was approximately $20 million. This included existing agency program funds as well as "new" money allocated to additional studies in the channels.

The impetus for this study was specifically for the improved regulatory management of point and nonpoint pollution sources in the four study areas. As such, the technical and management recommendations identified for each area are the key outputs of the study. It should be pointed out, however, that the regulatory agencies have not waited for the final release of this study before implementing controls. Numerous actions have been undertaken throughout the course of the study whenever investigations uncovered significant pollution sources and problems. For example, the total loadings of certain organic chemicals from Sarnia area chemical companies have been drastically reduced since late 1985 following the discovery of perchloroethylene puddles on the bed of the St. Clair River.

This report is volume II of a three volume set containing the complete output of the UGLCC Study. Volume I is an executive summary describing the major study findings and recommendations.

Volume III is a compilation of the many principal investigator reports, workgroup reports and other supporting documents. Copies are on file with each of the participating agencies and with the International Joint Commission in Windsor, Ontario.

This volume (II) is the main report describing the results of the UGLCC Studies. It consists of five introductory chapters and four area chapters (one for each study area). The introductory material covers study purpose and organization, characteristics of the four study areas, regulatory guidelines and programs, the data quality management program, and modeling activities. The last four chapters present the findings for each study area using a comparable reporting format.

Detailed study area maps are provided in Chapter II. These, along with tables and other information in Chapters III, IV, and V, are intended as reference material for the reader in support of the area chapters.

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CHAPTER I

INTRODUCTION

The Upper Great Lakes Connecting Channels (UGLCC), for the purpose of this report, includes the St. Marys River, St. Clair River, Lake St. Clair, and the Detroit River. They are important components of the Great Lakes Basin ecosystem and a valuable resource. They serve as commercial transportation corridors, as a source of drinking water and industrial water, as historical and recreational resources, and as habitat for a wide diversity of fauna and flora.

The intensive use which has taken place throughout this system has resulted in serious environmental degradation in many areas. As early as the 1940s concern existed about bacterial contamination, phenol problems and excessive levels of metals, phosphorus and mercury. Attention is currently being focused on toxic substances in water, sediment and biota throughout the system and their effects on human health and the ecosystem.

Since 1974 the Detroit, St. Clair, and St. Marys Rivers have been designated as "Problem Areas" and, more recently, as "Areas of Concern" by the International Joint Commission. Despite massive clean-up efforts and the expenditure of millions of dollars by industry and government there remain areas in which general or specific objectives of the 1978 Great Lakes Water Quality Agreement (GLWQA) are exceeded (1). There have been noticeable improvements since the 1960s; however, significant environmental degradation and continuing impairment of beneficial uses occur.

1. Purpose and Objectives

Although there have been numerous investigations and reports on the environmental quality of the Connecting Channels, there has previously been no attempt to integrate the information and focus the scientific studies to produce recommendations for specific action or identify remedial needs. This study was a landmark binational efforts in the continuing restoration of the Great Lakes system. This report, by the Management Committee of the UGLCC Study to the sponsoring agencies, is intended to provide guidance for the remediation of these degraded waters and a framework for long term monitoring to assess the effectiveness of pollution controls. The vehicle for the delivery of the recommendations, options and implementation will be the Remedial Action Plan (RAP) process. RAPs are currently being prepared for all 42 "Areas of Concern". These plans will identify problems, goals for remediation, and remedial actions as well as responsible agencies for implementation, a schedule for implementation, and necessary monitoring programs (1).

Specifically, the objectives for the study were as follows:

1) To determine the existing environmental condition of the St. Marys River, St. Clair River, Lake St. Clair and the Detroit River at its influx into the Western Basin of Lake Erie and to identify information gaps.

2) To undertake additional, needed studies to:

a) identify and quantify the impacts of conventional and toxic substances from point sources, nonpoint sources (both runoff and contaminated groundwater) and tributaries, on beneficial human uses and on plant and animal populations in, along, and below these waters;

b) determine the adequacy of existing or proposed control programs to ensure or restore beneficial uses; and

c) recommend appropriate control and surveillance programs to protect and monitor these waterways and the downstream lakes.

2. Study Approach

In establishing this study, certain concepts were identified based on the 1978 GLWQA and experience gained from earlier binational efforts. Of particular importance to the overall study design were the concepts: ecosystem approach, enhanced data quality management, mass balance requirements, and regulatory management focus.

i) Ecosystem Approach. The Connecting Channels and Lake St. Clair are complex ecosystems characterized by high volumes and flows, strong currents and circulation patterns, deposition and re-suspension of sediments, diverse biota, extensive wetlands, and atmospheric and terrestrial interactions. Superimposed on this system are human activities in terms of physical alterations and pollutant loadings. In order to identify impacts to the system and develop management scenarios for control and remediation, all factors and their interactions have to be evaluated and taken into consideration. This effectively is the ecosystem approach as defined in the Great Lakes Water Quality Agreement between Canada and the United States, (1978, amended 1987) (1).

ii) Enhanced Data Quality Management. The experience of earlier interagency, multi-media studies on the Great Lakes has demonstrated the need to recognize and incorporate data quality assurance and quality control (QA/QC) which are crucial to the overall utility of study results. These considerations need to be taken into account at the beginning of the study and not viewed in hindsight. This concept was given considerable priority within the UGLCC Study and responsibility was vested in a Data Quality Management Workgroup. Responsibilities of this workgroup included reviewing analytical and field protocols; reviewing internal quality assurance programs of participating laboratories; assessing the statistical validity of program results; and running a series of "round robin" analyses based on controlled mixtures. In addition, investigators were encouraged to exchange split samples.

iii) Mass Balance Requirements. In setting-up the UGLCC Study emphasis was placed on providing data that could be directly applied to identify remedial strategies and develop regulatory actions. In order to relate the potential source data to the environmental conditions, study participants agreed to explore the use of pollutant mass balance models. This was considered to be the most comprehensive approach for the study design and was also compatible with the ecosystem approach noted earlier. If mass balance models could be developed and verified, aquatic ecosystem objectives could easily be related to pollutant loads.

Ecosystem complexity and a general lack of historical data for some areas, along with the limited time frame of the UGLCC Study have limited the use of complex models. Preliminary models have been developed and will be utilized to provide a guide to the development of management options where possible.

iv) Regulatory Management Focus. Previous binational studies of the Great Lakes tended to emphasize baseline descriptions along with identification of stresses to the overall environment. Rarely have specific regulatory options and strategies been identified and agreed to by the participating jurisdictions. From the outset the UGLCC Study has emphasized regulatory management recommendations (i.e. control and abatement) as the key output for the study. This is particularly timely as given the request by the Great Lakes Water Quality Board of the International Joint Commission and the recently updated GLWQA for specific RAPs in the Areas of Concern.

These four concepts formed the framework to the study, although it should be noted that in all cases time and resource constraints prevented their complete implementation. However, their identification and subsequent guidance to the study were extremely valuable.

3. Management Structure

To oversee planning, implementation and reporting, a three-tier management structure was established consisting of the Management Committee, the Activities Integration Committee and eight specific activity workgroups. Resources necessary to undertake and maintain the planning and administration of the study were provided by the participating agencies. Secretarial support was provided by the U.S.EPA's Great Lakes National Program Office (GLNPO).

i) Management Committee. This committee consisted of representatives of the principal U.S. and Canadian agencies. It was co-chaired by U.S.EPA and Environment Canada. Members were agency managers who were in a position to ensure follow-up to study priorities and needs. In addition to the regular members, the chairperson of the International Joint Commission's UGLCC Task Force was an observer on this committee. He provided a formal link with the Great Lakes Water Quality Board.

The Management Committee provided overall guidance to the study by identifying issues, establishing the study's structure, approving the work plans, and approving the final report. This committee was also responsible for identifying environmental management requirements in the study area with regard to appropriate regulatory options.

ii) Activities Integration Committee. The AIC was a subcommittee of the Management Committee. It was responsible for preparing and overseeing implementation of the study work plans and for the final report. The AIC was co-chaired by Environment Canada and the U.S.EPA.

Members were workgroup chairpersons plus 2 scientific coordinators.

iii) Study Workgroups. Eight workgroups were established for this study: biota, sediment, water quality, data quality management, modeling, point source, nonpoint source, and long-term monitoring. A regulatory task force was established to review existing regulatory measures and help evaluate proposed remedial measures. The results of this review have been incorporated directly into the final report (Chapter III). Members of workgroups were technical experts from among the participating agencies. Each workgroup operated under the guidance of a single chairperson.

4. Schedule

The UGLCC Study was conducted in 3 phases. Phase 1 was the planning stage which included the development of work plans, quality assurance programs and preliminary models. This phase was initiated with a planning workshop for 60 key participants. A comprehensive technical literature review was also carried out during the planning phase in order to identify gaps and plan the next phase (2).

Phase II included the two field seasons (1985 and 1986). A mid-course workshop was held between the two study years for the benefit of about 100 of the principal investigators. This workshop was established to prepare work plans for the 1986 activities; exchange information from the previous field season; identify progress to date and additional needs; and identify and resolve logistics of ship support and equipment sharing.

The final phase - the report writing phase - began in January 1987 at a writers workshop held in Windsor. This workshop provided 40 workgroup participants, both chairmen and principal investigators, the opportunity to discuss and finalize reporting formats, writing process, logistics, and timing as well as identify inter and intra workgroup co-ordination needs. A workshop was held in Ann Arbor in January 1988 for six of the workgroups to present their results and information to those synthesizing workgroup reports into the four area reports. A final workshop, held in Burlington in June 1988, was conducted for the AIC to review each of the four area reports prior to submission of the draft final report to the Management Committee.

The report writing was carried-out in four stages. The first stage consisted of the preparation of the approximately 170 individual project reports by the principal investigators. The second stage consisted of 26 media specific workgroup reports (3) which were prepared from the project reports. Area synthesis writing constituted the 3rd stage. Four teams (1 for each geographic area), each with Canadian and U.S. co-leads, integrated the workgroup products into a single report for each of the geographic areas. The 4th stage of writing was the drafting of the final report and executive summary. At this stage the key conclusions and recommendations of the study were identified and prepared by the AIC. The draft final report was presented to the Management Committee on July 20, 1988 for final review. The technical comments that were received were used to prepare the final report which was formally submitted to the sponsoring agencies.

5. Technical Activities

In order to meet the objectives of the UGLCC Study a number of activities were identified with regard to technical data needs. These were grouped according to workgroup subject areas (eg. point source, biota, sediment, etc.) and formed the basis for defining specific projects or investigations. Activities included, for example, assessing combined sewer overflows, tributary monitoring, describing circulation patterns and sediment resuspension, and estimating nonpoint source loadings of nutrients and toxics. For the 1986 field season, 72 activities were defined and approximately 170 specific projects were undertaken.

The technical activities were designed particularly to: (1) describe the nature and abundance of macrophytes, benthos and fish in order to establish baseline conditions to which future monitoring of habitat and population structure could be compared; and (2) identify pollutant sources and loadings in order to drive the models and develop remedial strategies.

6. Parameters of Interest

The Activities Integration Committee identified a number of contaminants including heavy metals, organic contaminants and conventional pollutants which are known or suspected to be in exceedence of criteria or at high levels in portions of the study area. These are listed in Table I-1. For additional information on the selection of these parameters and their occurrence in the study area, the reader is referred to the report outlining pre-UGLCC Study conditions (2).

TABLE I-1

UGLCCS parameters of concern.

COMMON ABBREVIATIONS	PARAMETERS
Organics	
PCBs	Polychlorinated biphenyls
HCB	Hexachlorobenzene
OCS	Octachlorostyrene
PAHs	Polycyclic aromatic hydrocarbons
	Oil and Grease
	Phenols (total phenolics)
	Chlorinated phenols
Metals	
Cd	Cadmium
Pb	Lead
Zn	Zinc
Hg	Mercury
Cu	Copper
Ni	Nickel
Co	Cobalt
Fe	Iron
Cr	Chromium
Conventional/Other	
P	Phosphorus
NH3	Ammonia
	Chlorides
	Residule chlorine
	Cyanide
	Chloramines

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CHAPTER II

OVERVIEW OF THE UPPER GREAT LAKES CONNECTING CHANNELS

1. Introduction

The Upper Great Lakes Connecting Channels serve as conduits for the waters of the upper lakes (Superior, Michigan and Huron) to feed into the lower lakes (Erie and Ontario - Figure II-1).

The setting for the Connecting Channels is the Great Lakes Basin. This basin is the product of complex geological, hydrological, climatological, biological and sociological processes operating over various scales of time[1]. These processes are not static but dynamic and thus, the system will continue to evolve. This report is, therefore, very much a snapshot in time. However, its implications are far reaching. Implementation of the recommendations will influence the nature and quality of our Great Lakes Ecosystem as it evolves.

The Upper Great Lakes Connecting Channels are integral components of the Great Lakes Basin. They function as the plumbing system of the lakes' basins funnelling large volumes of water, sediment and nutrients through relatively narrow channels. As such they have been an attraction to both wildlife and humans.

Nutrients and diverse habitat conditions have provided sustenance to large populations of numerous species of flora and fauna, particularly fish and waterfowl. The abundance of game as well as fresh drinking water attracted native Indian settlements. Europeans, in turn, were attracted to these channels for the additional benefits related to shipping; relative ease of

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[1] For an overview of these process and additional references, the reader is referred to (1).

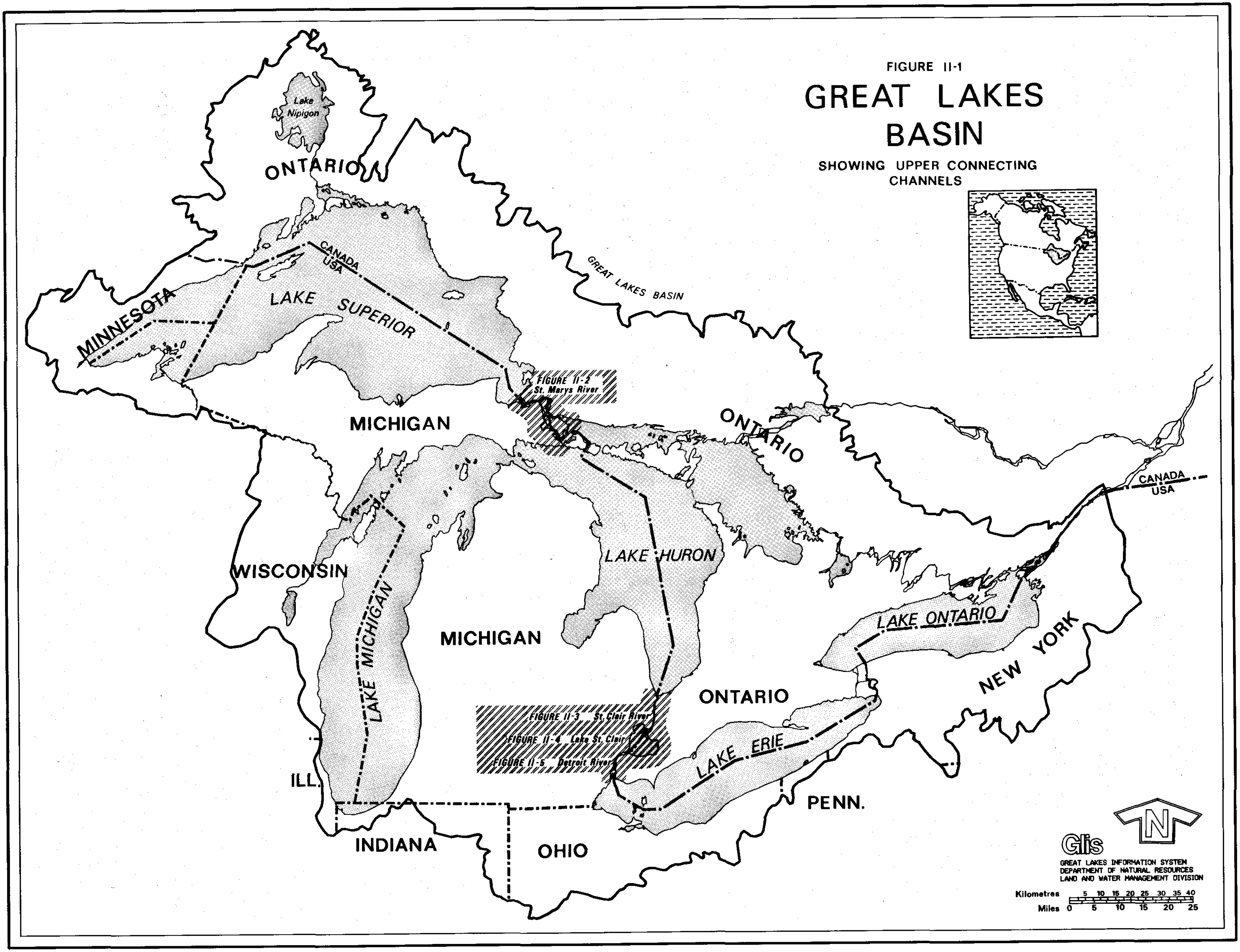

FIGURE II-1

GREAT LAKES BASIN

SHOWING UPPER CONNECTING CHANNELS

crossing (each river is currently a major international crossing point); large volumes of water for cheap power, industrial processes and waste receiving; and recreational pursuits.

The vastness of the Great Lakes' water and fisheries resources must have appeared limitless to the early Europeans. However, physical damages as a result of dredging (channels), filling (wetlands), increased sedimentation and water temperature (related to forest clearing for agriculture), and over-fishing, along with pathogen loadings (from human waste) quickly impacted the ecosystem. In less than 100 years of settlement, by the early 1900s, these impacts were considered very serious and resulted in disease and death among dwellers along the channels.

Physical and chemical disruptions continued through the 1900s resulting in crashes of certain native fish populations and increasing occurrences of oil films, human waste, dead fish, algae and other visible problems. Less visible but just as serious types of pollutants - heavy metals and organic chemicals - were released into the ecosystem virtually uncontrolled during the mid-1900s. Mercury, lead, DDT, PCBs, and others were released as products of the rapidly growing North American industrial complex. The Great Lakes Connecting Channels (including the Niagara and St. Lawrence Rivers) were home to many of the industries manufacturing, utilizing, and discarding these contaminants.

Since about 1970 environmental concern and actions by federal, state and provincial governments have resulted in dramatic improvements. Industrial and municipal sources of contaminants have been controlled to various degrees. However, we have the legacy of historical pollution manifested in river and lake sediments (in-place pollutants) and groundwater contributions from active and inactive waste sites.

Continued improvements to the Great Lakes ecosystem must consider these, along with ongoing discharges, and inputs from diffuse sources such as urban and agricultural runoff and atmospheric deposition.

The remainder of this chapter will summarize characteristics of the St. Marys, St. Clair and Detroit rivers and Lake St. Clair. Each area is portrayed in Figures II-2 through II-5 and specific information is provided in Tables II-1 through II-4. These tables summarize watershed characteristics (II-1), water uses (II-2), land uses (II-3), and environmental concerns (II-4) comparatively for each of the 4 study areas. Each area is discussed in detail with regard to study findings and recommendations for remedial measures in Chapters VI through IX.

TABLE II-1

Watershed characteristics of the Upper Great Lakes Connecting Channels.

	St. Marys River	St. Clair River	Lake St. Clair	Detroit River
Inlet	L. Superior	L. Huron	St. Clair R.	Lake St. Clair
Outlet	L. Huron	L. St. Clair	Detroit River	L. Erie
Length (Area)*	101-121 km	64 km	1,115 km^2	51 km
Elevation Fall(m)*	6.75	1.5	-	1.0
Flow $m^3/s \times 1000$**				
Minimum	1.2	3.0	-	3.2
Average	2.2	5.2	-	5.3
Maximum	3.7	6.7	-	7.1
Average Flow Vel. m/s*	0.6-1.5	0.6-1.8	0.02-0.08	0.3-0.6
Depth (m)*	Shallow-30	9-21	3.4 avg. 8.2 max.	6-15
Width (km)*	0.3-6.4	0.25-1.2	39	0.66-3.0
Retention Times	~2 days	21 hrs	2-9 days	21 hrs
Controlled Flow	Y	N	N	N
Land Drainage Area*** km^2 x 1,000 (cummulative total)	49.3	146.6	159.0	160.9

* LTI document (2).

** David Cowgill, U.S. Army Corps of Engineers, pers. comm.

*** Calculated from (1) and (2).

TABLE II-2

Water use of the Upper Great Lakes Connecting Channels.

	St. Marys River	St. Clair River	Lake St. Clair	Detroit River
Shipping	S	S	S	S
Commercial Fishing	L	N	F	N
Sport Fishing	S	S	S	S
Boating/Sailing	F	S	S	S
Swimming	L	F	S	O
SURFACE WATER SUPPLIES TO:				
Drinking Water Intake				
- Municipal	X	X	X	X
- Communal/Private	X	X	X	X
Industrial Intakes				
- Iron & Steel	X			X
- Pulp & Paper	X			
- Petrochemical		X		X
- Refining		X		X
- Thermal Generating		X		
- Hydroelectric	X			
- Navigation (Locks)	X			
- Mineral (Salt & Lime)	X			
RECEIVING WATER FOR:				
Municipal STP	X	X	X	X
Industrial				
- Iron & Steel	X			X
- Pulp & Paper	X			
- Petrochemical		X		X
- Refining		X		
- Thermal Generating		X		X
- Mineral (Salt & Lime)				X
- Fabrication (Auto)				X
Ship Ballast	X	X	X	X

N - Negligible Use
L - Limited Use
O - Occasional Use
F - Frequent Use
S - Significant - High Use
X - Present

TABLE II-3

Land use within 5 km of the Upper Great Lakes Connecting Channels' shoreline.

	St. Marys River	St. Clair River	Lake St. Clair	Detroit River
Urban	F	F	O	S
Rural Residential	O	S	O	F
Agricultural	N	O	S	O
Recreational (Marinas/Beaches)	O	F	S	S
Wildlife Habitat/Open Space	S	F	F	L
Industrial	O	S	N	S
Waste Disposal	X	X	X	X
Native Lands	X	X	X	N

N - Negigible Use
X - Present
L - Limited Use
O - Occasional Use
F - Frequent Use
S - Significant - High

TABLE II-4

Summary of contaminant concerns in the Upper Great Lakes Connecting Channels.

Contaminant	Water				Sediment				Biota			
	SM*	SC	LSC	D	SM	SC	LSC	D	SM	SC	LSC	D
Nutrients												
- Phosphorus	SM		LSC	D					SM		LSC	D
- Nitrogen	SM		LSC	D				D	SM		LSC	D
Bacteria	SM	SC		D		SC						
Chlorides		SC		D						SC		D
Oil and Grease	SM	SC		D	SM	SC		D	SM	SC	LSC	D
Phenols	SM	SC		D					SM	SC		D
Pesticides			LSC				LSC				LSC	D
PCBs				D	SM	SC	LSC	D	SM	SC	LSC	D
PAHs	SM			D	SM	SC	LSC	D	SM	SC	LSC	D
Other Organics		SC		D		SC	LSC	D		SC		D
Heavy Metals	SM	SC	LSC	D	SM	SC	LSC	D	SM	SC	LSC	D
Mercury		SC			SM	SC	LSC		SM	SC	LSC	D
Cyanide	SM											
Habitat Alteration			LSC			SC	LSC	D		SC	LSC	D

* SM - St. Marys River LSC - Lake St. Clair
D - Detroit River SC - St. Clair River

2. St. Marys River[2]

The St. Marys River delivers the outflow of Lake Superior to Lake Huron (Figure II-2). It is partially controlled by locks and compensating structures to allow navigation and power generation. Thus, the river is not subject to large unpredictable fluctuations in flow rates. Sediments in the river range from sands and gravels, particularly in the upper reaches and near the rapids, to silts and clays. The finer material generally occurs in downstream locations and in embayments. The St. Marys River has an active sports fishery based primarily on trout, salmon, walleye, yellow perch, pike, and smelt. It formerly supported a major whitefish commercial fishery. The river is known to have 75 species of fish.

Water is withdrawn to provide the major source of drinking water[3] for a U.S. population of approximately 15,000 as well as process water for the steel industry (Algoma Steel Co.), pulp and paper processing (St. Marys Paper) and other smaller industries. Most of the industrial development is found on the Canadian side of the River which is also home to the largest population along the river (85,000). Other primary water uses include navigation and recreational boating.

The watershed draining into the river is predominantly forested with low intensity agriculture occurring on the relatively flat-lying plains or either side of the river.

Industrial and municipal effluents have resulted in contaminant problems in sediment and water related to phenols, cyanide, PAHs, PCBs, iron, zinc, phosphorus and ammonia. Contaminant problems have also resulted in impaired benthic fauna. Physical disruption related to power generation and navigation has also adversely impacted fish habitat. Past surveys of sediment, benthos and water quality indicate that conditions along the U.S. shore and in Lake Nicolet are good and these areas can support a variety of water uses. The zone of greatest impact in the St. Marys River is along the Canadian shore downstream of industrial and municipal discharges. This zone includes the Algoma slip, the area below the rapids, the Sault Ste. Marie waterfront and downstream of the East End Sewage Treatment Plant in the channel feeding Lake George.

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[2] Primary sources for sections 2 to 5 are (2,3).

[3] Wells provide the primary source of drinking water for the Canadian population. It is supplemented with St. Marys River water as necessary.

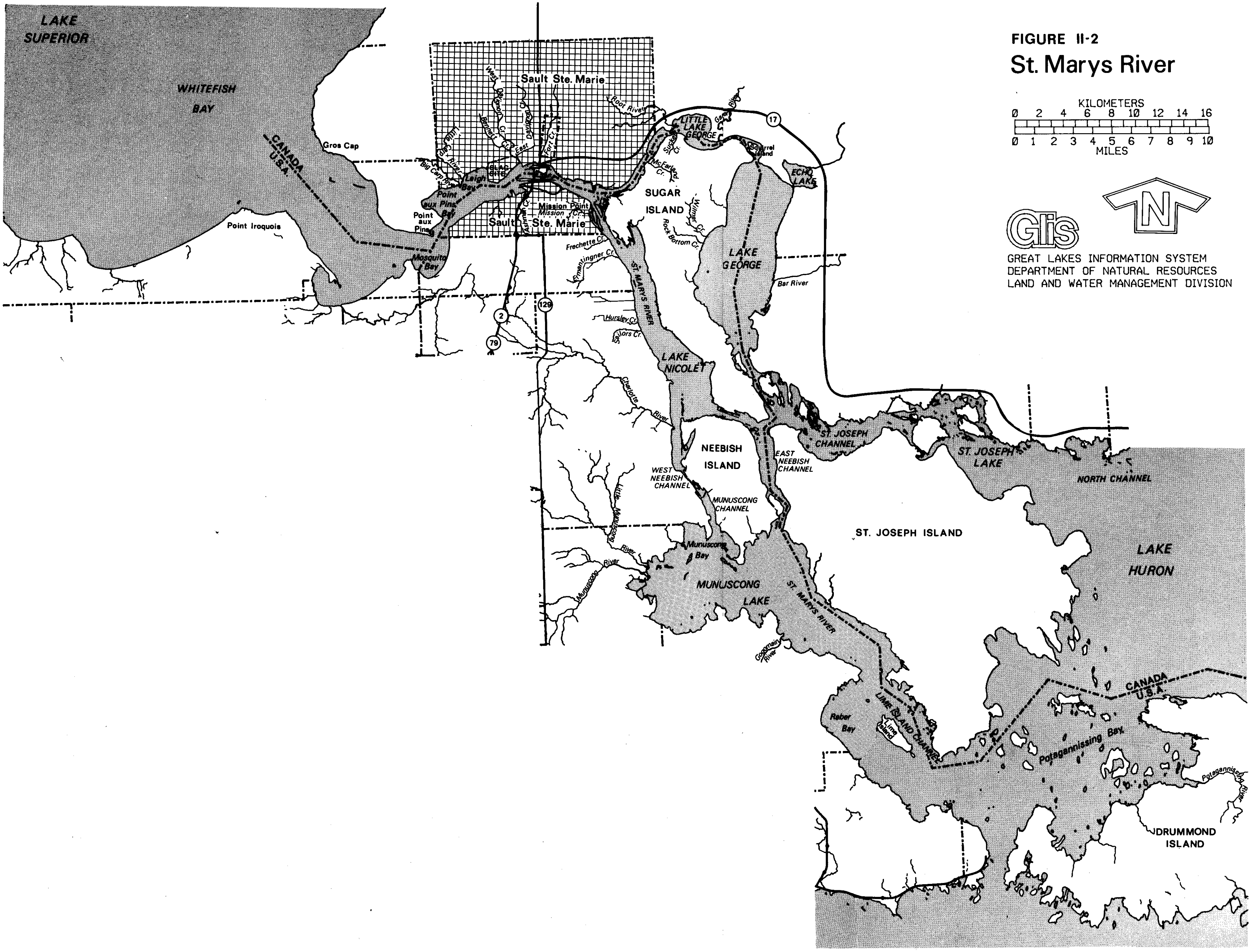

FIGURE II-2

St. Marys River

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LAND AND WATER MANAGEMENT DIVISION

3. St. Clair River

The St. Clair River is not controlled in any manner. It serves as the natural outlet of Lake Huron and drains into Lake St. Clair where it has formed the only major riverine delta on the Great Lakes - the St. Clair delta, also known as the St. Clair flats (Figure II-3). The conditions which have contributed to the formation of this delta include: rapid deceleration of the flow from the river as it disperses into the wide shallow basin of Lake St. Clair; very high suspended sediment loads carried by the river from sources in the Lake Huron watershed; stable conditions at the river/lake interface since the channel was first established; and the straight channel of the St. Clair River with few islands or other depositional sites.

The bed of the river is characterized by relatively coarse fractions consisting of sand and gravel and by an erosional surface of clay till. This reflects the high energy environment of the river which acts as a conduit to Lake St. Clair and the delta for the finer material (fine sands, silts, and clays) originating in the Lake Huron watershed.

The St. Clair River provides a corridor for fish between Lakes Huron and Erie but also supports an indigenous fishery. Prominent species include walleye, muskellunge, rainbow trout, lake sturgeon, smelt, salmon, bass, catfish, yellow perch and freshwater drum. The St. Clair River and its delta are known to serve as habitat for fish during their sensitive life stages (spawning, rearing). The delta is unique, serving not only as an important fish habitat but also as habitat for other wildlife including waterfowl, reptiles, amphibians, fur-bearing mammals and plant species. This diversity is due, in large part, to the remaining extensive wetlands and wetland-upland complexes of the delta and its environs.

The St. Clair River serves as a major shipping channel; as a recreational resource (including boating, fishing, hunting, and swimming); a food source for native Canadians; a source of drinking water for U.S. and Canadian citizens; industrial process water for Canada's largest petro-chemical complex; and a receptacle for treated municipal and industrial effluents. Clearly, these uses conflict in terms of maintaining good water, sediment and biota quality.

The immediate shores of the river are used for a mixture of urban, industrial and recreational uses. Inland, the predominant land use is intensive agriculture.

Contaminant problems specific to the St. Clair River include sediment contaminated with PCBs, oil and grease, mercury, and other metals; and fisheries impacted by PCBs and mercury. Contaminants characteristic of the petro-chemical industry and found

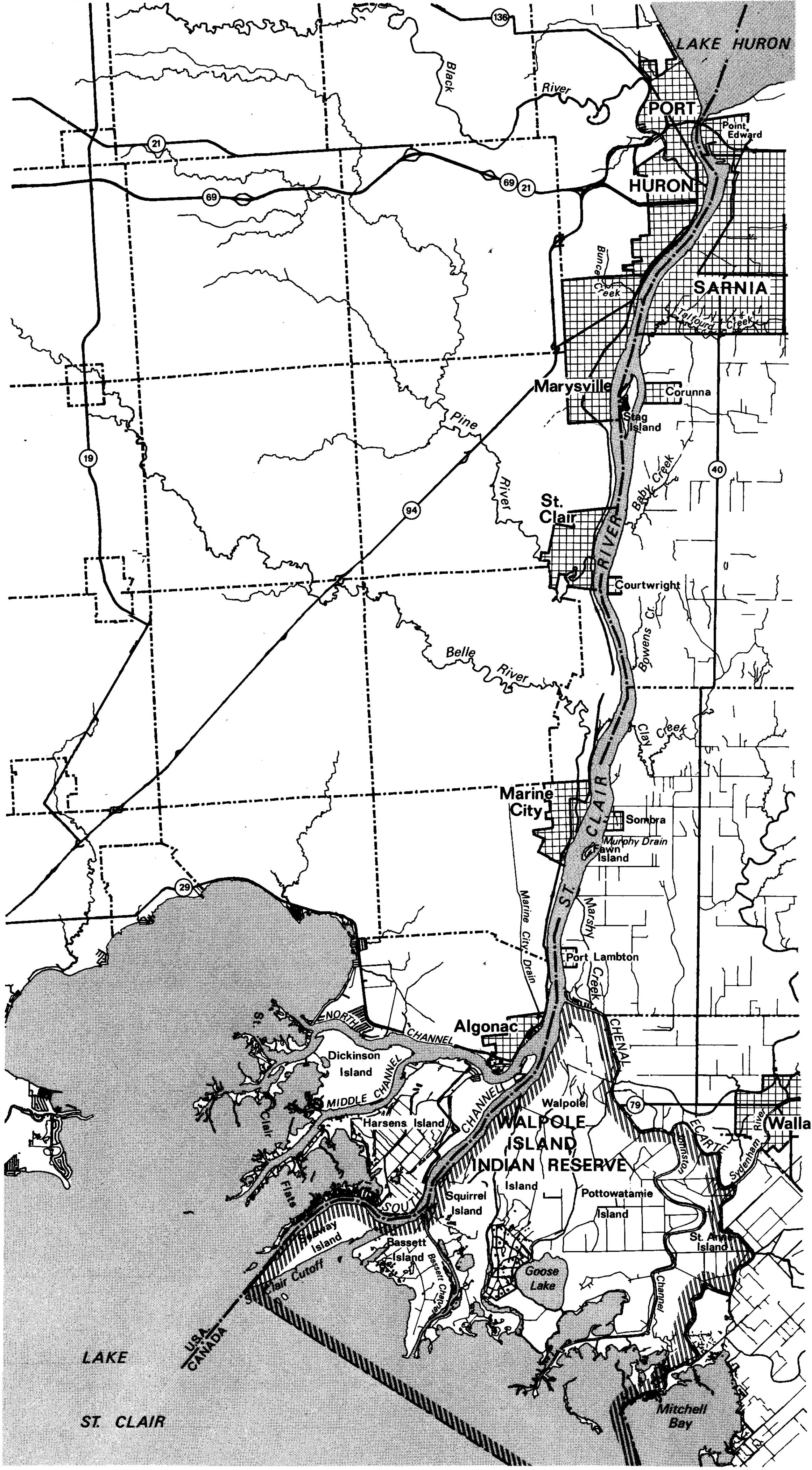

FIGURE II-3
St. Clair River

in elevated levels in biota, sediment and water include; hexachlorobenzene, hexachlorobutadiene, octachlorostyrene, carbon tetrachloride, perchloroethylene, and hexachloroethane. These chemicals are confined to a band of water approximately 100 m wide along the Ontario shoreline adjacent to the industrial area at Sarnia.

In addition to direct point discharges from industrial and municipal sources, concern for ongoing and potential contamination of the river has been identified for such nonpoint sources as: surface landfill sites, liquid waste disposal zones in deep geological strata ("deep wells"), urban runoff, and agricultural runoff. Even though the petrochemical industry is concentrated on the Canadian side of the river, municipal outfalls and similar nonpoint sources occur on the U.S. side.

Recent surveys of benthic organisms in the St. Clair River indicate that the benthic community is impaired in the immediate vicinity of the petro-chemical industry. However, the zone of impairment has decreased significantly since the late 1960s. This reflects improvements in industrial and municipal effluent quality throughout the 1970s and 1980s. Significant reductions of organic contaminants (80 to 90%) in certain outfalls have been achieved even since the initiation of the Upper Great Lakes Connecting Channels Study (4).

4. Lake St. Clair

Lake St. Clair is not considered one of the five Great Lakes, however, it is a large lake (Figure II-4 and Table II-3). It is a very shallow lake compared to its surface area, resulting in extreme variability in water levels over space and time due to short term climatic changes (winds, barometric pressure) and hydrologic flow regime (inflow-outflow).

The shallow character of the lake also influences sediment dynamics. The primary source for sediments is the Lake Huron watershed via the St. Clair River. Deltaic formation at the mouth of the river has, in a relatively short geologic time (post-glacial), resulted in the in-filling of approximately one-fifth of the lake area. Fine grained sediments, particulary clays, are deposited in the deeper portions of the lake. The majority of the lake bottom, however, consists of relatively coarse sands and gravels reflecting the high wave-energy environment. Sediment depth in the main body of the lake, in fact, averages only 7 cm overlying the glacial till. Thus, much of the material entering the lake from the delta and its major tributaries (the Clinton, Sydenham and Thames Rivers) ultimately moves out of the lake, through the Detroit River and into Lake Erie.

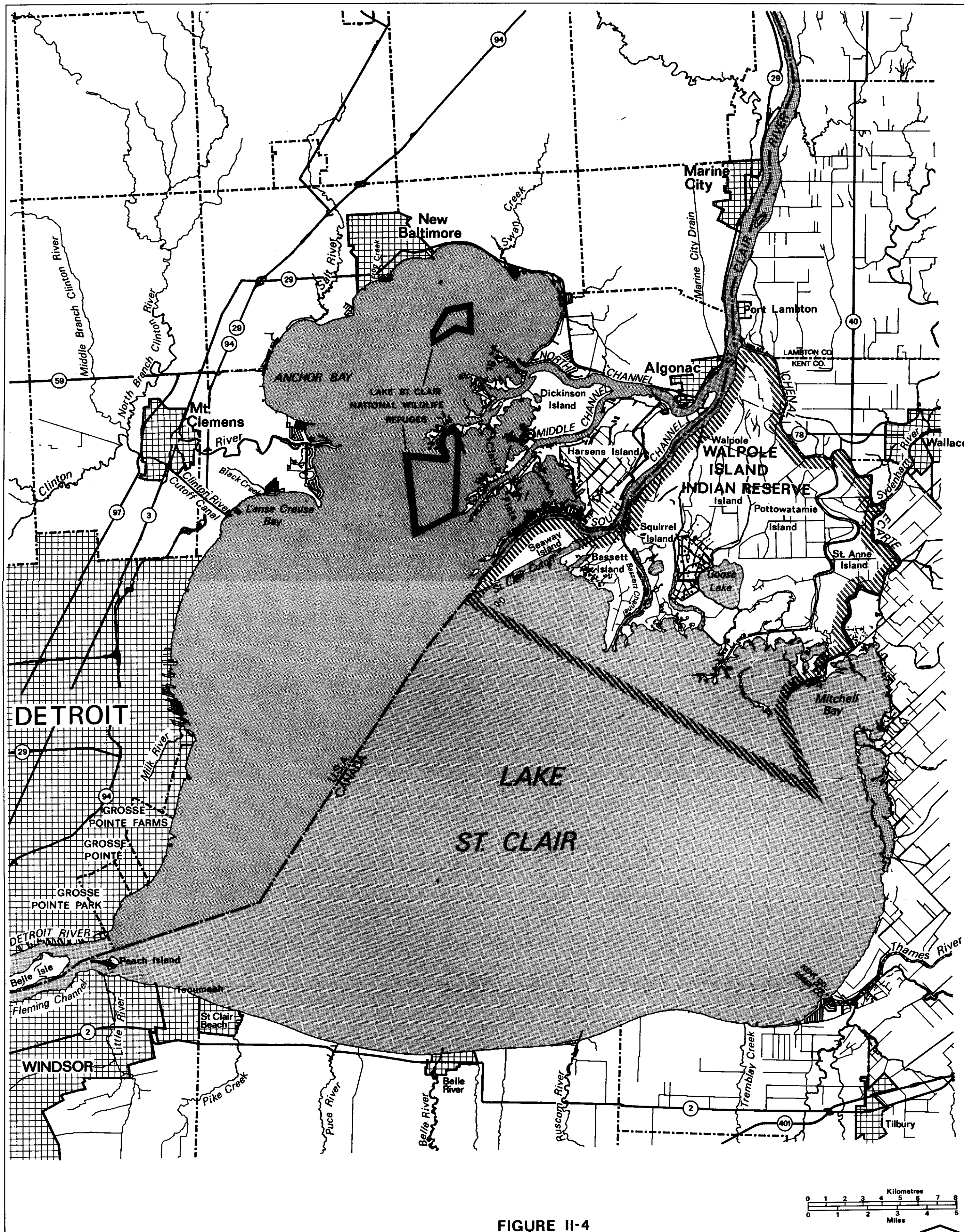

FIGURE II-4

Lake St. Clair

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Over 70 species of fish are known to reside in or migrate through Lake St. Clair. The lake is particularly known for its muskellunge fishing. Other warm water species common to the lake include pike, bass, perch, crappie, and bluegills. Walleye, salmon, trout, whitefish, smelt, and suckers are also part of the sport fishery. The delta area and Anchor Bay are known to be the most active spawning areas of the lake. Generally, the near shore areas and tributaries to the lake provide habitat which is crucial to the lakes' fishery. The impressive fisheries and other wildlife resources (both indigenous and migratory) owe their existence, in large part, to the extensive wetland communities in the delta and along most of the undeveloped shoreline of Lake St. Clair.

Direct uses of the lake are primarily recreational. This includes the largest number of registered boats on the Great Lakes as well as fishing, and hunting for fur-bearing animals and waterfowl. Other uses include drinking water and commercial shipping. Lake St. Clair is unique among the other UGLCCS areas in that there are no significant industries or major urban centres located on its shores (except for the northern portion of the Detroit Metropolitan area). However, several large communities are found on the tributaries which feed into the lake.

Surrounding land uses are primarily natural (wetlands) and intensive agriculture. Large expanses of the original wetlands have been drained for agricultural purposes. In Ontario, for example, over 90% of the original wetland area surrounding Lake St. Clair has been converted to agriculture (5). In fact, over 400,000 ha of wetlands in three contiguous counties have been converted since the late 1800s. This has undoubtedly exerted a very significant impact on the wildlife resources of Lake St. Clair and its environs.

Lake St. Clair is the only UGLCCS area which is not also classified by the IJC as an "Area of Concern". There is a lack of direct point sources of contaminants and/or heavily contaminated sediments. The lake does, however, act as a mixing zone for various organic and inorganic contaminants originating from upstream sources and from atmospheric deposition. These include industrial and municipal sources from 2 Areas of Concern (St. Clair and Clinton Rivers) and nutrients and pesticides from agricultural drainage via drainage ditches and the tributary rivers. Phosphorus loadings (primarily agricultural) and mercury contamination of the fishery are primary concerns in Lake St. Clair. Levels of mercury in fish have declined since the early 1970s and conservation authorities in southwestern Ontario (particularly the Thames River C.A.) have developed programs to reduce sediment loads derived from agricultural lands (and hence adsorbed nutrients/pesticides).

5. Detroit River

The Detroit River is the furthest downstream Connecting Channel of this study. It connects Lake St. Clair with Lake Erie (Figure II-5). Flow in the Detroit River is complex due to numerous islands and channels, particularly in the lower half of its reach, and to unique effects from fluctuating water levels in Lake Erie. Wind set-up and barometric pressure changes can cause the western portion of Lake Erie to rise 2 to 2.5 m during storms. This is greater than the total elevation change of the Detroit River from head to mouth (< 1 m). When such conditions occur, the river flow slows down and actually reverses for short distances.

Bottom sediments in the Detroit River vary from clay to boulders and bedrock. Overall, sediments tend to be coarse (sand and gravel) due to medium to high current velocities which transport most of the suspended materials into the western portion of Lake Erie. Minor depositional zones for fine material (clays, silts) occur in the river adjacent to islands (particulary downstream of the islands) and the near shore (mostly along the Canadian side). Bedrock forms the river bed in some portions of the lower channel such as in the 10 km reach between Fighting and Bois Blanc Islands.

Although fish spawning and nursery habitats are less available in the Detroit River than in Lake St. Clair, the river sustains a diverse fishery. Both resident (rainbow smelt, alewives and gizzard shad) and migratory species are known to be present. Species common to this river include walleye, bass, and yellow and white perch. The river is considered to have a fairly healthy fishery in terms of numbers and diversity given its history and degree of pollution and habitat alterations (dredging, filling, bulkheading, etc). However, these activities, due to large scale urbanization, have clearly restricted plant and other wildlife abundance and diversity relative to the study areas. During spring and fall migrations, the lower Detroit River, encompassing the Wyandotte National Wildlife Refuge, is especially critical as a feeding and staging area for several waterfowl species.

The Detroit River watershed is the most urbanized of the four areas covered in this study. It is home to a population greater than 5 million and is one of the world's most heavily industrialized areas. This industry includes a vast automotive complex including fabrication and assembly as well as many metal and plastic based support industries. Numerous other types of manufacturing also occur. Water uses include drinking water, recreational activities (boating and fishing), shipping, industrial cooling and process water withdrawals, and municipal and industrial waste discharges.

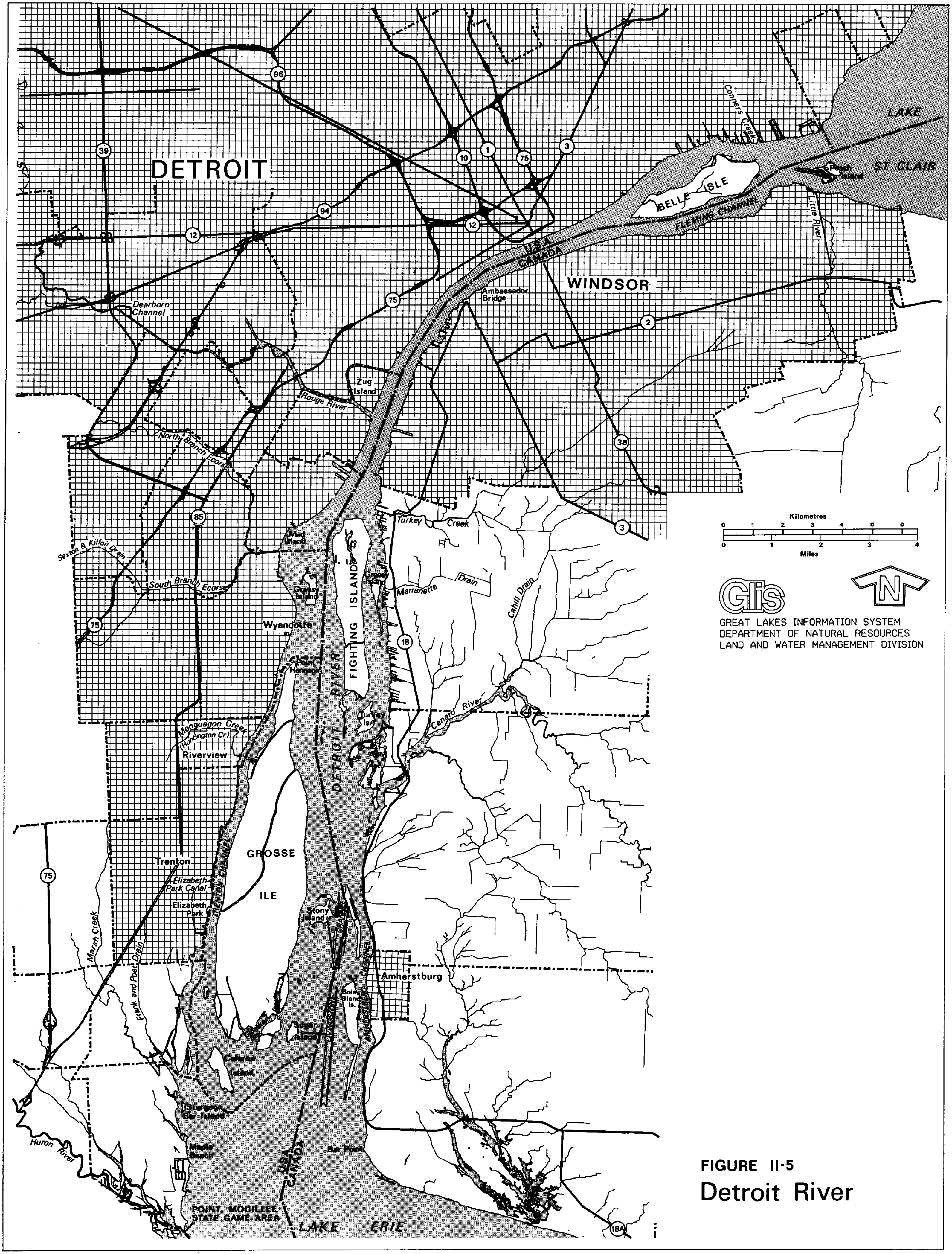

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FIGURE II-5
Detroit River

Surrounding land uses are principally urban (U.S.) and agricultural (Canada) although numerous recreational areas are present (e.g. Belle Island, Boblo Island and Dieppe Park). A particular concern is the restricted river access due to urban and industrial developments along the waterfront, particularly on the U.S. side.

Contamination problems in the Detroit River include: sediments contaminated with PCBs, oil and grease, mercury, and other metals; water quality violations for phenols, iron, and fecal coliform; and an impacted fishery (particularly by PCBs), waterfowl and benthic community. Surveys of benthic communities show a zone severely impacted by contamination off-shore and just downstream of Zug Island. The remainder of the river downstream of this island, but confined to the U.S. shore, also shows evidence of severe impairment. Normal communities are found upstream of Zug Island and along the entire Canadian shore.

Contaminants originate from point and nonpoint sources including numerous municipal and industrial outfalls, urban runoff, combined sewer overflows, agricultural runoff, and shallow groundwater contributions impacted by many waste sites. In addition to these, the river receives contaminants from upstream sources including 3 IJC Areas of Concern (St. Clair River, Clinton River and Rouge River).

6. References

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3. Great Lakes Water Quality Board. 1987. 1987 Report on Great Lakes Water Quality. GLWQB, International Joint Comm., Windsor, Ontario. 236p.

4. Ontario Ministry of the Environment and Environment Canada. 1988. Status report of the recommendations of the 1986 St. Clair River Pollution Investigation Report. OMOE and DOE, Toronto.

5. Snell, E.A. 1987. Wetland distribution and conversion in southern Ontario. Lands Dir, Env. Can., Ottawa, Working Paper #48. 53p.

CHAPTER III

REGULATORY BASIS OF ENVIRONMENTAL QUALITY CONTROL

A. INTRODUCTION

Environmental quality of the Upper Great Lakes Connecting Channels is influenced by major environmental regulations, agreements and programs which have been developed at several governmental levels. The Canadian and United States federal governments, the State of Michigan, the Province of Ontario, and their regulatory agencies have promulgated acts and regulations to protect and enhance the environmental quality of the Great Lakes. Binational agreements at both the federal, state and provincial level have also been made. As a result, an extensive and comprehensive base of legislation and agreements exists to protect environmental quality of the connecting channels.

This chapter provides an overview of existing regulatory and administrative programs which act to protect and enhance the environmental quality of the Upper Great Lakes Connecting Channels. A more extensive review of existing regulatory programs pertinent to these shared waterways is presented in Appendix 3.

1. Binational Agreements

The governments of Canada and the United States have long shared a concern for the environmental quality of the Great Lakes Basin. To confirm their commitment to restore and enhance the water quality of the Great Lakes both federal governments entered into the Great Lakes Water Quality Agreement in 1972 (GLWQA). The GLWQA and its associated Annexes were subsequently amended in 1978, 1985 and 1987. The Agreement contains general and specific objectives to maintain and augment water quality by ensuring the Great Lakes are free from substances resulting from human activity, are unsightly or deleterious, or interfere with beneficial uses of the water. The seventeen Annexes of the GLWQA outline specific objectives and programs aimed at maintaining and improving the quality of these shared waters. For many parameters, the Annexes provide numerical ambient water quality and fish contaminant objectives, as well as narrative guidelines for other categories of contaminants and discharges. The GLWQA, while outlining objectives which both governments strive to achieve, is an agreement only and has no regulatory authority in and of itself.

Ontario and Michigan have also entered into binational agreements regarding Great Lakes water quality issues. Recently, in April 1988, two Memoranda of Understanding were signed; one concerning accidental discharges of contaminants into the Great Lakes and the other, an associated Joint Notification Plan for such discharges.

2. Federal, State and Provincial Environmental Control Legislation and Programs - An Overview

Numerous legislative acts, regulations and programs exist at the federal, state and provincial levels which regulate point and some nonpoint source discharges, and affect ambient water, sediment and biota quality. Table III-1 lists major environmental acts from which specific environmental regulations and programs are derived. In most cases, a variety of regulations and programs are developed from each act, making their effect far-reaching. These major acts provide a comprehensive framework with which to control or reduce inputs of contaminants to the Great Lakes basin, and are discussed below.

TABLE III-1

Environmental Legislation affecting Great Lakes ecosystem quality.

BINATIONAL LEGISLATION	MEDIA OR ACTIVITY ADDRESSED												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Great Lakes Water Quality Agreement (GLWQA)	2	2	2	2	2	2	2	2	2	2	2	2	2
Ontario-Michigan Memorandum of Understanding on Notification									2		2		
Ontario-Michigan Declaration on Partnership and Memorandum on Cooperation	2	2	2	2	2		2	2	2	2	2		2

KEY TO CODES:

A: Ambient Surface Water and Ground Water Quality and Management
B: Sediment Quality and Management
C: Biota Quality and Habitat Management
D: Industrial Point Source Discharge Control
E: Municipal Point Source Discharge Control
F: Solid and Hazardous Waste Management
G: Pesticide Manufacture and Management
H: Urban Runoff and Combined Sewer Overflow Management
I: Air Point Source Discharge and Ambient Air Quality Control
J: Agricultural Land Management
K: Spills and Shipping Activities
L: Drinking Water Quality Control and Management
M: Fish Consumption Guidelines or Advisories

1: Legislation is responsible for legally enforceable standards and/or has direct authority over the media or activity.
2: Legislation provides non-enforceable guidance or authority over media or activity.
3: Legislation is not directly applicable to the media or activity, but media/activity may be impacted by execution of its legislative mandate.

TABLE III-1. (cont'd 2)

CANADA LEGISLATION	MEDIA OR ACTIVITY ADDRESSED												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Fisheries Act	1	3	1	1		3							3
Canada Water Act	2	2	3		2								
Canadian Environmental Protection Act (CEPA)	3	3	3	1	1	1	1	2	1		1		
Food and Drug Act													1
Canada Shipping Act	3	3	3								1		
Transportation of Dangerous Goods Act (TDGA)	3	3	3								1		
Pest Control Products Act (PCPA)							1			3			
Canadian Clean Air Act									1				
Environmental Contaminants Act						1							

ONTARIO LEGISLATION	MEDIA OR ACTIVITY ADDRESSED												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Ontario Water Resources Act (OWRA)	1	3	1	1	1					2		1	
Ontario Environmental Protection Act (EPA)	3	2	3	1	1	1		2	1	3	1		
Dangerous Goods Act						1					1		
Drainage Act								2			2		
Pesticides Act							1			1			

TABLE III-1. (cont'd 3)

UNITED STATES LEGISLATION	MEDIA OR ACTIVITY ADDRESSED												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Clean Water Act (CWA)	1	1	1	1	1	3		2			1		
Safe Drinking Water Act (SDWA)	1					1						1	
Food, Drug and Cosmetic Act							3						1
Clean Air Act (CAA)						3			1				
Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)	1	3	3			1					1		
Solid Waste Disposal Act (SWDA)						1	1				1		
Toxic Substances Control Act (TSCA)						1	1				1		
Federal Insecticide, Fungicide and Rodenticide Act (FIFRA)							1			3			
Agricultural, Rural Development and Related Agencies Appropriations Act	2									2			
Soil Conservation and Domestic Allotment Act	3									2			
Endangered Species Act			1			3							
National Environmental Policy Act (NEPA)*	2	2	2	2	2	2	2	2	2	2	2	2	2

* NEPA is discussed in Appendix 3.

TABLE III-1. (cont'd 4)

MICHIGAN LEGISLATION	MEDIA OR ACTIVITY ADDRESSED												
	A	B	C	D	E	F	G	H	I	J	K	L	M
Water Resources Commission Act (Act 245)	1	3	1	1	1		1	1		1	1		
Safe Drinking Water Act (Act 399)	1					1						1	
Michigan Air Pollution Act									1				
Watercraft Pollution Control Act (Act 167)											1		
Michigan Hazardous Waste Management Act (Act 64)	3					1	1				1		
Michigan Liquid Industrial Waste Disposal Act (Act 136)						1					1		
Michigan Solid Waste Management Act (Act 641)	3					1					1		
Michigan Environmental Response Act (Act 307)						1							
Inland Lakes and Streams Act (Act 346)	1	1	3										
Great Lakes Submerged Lands Act (Act 247)		2											
Michigan Resource Recovery Act (Act 366)						2							
Michigan Underground Storage Tank Act (Act 423)						1							
Michigan Wetlands Protection Act	1	1	3										
Michigan Shorelines Protection and Management Act	1		1										
Michigan Motor Vehicle Emissions Inspection Act (Act 83)									1				
Michigan Oil & Gas Act (Act 61)	3	3	3			1					1		
Michigan Act 98					1								

B. ENVIRONMENTAL MEDIA STANDARDS, CRITERIA, OBJECTIVES AND GUIDELINES

Media quality is often evaluated by comparing media contaminant concentrations with numerical concentration limits, set by regulation or agreement. Point source discharges are often controlled by the imposition of contaminant concentration or loading limits on effluent or stack air emissions. Various regulations and agreements have developed "standards", "criteria", "objectives" or "guidelines" to specify these concentration or loading limits. In general, standards, and in some cases criteria, are enforceable by law. These limits are usually based on regulatory agency policies (e.g., state water quality standards), but may be derived from scientific principles or studies (e.g., concentration and loading limits achieved by the use of best available technology).

Objectives, guidelines and, in most cases, criteria are suggested limits established by regulatory agencies, such as the United States Environmental Protection Agency (U.S.EPA), Michigan Department of Natural Resources (MDNR) or Ontario Ministry of the Environment (OMOE), as well as by other non-regulatory agencies, such as the International Joint Commission (IJC). These limits are often based upon known or suspected impacts on human, animal or aquatic life, and may be used to establish legally enforceable limits as agency standards, or by incorporation into specific agency documents, such as Certificates of Approval.

1. Water Quality Regulations and Guidelines

Numerical ambient water quality limits have been established by federal, state and provincial statutes, as well as by binational agreement. Parameter-specific ambient water quality standards, criteria or objectives applicable to the UGLCC Study parameters of concern are summarized in Table III-2; a comprehensive list of ambient water quality limits is contained in the Regulatory Task Force Report (1). These limits establish maximum concentrations allowable in surface waters for the protection of human health, animal and aquatic life and recreational use. These limits are continually being reviewed and updated by state, provincial and federal agencies. Regulatory agencies may adopt objectives set by other regulatory or nonregulatory agencies on an interim basis for parameters for which agency objectives have not been established.

GLWQA specific objectives are nonenforceable goals for water bodies within the Great Lakes Basin, in both the US and Canada. Ontario Provincial Water Quality Objectives (PWQO), developed under the authority of the Ontario Water Resources Act, and U.S.EPA Ambient Water Quality Criteria (AWQC), developed under the authority of the Clean Water Act, are similar in that they

TABLE III-2

Ambient water quality criteria, guidelines, or objectives for parameters of concern in the UGLCC (ug/L).

PARAMETER	GREAT LAKES WATER QUALITY AGREEMENT SPECIFIC OBJECTIVE	ONTARIO WATER QUALITY OBJECTIVE (PWQO)	U.S.EPA ACUTE AMBIENT WATER QUALITY CRITERIA (AWQC)	U.S.EPA CHRONIC AMBIENT WATER QUALITY CRITERIA (AWQC)	U.S.EPA AWQC HUMAN HEALTH CRITERIA (Water & Fish)[1]	U.S.EPA AWQC HUMAN HEALTH CRITERIA (Fish only)[1]	MICHIGAN RULE 57(2) GUIDELINE LEVELS[2]
AMMONIA	0.02	0.02	pH/temp dependent		-	-	20(coldwater)
CADMIUM	0.2	0.2	3.9+	1.1+	10	-	0.4+
CHLORAMINES	-	-	-	-	-	-	-
CHLORIDES	-	-	-	-	-	-	-
CHLORINE	-	0.002	0.019	0.011	-	-	6
CHLORINATED PHENOLS	-	-	-	-	-	-	-[4]
CHROMIUM (TOTAL)	50	100	-	-	-	-	52+
CHROMIUM (HEXA)	-	-	16	11	50	-	6
CHROMIUM (TRI)	-	-	1700+	210+	170mg/L	3,433mg/L	-
COBALT	-	-	-	-	-	-	-
COPPER	5	5	18+	12+	-	-	21+
CYANIDE	-	5	22	5.2	200	-	5
HCB	-	0.0065	-	-	0.72ng/L	0.74ng/L	0.0019
IRON	300	300	-	1000	300	-	-
LEAD	25^3	25	82+	3.2+	50	-	3+
MERCURY	0.2	0.2	2.4	0.012	144ng/L	146ng/L	$0.6ng/L^5$
NICKEL	25	25	1400+	160+	13.4	100	78+
OIL/GREASE	-	-	-	-	-	-	-
OCS	-	-	-	-	-	-	-
PHENOL	-	-	10,200*	2560*	3500	-	230
PHOSPHORUS (LAKES)	-	0.02	-	-	-	-	-
PHOSPHORUS (RIVERS)	-	0.03	-	-	-	-	-
PCB	-	0.001	2.0	0.014	0.079ng/L	0.079ng/L	0.012ng/L
PAH	-	-	-	-	2.8ng/L	31.1ng/L	-
ZINC	30	30	120+	110+	-	-	98

\+ Criteria is hardness-dependent. Value shown is based on a calcium carbonate hardness of 100 mg/L.

* Value shown is not criteria, but is lowest observed adverse effect level (LOAEL).

[1] U.S.EPA Ambient Water Quality Criteria for Human Health is based on either consumption of 2 liters of water per day and 6.5 gm of fish per day, or consumption of 6.5 g of fish per day only. Guidance for carcinogens is based on a 1E-06 risk level, using the U.S.EPA-adopted risk extrapolation method.

[2] Michigan Rule 57(2) Guidelines apply to contaminant concentrations at the edge of a defined mixing zone (values as of January 1988, subject to change)

[3] Not applicable to Lakes Huron or Superior.

[4] Guidelines do exist for specific chlorinated phenols; see Appendix 3.

[5] Guideline is for methyl mercury.

are also goals for water quality. However, both PWQO and AWQC are often the starting point for the development of point source effluent limitations, and in the case of AWQC, become enforceable state water quality standards in states which have not promulgated more stringent state standards. U.S.EPA AWQC Human Health Criteria are criteria for water quality, based on the potential human health effects resulting from consumption of 2 liters of water and 6.5 g of fish per day, or consumption of 6.5 g fish per day only.

In Michigan, criteria for ambient water concentrations of toxic contaminants are based on Rule 57(2), which is based on Part 4 of the Michigan Water Resources Commission rules. Rule 57(2) was developed to protect human health, fish and wildlife from exposure to toxicants in surface water. It is a narrative rule for the calculation of "edge-of-the-mixing-zone" concentrations for toxics and is intended to be used in determining allowable levels for point source discharges. However, MDNR uses Rule 57(2) allowable levels as goals, particularly where ambient concentrations are in excess of these values. Rule 57(2) values are water body-specific, where appropriate, and are based on the most restrictive of human health, fish or wildlife criteria. Use of Rule 57(2) values may not be appropriate if ambient water quality exceeds Rule 57(2) allowable levels. In such cases, Rule 98, Antidegradation, may be more appropriate.

Both federal governments and the province have also established drinking water quality limits to protect human health. These limits for the UGLCC Study parameters of concern are summarized in Table III-3; a comprehensive list of drinking water limits is provided in the Regulatory Task Force Report (1). These requirements are based on known or suspected human health effects, but may include consideration of other factors such as treatment techniques, cost and available laboratory analyses. Drinking water limits may also be promulgated for nonhealth based parameters, such as odor and color, which are used to judge the acceptability of surface water supplies and treated water quality for drinking water purposes. Drinking water quality limits may be more or less stringent than ambient water quality objectives, standards or criteria, depending on the parameter considered.

The U.S.EPA National Primary Drinking Water Regulations, developed under the authority of the Safe Drinking Water Act, include Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs). MCLs are enforceable drinking water standards with which drinking water supplies must comply. MCLs are based on health effects, but also consider economic and technical factors. MCLGs are entirely health-based and are not enforceable. A chemical's MCLG serves as a starting point for the development of its MCL, which is set as close to the MCLG as feasible. U.S. EPA Secondary Drinking Water Regulations (also called MCLs) are recommended limits for aesthetic qualities of drinking water,

TABLE III-3

Drinking water standards, objectives and criteria for parameters of concern in the UGLCC (mg/L).

PARAMETER	U.S.EPA MAXIMUM CONTAMINANT LEVEL (MCL)[1,2]	U.S.EPA MAXIMUM CONTAMINANT LEVEL GOAL (MCLG)[1,3]	U.S.EPA SECONDARY DRINKING WATER REQUIREMENT (MCL)[4]	HEALTH&WELFARE CANADA MAXIMUM ACCEPTABLE CONCENTRATION (MAC)[2]	ONTARIO MAXIMUM ACCEPTABLE CONCENTRATION (MAC)[2]	ONTARIO MAXIMUM DESIRABLE CONCENTRATION (MDC)[4]
AMMONIA	-	-	-	-	-	-
CADMIUM	0.01	0.005	-	0.005	0.005	-
CHLORAMINES	-	-	-	-	-	-
CHLORIDE	-	-	250	250	-	250
CHLORINE	-	-	-	-	-	-
CHLORINATED PHENOLS	-	-	-	-	-	-
CHROMIUM	0.05	0.12	-	0.05	0.05	-
COBALT	-	-	-	-	-	-
COPPER	-	1.3	1.0	-	1.0	1.0
CYANIDE	-	-	-	0.2	0.2	-
HCB	-	-	-	-	-	-
IRON	-	-	0.3	-	0.3	0.3
LEAD	0.05	0.02	-	0.05	0.05	-
MERCURY	0.002	0.003	-	0.001	0.001	-
NICKEL	-	-	-	-	-	-
OIL/GREASE	-	-	-	-	-	-
OCS	-	-	-	-	-	-
PHENOLS	-	-	-	-	-	0.002
PHOSPHORUS	-	-	-	-	-	-
PCB (total)	-	-	-	-	0.003	-
PAH (total)	-	-	-	-	-	-
ZINC	-	-	5	-	-	5

[1] National Primary Drinking Water Regulations.
[2] Enforceable drinking water requirement.
[3] Nonenforceable health-based drinking water guidance.
[4] Nonenforceable guidance for aesthetics.

such as color, taste and odor, and are not federally enforceable. There are no state-developed drinking water standards, however, Michigan uses the federal standards by reference in the state's Drinking Water Act.

The Health and Welfare Canada Maximum Acceptable Concentration (MAC) is the enforceable drinking water requirement in Canada. Ontario has adopted most of these MACs for the provincial standards, which are developed under the authority of the Ontario Water Resources Act. The Ontario MACs are based on known or suspected human health effects, and are enforceable standards for drinking water supplies in Ontario. The Ontario Maximum Desirable Concentration (MDC) is based on aesthetics, and is a nonenforceable goal.

Other statues which can impact on surface water quality include, in Canada, the Fisheries Act and the Canadian Environmental Protection Act (CEPA), and in Michigan, the Michigan Wetlands Protection Act (Act 203), the Inland Lakes and Streams Act (Act 346), the Michigan Shorelines Protection and Management Act (Act 245) and the Great Lakes Submerged Lands Act (Act 247).

2. Sediment Quality Regulations or Guidelines

The GLWQA, in Annexes 7 and 14, addresses sediment quality from the perspective of studying, evaluating and monitoring dredging activities and in-place, contaminated sediments within the Great Lakes, but has not derived specific objectives for contaminants in sediments.

Guidelines for the disposal of dredged material, based on contaminant concentrations in sediments, have been established by the OMOE 1978 revised Guidelines for Dredged Spoils for Open Water Disposal and the U.S.EPA Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments. The OMOE allows open water disposal of dredged materials that meet or are lower than the established guidelines, providing existing water uses are not affected. The U.S.EPA Region V Guidelines were developed under pressure for the need for some guidance, but have not been adequately related to the impact of sediments on lakes, and should be considered interim guidelines until more scientifically sound guidelines are developed. The U.S.EPA is in the process of developing sediment criteria. Dredging guidelines are summarized in Table III-4. Table III-4 also shows the guidelines for evaluation of Great Lakes Dredging Projects, developed by the Dredging Subcommittee of the Great Lakes Water Quality Board. These guidelines are average concentrations of surficial sediments in Lakes Huron and Erie (guidelines for the other lakes have also been developed). Sediment concentrations exceeding these levels

TABLE III-4

USEPA, OMOE and Great Lakes Water Quality Board sediment dredging guidelines (mg/kg).

PARAMETER	ONTARIO MOE GUIDELINES[1]	U.S.EPA GUIDELINES[2] Nonpolluted	U.S.EPA GUIDELINES[2] Moderately Polluted	U.S.EPA GUIDELINES[2] Heavily Polluted	GLWQB DREDGING GUIDELINES[3] Lake Huron	GLWQB DREDGING GUIDELINES[3] Lake Erie
Total Phosphorus	1000	<420	420-650	>650	570	960
Total Kjeldahl Nitrogen	2000	<1000	1000-2000	>2000	-	-
Ammonia	100	<75	75-200	>200	-	-
Volatile Solids	60,000	<50,000	50,000-80,000	>80,000	-	-
Chemical Oxygen Demand	50,000	<40,000	40,000-80,000	>80,000	-	-
Oil & Grease	1500	<1000	1000-2000	>2000	-	-
Arsenic	8	<3	3-8	>8	1.1	3.2
Barium	-	<20	20-60	>60	-	-
Cadmium	1	-	-	>6	1.4	2.5
Chromium	25	<25	25-75	>75	32	53
Cobalt	50	-	-	-	-	-
Copper	25	<25	25-50	>50	32	39
Cyanide	0.1	<0.1	0.1-0.25	>0.25	-	-
Iron	10,000	<17,000	17,000-25,000	>25,000	-	-
Lead	50	<40	40-60	>60	49	112
Manganese	-	<300	300-500	>500	-	-
Mercury	0.3		>1 ("Polluted")		0.22	0.58
Nickel	25	<20	20-50	>50	39	49
PCB	0.05		>10("Polluted")		0.009-0.033	0.074-0.252
Silver	0.5	-	-	-	-	-
Selenium	-	-	-	-	0.9	0.79
Zinc	100	<90	90-200	>200	62	177

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[1] Ontario Ministry of the Environment Guidelines for Dredge Spoils for Open Water Disposal

[2] U.S.EPA Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments

[3] Guidelines for the Evaluation of Great Lakes Dredging Projects, Dredging Subcommittee, Great Lakes Water Quality Board, International Joint Commission.

are considered degraded and should not be disposed in the open lake. Since guidelines for contaminant concentrations in in-place sediments have not been derived, these dredging guidelines are often used in place of sediment criteria.

Contaminated sediments constitute a significant environmental concern in the Great Lakes Basin, and these guidelines are under review by most agencies. Special advisory groups, such as the Polluted Sediment Subcommittee under the Canada-Ontario Agreement, have been established to review sediment guidelines and assessment criteria, to evaluate dredging activities and in-place remedial options, and to provide expert advice on infilling practices.

Regulations which address dredging or remediation of contaminated sediments are discussed in a later section.

3. Aquatic Biota Quality Regulations or Guidelines

Many of the ambient water quality limits and guidelines were developed from an understanding of the effects of contaminants on aquatic life. Therefore, such limits and guidelines directly affect the health of aquatic biota. There is considerable legislation, not directly related to environmental quality, which exists to protect terrestrial and aquatic species, such as the U.S. Endangered Species Act of 1973, which identifies threatened and endangered species and their habitats. A more complete discussion on such legislation is contained in the Regulatory Task Force Report (1).

The quality of aquatic biota is also important from a human health perspective, when biota are consumed as a food source. Fish consumption advisories are developed by different regulatory agencies to provide guidance to the public on the safety of consuming fish which are, or may be, contaminated. These advisories are usually based on the concentration of contaminants contained in the edible portion of fish, and restrict consumption to varying degrees when contaminant concentrations exceed these levels.

Different concentration limits have been established by the GLWQA, the U.S. Food and Drug Administration (FDA), Ontario Ministry of the Environment, Health and Welfare Canada, and the Michigan Department of Public Health. Table III-5 summarizes these limits. Some of the sampling and analytical techniques associated with determining contaminant concentrations may vary from jurisdiction to jurisdiction. For example, Ontario employs a skinless fillet as an edible portion, whereas Michigan employs a skin-on fillet for some fish and a skin-off fillet for others.

TABLE III-5

Fish consumption guidelines, objectives, tolerances and action levels applicable to the UGLCC (ug/g).

PARAMETER	GREAT LAKES WATER QUALITY AGREEMENT SPECIFIC OBJECTIVE[1]	U.S.FDA ACTION LEVEL(A) OR TOLERANCE(T)[2]	HEALTH & WELFARE CANADA FISH CONSUMPTION ADVISORIES[3]	ONTARIO FISH CONSUMPTION GUIDELINES[4] (Restricted Consumption)	ONTARIO FISH CONSUMPTION GUIDELINES[5] (No Consumption)	MICHIGAN PUBLIC HEALTH FISH CONSUMPTION ADVISORY TRIGGER LEVELS[6]
Aldrin	0.3	0.3(A)	-	-	-	0.3
Chlordane	-	0.3(A)	-	-	-	0.3
Chlordecone	-	0.3(A)	-	-	-	-
2,4D	-	1.0(T)	-	-	-	-
DDT	1.0	-	5.0	5.0	-	5.0
Dieldrin	0.3	-	-	-	-	0.3
Diquat	-	0.1(T)	-	-	-	-
Endrin	0.3	0.3(A)	-	-	-	0.3
Fluridone	-	0.5(T)	-	-	-	-
Glyphosate	-	0.25(T)	-	-	-	-
Heptachlor & H.Epoxide	0.3	0.3(A)	-	-	-	0.3
Lead	-	-	-	1.0	-	-
Lindane	0.3	-	-	-	-	-
Mercury	0.5	1.0(A)	0.5	0.5	1.5	0.5
Mirex	<DL	0.1(A)	0.1	0.1	-	0.1
PCB	0.1	2.0(A)	2.0	2.0	-	2.0
Simazine	-	12.0(T)	-	-	-	-
Toxaphene	-	-	-	-	-	5.0
Triclopyr	-	0.2(T)	-	-	-	-
2378-TCDD (ppt)	-	25[7] (limited consumption)	20	20	-	10
2378-TCDD (ppt)	-	50[7] (no consumption)				

<DL Less than Detection Limit.

[1] The GLWQA specific objectives refers to concentrations in the edible portion of fish, wet weight, for all contaminants except DDT, mercury and PCB, which are for whole fish concentrations.

[2] U.S. Food and Drug Administration Action Levels and Tolerances are based on edible portions of fish; discussion on Action Levels vs. Tolerances is discussed in text.

[3] Health and Welfare Canada requirements are for fish in commerce only.

[4] Ontario Fish Consumption Guidelines are based on a skinless dorsal fillet. Restricted consumption guidelines: unrestricted consumption below and restricted consumption above this guideline, except for women of child-bearing age and children under 15 years of age, where restricted consumption below and no consumption above this guideline is recommended.

[5] No consumption is recommended above this guideline for all populations.

[6] Michigan Trigger Levels are based on analyses from skin-on fillets or skinless fillets, depending on fish type.

[7] U.S.FDA limits for 2,3,7,8-tetrachlorodibenzo(p)dioxin (2378-TCDD) are guidance only.

FDA action levels and tolerances are contaminant limits in edible fish flesh developed by either the FDA or the U.S.EPA, and apply only to fish in interstate commerce. The authority for the development of action levels and tolerances comes from the Federal Food, Drug and Cosmetic Act. FDA action levels and tolerances differ in that tolerances apply to registered chemicals in current use and action levels to chemicals for which legal use has been prohibited. FDA action levels and tolerances are not intended to be used to regulate sport-caught fish. Michigan Trigger Levels, which do apply to sport-caught fish, are, in many cases, identical to FDA action levels and tolerances; however, the Trigger Levels were derived independently.

Health and Welfare Canada, under the Food and Drug Act, has established some federal fish consumption advisories, with restricted consumption being advised for fish exceeding the guidelines. The Ontario Fish Consumption Guidelines, developed by OMOE and Ontario Ministry of Natural Resources, based on guidance from the federal Food and Drug Act, have adopted many of the federal consumption guidelines, and provide restricted consumption guidelines below which consumption may be unrestricted and above which restricted consumption is advised (or no consumption, in the cases of women of child-bearing age and children under 15 years of age). Mercury also has a No Consumption guideline, above which no consumption is advised for all populations.

Both Ontario and Michigan publish readily available fish consumption advisory guides identifying consumption advisories in effect for various fish species, sizes and water bodies. The GLWQA has established specific objectives for several contaminants in the edible portion of fish for the protection of human health, in addition to contaminants in whole fish for the protection of fish-consuming wildlife and aquatic birds.

C. POINT SOURCE CONTAMINANT CONTROLS

Much of the focus of federal, provincial and state legislation and the GLWQA is directed towards the control and reduction of excessive contaminant input from point source dischargers. The regulatory basis for these control programs is discussed below.

1. Industrial Point Sources

Surface and Groundwater

Article VI of the GLWQA requires the governments of Canada and the U.S. to develop and implement programs to abate, control and prevent pollution resulting from industrial point sources by establishing effluent limits and effective enforcement programs.

Environment Canada, through industry-specific regulations under the Fisheries Act, regulates the discharge of conventional contaminants and acute toxicity (defined by bioassays) from petroleum refineries, pulp and paper mills and other specific industrial sectors. These federal regulations and guidelines for effluent quality are based on the application of best practicable technology. Regulations and guidelines have not been promulgated for some major industrial sectors, such as organic chemical, iron and steel industries.

Ontario establishes and enforces effluent requirements at least as stringent as that established by the federal government. In addition, provincial objectives are implemented under the Environmental Protection Act (EPA) and the Ontario Water Resources Act (OWRA), using voluntary measures, formal programs, Control Orders, Directions and Requirements, Certificates of Approval and prosecution. Industrial effluent objectives for conventional parameters, metals, phenols and some toxic substances are established under OWRA, which sets out desirable effluent discharge characteristics necessary to protect receiving water quality. These industrial effluent objectives are shown in Table III-6. Enforceable effluent limits, such as Control Orders, may require the attainment of the industrial effluent objectives and may also require compliance with additional parameters.

A recent initiative is being taken in Ontario to reduce toxic substance discharges to surface waters: the Municipal and Industrial Strategy for Abatement (MISA). MISA will require, by regulation, each of nine industrial sectors and the municipal sector to implement a comprehensive monitoring program to characterize its effluent and then to implement the best available technology economically achievable (BATEA) to reduce the discharge of toxic contaminants. If, after installation of BATEA, any environmental impacts resulting from a facility's discharge

TABLE III-6

Ontario industrial effluent objectives[1].

PARAMETER	ONTARIO INDUSTRIAL EFFLUENT OBJECTIVE
Ammonia-Nitrogen mg/L	10
BOD_5 mg/L[2]	15
Cadmium mg/L	0.001
Chromium mg/L	1.0
Copper mg/L	1.0
Fecal Coliforms MF/100mL	-
Lead mg/L	1.0
Mercury mg/L	0.001
Nickel mg/L	1.0
Oil and Grease mg/L	15
pH	5.5-9.5
Phenols mg/L	0.02
Phosphorus mg/L	-
Suspended Solids mg/L	15
Tin mg/L	1.0
Total Residual Chlorine mg/L	-
Zinc mg/L	1.0

[1] Established under Ontario Water Resources Act

[2] 5-day biological oxygen demand

persist, the facility will be required to implement additional effluent treatment. Implementation of MISA monitoring and effluent limit regulations will occur over the next two years.

The U.S. Clean Water Act authorizes the U.S.EPA to delegate, to state regulatory agencies, regulatory authority over the discharge of contaminants from municipal and industrial point sources. Michigan was delegated this authority in 1973, and directs the National Pollutant Discharge Elimination System (NPDES) permit program for point sources in the state. Under this program, discharge permits are issued to facilities, and stipulate the extent of allowable contaminant discharge. Effluent limits are often based on best available technology (BAT) for unconventional and toxic pollutants and on best conventional technology (BCT) for conventional pollutants, and may be expressed as a concentration, a mass loading limit or both. Often, effluent limitations are placed on only a few parameters, usually conventional pollutants. Industries may discharge to the sewer system of a municipal waste treatment facility, rather than discharging directly to a surface water body. In such cases, the municipal facility may issue an Industrial Pretreatment Program (IPP) permit to the industry, specifying acceptable industrial effluent quality. Alternately, states may issue the IPP permit to the industrial facility.

In both Ontario and Michigan, site-specific effluent requirements are frequently based on protection of the receiving water. In Ontario, this is done by way of requirements and Direction, or Certificates of Approval, both under the Ontario Water Resources Act, or by Orders (e.g., Control or Directors Orders) under the Environmental Protection Act. In Michigan, this is accomplished under the NPDES permit program.

Air

Annex 15 of the GLWQA instructs the two governments to conduct research, surveillance and monitoring, and to implement control measures to reduce atmospheric deposition of toxic substances to the Great Lakes Basin. The Agreement calls for the development of control measures and technologies to reduce the sources of atmospheric emissions.

Under Canada's Environmental Protection Act (CEPA), industrial emission standards, regulations and guidelines have been established for several substances. The provincial Air Pollution Control (General) Regulations prescribe the maximum concentration of a contaminant at a point of impingement.

In the U.S., the Clean Air Act (CAA) gives authority to the U.S. EPA to develop programs affecting air quality. The U.S.EPA has developed ambient air standards and emission standards for specific pollutants. National Ambient Air Quality Standards (NAAQS) have been developed for several chemicals. Control of these and other "hazardous" air pollutants (as defined) is obtained by regulating their emission from point sources. The basic point source emission standard developed under the CAA is the National Emission Standard for Hazardous Air Pollutants (NESHAP). NESHAPs are applied to different industrial categories. For certain classes of new industrial sources, New Source Performance Standards (NSPS), based on best demonstrated technology, also apply. In addition, other emission permits may be needed.

Under the CAA, primary control over point source air emissions and other air programs occurs at the state level through state air programs. In 1973, Michigan submitted, and subsequently received approval for, their State Implementation Plan (SIP). Through the SIP, Michigan's Air Quality Division has delegation of authority from the U.S.EPA for compliance and enforcement of NESHAPs. Inspection of NESHAP sources are required to be routinely performed.

2. Municipal Point Sources

Article VI and Annex 3 of the GLWQA support the adoption of controls to reduce pollution resulting from municipal waste treatment facilities. Goals include the development of programs and measures to ensure proper facility construction and operation, development of pretreatment requirements, establishment of effective enforcement programs, and the reduction of most effluent phosphorus concentrations to 1 mg/L or below.

In Canada, control over municipal waste treatment facilities lies primarily with the provincial government, under the authority of the Ontario Water Resources Act and the Ontario Environmental Protection Act. The federal government does, however, restrict the phosphorus content in detergents to 0.5% (as phosphorus pentoxide on a weight/weight basis) as a method of reducing phosphorus discharges from municipal facilities, and has recommended municipal effluent objectives. The provincial government establishes minimum treatment requirements for municipal facilities, which limit concentrations of total phosphorus in effluent to 1 mg/L, as well as specifying minimum removal rates or maximum concentrations for biological oxygen demand (BOD_5) and total suspended solids (TSS), based on the level of treatment performed at the facility (Table III-7). Municipal waste treatment facilities will also be regulated under the MISA program.

In the U.S., the NPDES program of the Clean Water Act regulates municipal facilities, and permits are issued to individual

TABLE III-7

Revised Ontario effluent guidelines for wastewater treatment facilities (OMOE policy 08-01).

TREATMENT	BIOLOGICAL OXYGEN DEMAND	SUSPENDED SOLIDS	TOTAL PHOSPHORUS (mg/L)
PRIMARY			
without P removal	30% removal	50% removal	-
with P removal	50% removal	70% removal	1.0
SECONDARY			
without P removal	25 mg/L	25 mg/L	-
with P removal	25 mg/L	25 mg/L	1.0
CONTINUOUS DISCHARGE LAGOON			
without P removal	30 mg/L	40 mg/L	-
with P removal	30 mg/L	40 mg/L	1.0
SEASONAL DISCHARGE LAGOON			
with P removal	30 mg/L	40 mg/L	-
continuous P removal	30 mg/L	40 mg/L	1.0
batch P removal	25 mg/L	25 mg/L	1.0

Note: "Where warranted, a higher degree of treatment shall be required to meet the site-specific effluent requirements developed for each particular receiving water."

Table Adapted from "Report to the Great Lakes Water Quality Board, Guidance on Characterization of Toxic Substances Problems in Areas of Concern in the Great Lakes Basin.", March, 1987.

facilities specifying concentration and/or mass loading discharge limits on specific parameters, usually conventional pollutants. As mentioned, Michigan has obtained primacy for control of this program, and NPDES permits are issued by the MDNR. Among other previously mentioned legislation, Michigan's Act 98, as amended, provides for the classification, specification, certification and supervision of municipal waste treatment systems by the state health commissioner, as well as providing penalties for violations.

Municipal facilities which receive waste water from industrial facilities usually operate an industrial pretreatment program (IPP). In this program, permits are issued by either the municipal waste treatment facility or the state to industries which discharge to sewer systems, and specify pretreatment requirements for the effluent. The pretreatment requirements are either local limits developed for the protection of the waste treatment facility, or federally promulgated categorical pretreatment requirements, whichever are more stringent.

D. NONPOINT SOURCE CONTAMINANT CONTROL

1. Agricultural Runoff

The GLWQA identifies agriculture as an activity which requires management programs to reduce contaminant and nutrient loading and soil erosion to adjacent surface waters. The Agreement supports the implementation of programs which are consonant with these goals, including improved fertilization and manure management practices, conservation tillage practices and others.

Agriculture Canada and the Ontario Ministry of Agriculture and Food (OMAF) have instituted programs to educate farmers on new technologies, crop rotation and soil conservation practices through the Soil and Water Environmental Enhancement Program (SWEEP). OMAF provides soil testing services for farmers to determine appropriate application rates for fertilizers and lime. The Agricultural Code of Practices for Ontario (1973) promotes proper application of livestock manure to cropland in order to reduce nutrient loads to ground- or surface water. The Ontario Ministry of the Environment has outlined restrictions on application rates and times and contaminant concentrations in sewage sludges applied to agricultural land, as shown in Table III-8.

In the U.S., control of pollution from agricultural activities is also based on a management approach. The U.S. Department of Agriculture (USDA) can reduce funding benefits to farmers who produce agricultural commodities on highly erodible lands or wetlands as an indirect incentive to reduce erosion and preserve wetlands. The USDA and the U.S. EPA also use programs developed under the Agricultural, Rural Development and Related Agencies Appropriations Act and the Soil Conservation and Allotment Act to protect against soil erosion, and to prevent and/or abate water pollution for agricultural sources. Michigan's Nonpoint Sources Management Program, the Michigan Phosphorus Reduction Strategy and the Michigan Energy Conservation Program are all intended to provide management, technical, or financial support to minimize erosion and the loss of fertilizers, pesticides and manure to rural surface waters. Michigan's Guidance for Land Application of Wastewater Sludge is shown in Table III-8.

2. Pesticides

Article VI of the GLWQA calls for measures to inventory, control and research the impacts of pesticides used in the Great Lakes Basin, and to ensure they are used in a correct and legal manner. The GLWQA has also developed specific objectives for several pesticides in both water and biota.

TABLE III-8

Guidelines and criteria for agricultural application of wastewater sludge.

PARAMETER	ONTARIO MAXIMUM PERMISSIBLE CONCENTRATION (mg/kg solids)[1]	MICHIGAN GUIDELINES FOR APPLICATION OF WASTEWATER SLUDGE		
		CLASS 1[2] (mg/kg)	CLASS 2[3] (mg/kg)	CLASS 3[4] (mg/kg)
Arsenic	170	100	100-2000	2000
Cadmium	34	5	5-125	125
Chromium	2800	50	50-5000	5000
Cobalt	340	-	-	-
Copper	1700	250	250-2000	2000
Lead	1100	250	250-2000	2000
Mercury	11	2	2-10	10
Molybdenum	94	10	10-50	50
Nickel	420	25	25-1000	1000
PCB	-	1	1-10	NA
Selenium	34	10	10-80	80
Zinc	4200	750	750-5000	5000

[1] For all aerobic sewage sludge and dried/dewatered anaerobic sewage sludge; other regulations apply for liquid anaerobic sludge.

[2] May be applied to all manner of crops with little restrictions on use.

[3] May be applied to crops in accordance with computed site limitations on annual and lifetime metals accumulation.

[4] May only be applied to crop lands under carefully controlled rates which are consistent with computed site assimilation rates; sludges containing greater than 10 ppm PCB may not be land-applied.

Canada's federal Pest Control Products Act, and the Ontario Pesticides Act regulate the manufacture, registration and use of pesticides in Canada. Nonregulatory programs at the federal level include the Integrated Pest Management Program, currently being developed by Agriculture Canada. Its aim is to develop a management scheme to reduce reliance on chemical pest control. The Provincial Pesticides Act prohibits the harmful discharge of pesticides and requires the licensing of commercial pesticide applicators. The Ontario Ministry of Agriculture and Food (OMAF) is also involved in the Integrated Pest Management Program.

In the U.S., the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) regulations address the manufacture, distribution, storage, disposal and use of approximately 50,000 pesticide products and devices. FIFRA also provides standards for the certification of commercial and private applicators of restricted use pesticides. Regulations under the Federal Food, Drug and Cosmetic Act establish allowable limits (residues) of pesticides in food or feed crops prior to pesticide registration. The Resource Conservation and Recovery Act (RCRA) regulates the treatment, storage and disposal of some pesticides. Many aspects of Michigan's Nonpoint Source Management Program address the use of pesticides used on agricultural land.

3. Shipping

Article VI and Annexes 5 and 6 of the GLWQA contain provisions for the control of contaminants from shipping activities. Of primary concern are discharges of oily waste water, bilge water and untreated sewage, along with garbage and other hazardous substances in washings or spills.

The Canada Shipping Act (CSA) has spawned regulations directed at shipping that control discharges of oil and vessel wastes. The CSA requires ships to either treat their sewage before discharge or install holding tanks. The Transportation of Dangerous Goods Act (TDGA) prescribes safety requirements and standards for all means of transportation across Canada, including shipping. Ontario's Environmental Protection Act requires pleasure craft to be fitted with sewage holding tanks to contain waste water, which are emptied in a controlled manner at marinas.

In the U.S., the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) is, in part, concerned with the discharge of oil to navigable waters of the U.S. Michigan's Watercraft Control Act of 1970 prohibits the activities of littering or polluting the state's waters with sewage, oil or other liquid or solid material. Violators are fined and are responsible for cleanup of wastes.

4. Spills

Annex 9 of the GLWQA calls for a coordinated and integrated response to pollution incidents in the Great Lakes by responsible federal, state, provincial and local agencies through a Joint Contingency Plan. The objectives of this plan include development of preparedness measures, adequate cleanup response and extent, and other factors. Ontario and Michigan entered into such an agreement in April 1988, with the signing of the Ontario-Michigan Letter of Intent on Notification and Consultation Procedures for Unanticipated or Accidental Discharges of Pollutants into Shared Waters of the Great Lakes and Interconnecting Channels.

In Canada, control over spills lies primarily with the provincial government. The "Spills Bill", part IX of Ontario's Environmental Protection Act, deals with spills of pollutants into the natural environment, and establishes notification requirements, response procedures and compensation mechanisms. Ontario's Spills Action Centre (SAC) coordinates the Ministry's response network and other emergency responders.

In the U.S., regulations under CERCLA identify "hazardous substances", reportable quantities of these substances and notification requirements in the event of a release. CERCLA created the NCP, which is concerned with oil and hazardous material spills in navigable waters and the environment. The Clean Water Act also prohibits discharge of oil in harmful quantities, and requires owners and/or operators of facilities which present a threat of an oil discharge to surface water to prepare a Spill Prevention Control and Countermeasure (SPCC) plan. The Solid Waste Disposal Act (a.k.a. RCRA) requires transporters of hazardous substances to take appropriate action in the event of a spill, and to notify the National Response Center. The Emergency Planning and Right-To-Know Act requires participation by certain facilities in emergency planning procedures for spills. The Toxic Substances Control Act (TSCA) contains the PCB spill cleanup policy.

Michigan's Water Resources Commission Act rules (Part 5, Rules 151-169) regulate oil loading and unloading and storage, and specifies emergency response procedures for spills. Michigan Act 61, referred to as the Oil and Gas Act, requires operation of production and disposal wells in the state in such a manner as to prevent the escape of oil, gas, saltwater, brine or oil field wastes which would pollute, damage or destroy freshwater resources. Michigan DNR's Pollutional Emergency Alert System (PEAS) investigates and responds to emergency spill occurrences and coordinates with other concerned agencies.

5. Urban Runoff and Combined Sewer Overflows

Annex 13 of the GLWQA calls for the development of programs to abate, control and prevent contaminants from being discharged from nonpoint sources, including runoff from urban land. Article VI calls for, in part, control of contaminants from combined sewer systems.

In Canada, Guidance for Urban Drainage Design, Erosion and Sediment Control for Urban Construction Sites is developed under the provincial Drainage Act, while stormwater is informally controlled through reviews and comments on official plans and applications for development of subdivisions. No control strategies exist for treatment of combined sewer overflows (CSOs); however, the province has worked with municipalities to segregate sanitary and storm sewers. The MISA program will consider abatement requirements for CSOs. Guidelines for Snow Disposal and Deicing Operations in Ontario minimize impacts on surface and groundwaters.

The U.S.EPA Region V (Chicago) has developed a two-phased management program of CSOs under the authority of the CWA through the municipal waste treatment facility NPDES permit process. The purpose of the Region V NPDES Permit Strategy for Combined Sewer Systems is to incorporate planning and management procedures into combined sewer system operations to result in a more effective management of the system. The program initially institutes management controls on the existing combined sewer system, in an attempt to reduce receiving water impacts. If satisfactory results are not achieved, rehabilitation of the sewer system, or other more extensive steps, may be required. In addition, Michigan has drafted a CSO policy which may contain limitations much like any other point source discharge.

6. Atmospheric Deposition

Annex 15 of the GLWQA calls for research, surveillance and monitoring, and implementation of control measures to reduce atmospheric deposition of toxic substances to the Great Lakes Basin. Annex 15 also requires that measures to control emission sources which significantly contribute to pollution of the Great Lakes be studied, developed and implemented. The Memorandum of Understanding between Ontario and Michigan, recently signed, contains the Ontario-Michigan Joint Notification Plan for Unanticipated or Accidental Discharges of Airborne Pollutants, outlining steps and actions to be taken by both governments in the event of such an incident.

In Canada, National Ambient Air Quality Objectives have been established under the Canadian Clean Air Act as a guide in developing programs to reduce the damaging effects of air pollution.

These national objectives assist in establishing priorities for reducing contaminant levels and the extent of pollution control needed, provide a uniform yardstick for assessing air quality in all parts of Canada, and indicate the need for and extent of monitoring programs. CEPA, in addition to regulating point sources of air emissions, also has the authority to regulate fuel and fuel additives, which may impact on atmospheric deposition of combustion products and lead. Provincial Ambient Air Quality Criteria are developed under the Ontario Environmental Protection Act. OMOE, often in conjunction with other groups and agencies, prepares a yearly summary of transboundary air contaminant movement and conducts studies on the long range transportation and deposition of contaminants to the Great Lakes.

In the U.S., the Clean Air Act (CAA) gives authority to the U.S.EPA to approve programs affecting air quality, implemented at the state level. National Ambient Air Quality Standards (NAAQS) have been developed by the U.S.EPA, and consist of both primary and secondary standards, to protect public health and welfare, respectively. A few atmospheric nonpoint source programs have been implemented at the federal level. The CAA provides the U.S.EPA with authority to control and/or prohibit fuels and fuel additives used in motor vehicles which have been determined to endanger public health. To this end, the U.S.EPA requires registration of fuel and fuel additives, and prohibits the production or importation of gasoline containing an average lead concentration of 0.1 g lead/gallon fuel or greater. The CAA regulations stipulate emission requirements for new motor vehicles as a method of controlling air quality. Michigan manages its own air program, adopting and adhering to the federal NAAQS. Ambient air monitoring is conducted in Michigan in some industrial areas known or suspected of having significant releases of toxic air pollutants. An Air Quality Index is reported to the public daily.

7. In-place Pollutants

Article VI and Annex 7 of the GLWQA provide for the development of a Subcommittee on Dredging to review the existing practices in the U.S. and Canada relating to dredging activities, and to develop guidelines and criteria for dredging activities in boundary waters of the Great Lakes. Annex 14 of the GLWQA calls for parties to develop a standard approach and agreed upon procedures for the management of contaminated sediments.

In Canada, federal authority over contaminated sediments in the Great Lakes is limited; the province of Ontario is primarily responsible. However, under the Canada-Ontario Agreement, a Polluted Sediment Subcommittee has been formed, charged with developing a standardized assessment procedure for assessing contaminated sediments and their remedial options. Under the

Environmental Protection Act, the Ontario Minister of Environment can order the removal of contaminated sediments.

In the U.S., the Clean Water Act authorizes funds to identify areas containing contaminated sediments and to develop plans for sediment removal and disposal from critical ports and harbors. Section 404(b) of the CWA empowers the U.S. Army Corps of Engineers to issue permits to govern dredging and fill operations for the purposes of navigation. Control over the discharge of dredged and fill material at specified disposal sites is maintained through a permitting process. In some instances, contaminated sediments may be regulated under RCRA, such as in instances when dredged sediments exhibit one or more of the hazardous waste characteristics defined under RCRA, or if a release occurs at a Treatment, Storage and Disposal facility, as defined under RCRA. All dredging projects in Michigan are subject to review and certification under the CWA. Dredging permits may also be required under Michigan's Inland Lakes and Stream Acts (Act 346) and the Great Lakes Submerged Lands Act (Act 247).

E. SOLID, LIQUID AND HAZARDOUS WASTE CONTROLS

The GLWQA, in Annex 13, calls for the development of programs to abate and reduce pollution resulting from land use activities, including waste disposal sites. At the present time, no specific guidelines are developed for siting or management of solid or hazardous waste sites.

Regulations concerning the use, handling, storage and disposal of hazardous wastes in Canada are primarily developed at the provincial, rather than federal, level. Some federal statutes do, however, offer some control. The federal Environmental Contaminants Act restricts the use, handling and/or disposal of selected hazardous substances: PCB and PCB products, mirex, polychlorinated terphenyls and polybrominated biphenyls. The recent passed Canadian Environmental Protection Act (CEPA) provides control over the manufacture, transportation, use, disposal, importation and exportation of chemicals and wastes where not adequately controlled by regulation in other legislation. The federal Transportation of Dangerous Goods Act prescribes safety requirements, standards and safety marks on all means of transport across Canada, including the transport of hazardous material.

At the provincial level, solid and hazardous waste programs are regulated under the Environmental Protection Act (EPA). The EPA develops standards for siting, maintenance and operation of waste sites, and operates a paperwork manifest system to monitor the transport and handling of hazardous wastes. Under EPA, all waste sites are required to have a Certificate of Approval prior to operation. In addition, Ontario regulations prohibit deep well injection of any liquid industrial waste into the Detroit River Group geological formation in Lambton County, and prohibits the deep well injection of brines within 8 km of the St. Clair River.

In the U.S., the federal Solid Waste Disposal Act (SWDA), as amended (which includes the Resource Conservation and Recovery Act and the Hazardous and Solid Waste Amendments), develops regulations to manage solid and hazardous wastes. Three distinct programs have been developed: the Solid Waste Program, the Hazardous Waste Program and the Underground Storage Tank Program. The Solid Waste Program defines both technical and management criteria for the proper operation of a solid waste facility. The Hazardous Waste Program defines certain wastes or characteristics as "hazardous", describes the Uniform Hazardous Waste Manifest System for the tracking of hazardous waste movement, and develops requirements for generators, transporters and owner/operators of Treatment, Storage and Disposal facilities. The Underground Storage Tank program develops construction criteria, performance standards and notification requirements for underground storage tanks. Michigan has obtained primacy for most of these solid and hazardous waste programs, with regulations being developed under

Michigan Act 64 (Michigan Hazardous Waste Management Act), Act 136 (Michigan Liquid Industrial Waste Disposal Act), Act 641 (Michigan Solid Waste Management Act), Act 423 (Michigan Underground Storage Tank Act) and Act 366 (Michigan Resource Recovery Act). Michigan Act 61, referred to as the Oil and Gas Act, which generally addresses permitting, drilling, production and abandonment of production and disposal wells, specifically requires operation of the wells in such a manner as to prevent the escape of oil, gas, saltwater, brine or oil field wastes which would be damaging to fresh water resources.

The U.S. federal Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), colloquially referred to as "Superfund", was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA) (which contains the Emergency Planning and Community Right To Know Act of 1986 (Title III) and the Radon Gas and Indoor Air Quality Research Act of 1986 (Title IV)). CERCLA identifies an extensive list of substances as "hazardous", and authorizes the remediation of uncontrolled waste sites containing hazardous materials, involving a stepwise evaluation of the hazards present. CERCLA, sharing a dual authority with the Clean Water Act, is also concerned with uncontrolled releases of oil and hazardous materials to navigable waters to the U.S. The Michigan Environmental Response Act (Act 307) provides for the prioritization of hazardous waste sites in the state, and recommends state funds for remediation. Michigan may, through this regulation, remediate sites not being addressed by the federal Superfund program.

The U.S. Toxic Substances Control Act (TSCA) provides the U.S.EPA with broad authority over the manufacturing, importation and processing of about 63,000 chemical substances intended for commercial purposes. TSCA has effectively banned the manufacture and use of PCB and PCB products, prohibited chlorofluorocarbon use as a propellant, and has proposed a phased-in ban on the use and importation of asbestos.

Summarization

This chapter has provided an overview of existing environmental legislation and programs within the U.S. and Canadian federal governments, the State of Michigan and the Province of Ontario. Considerable legislation exists to control and influence environmental quality in the Great Lakes Basin, along with mechanisms to effect further improvements in Great Lakes ecosystem quality. Discussion of each Act or program mentioned within this chapter, along with others, is expanded upon in a more comprehensive review of regulatory programs in the Regulatory Task Force Report (1) which is included in Volume III.

F. REFERENCE

1. Regulatory Task Force Report, UGLCCS. 1988. Summarization of environmental regulations, agreements and programs in the United States, Canada, Ontario and Michigan. C. Fuller (chairperson). Final Rept June, 1988.

CHAPTER IV

DATA QUALITY MANAGEMENT

A. DATA REQUIREMENTS AND PROCEDURES

1. Intended Use of Data

The UGLCC Study's main objectives were to assess the current status of the ecosystem and recommend remedial action where necessary. Parameters were selected for study based on historical problems in the various study areas and to provide information on a range of chemicals with different properties. Analytical methods for most of the study parameters are well established. The only exception to this was the analysis of trace organics at ambient concentrations in water. For the most part, only research laboratories have the capability to perform these analyses because of the low detection limits (parts per trillion) required.

The data generated for the study needed to be of sufficient quality to provide the approximate concentrations of the study parameters in the various media so that these concentrations could be related to ecosystem objectives. The data also needed to be of sufficient quality to show whether a particular study area was a net source or sink for the study parameter. The UGLCC Study was not intended to provide accurate loadings of the contaminants to the system or precise concentrations in all media; however, estimates of loadings and concentrations permit relative comparisons between contaminant sources.

A secondary study objective was to identify additional toxic contaminants that could be causing problems in the study areas. Thus, the laboratories must be able to identify the presence of these contaminants and to estimate their approximate concentration in the media analyzed.

2. Field and Laboratory Procedures

Sample collection procedures followed by all agencies are well documented in the principal investigator reports. For the most part, sampling was conducted according to established protocols. For specialized sampling, such as ambient waters, thoroughly tested published procedures were used. Water and effluent samples were stored at 4^0C with the addition of appropriate preservatives (for example, acid for metal analyses). Sediment and biota samples were kept frozen until analysis.

Samples of effluent for the point source survey were 24 hour (U.S.) or 3 to 6 day (Canada) composites. Most other samples collected were grab samples. The samples collected were appropriate to address the objectives of the study. For all studies the number of samples collected was limited.

Field blanks and replicates comprised over 10% of the analytical output of the study. In general, most parameters were not detected in the field blanks. In most cases the percent deviation between field replicates was less than 20%.

U.S.EPA methods were used by most laboratories for the analyses. These methods specify frequencies of calibration, blanks, spikes, duplicates, and surrogate spikes. The achievement of lower detection limits by some research laboratories required the use of large volume samples (up to 200 litres), larger than are specified in the U.S.EPA methods. Proportionally larger volumes of extraction solvents were used for these samples. The final determinations were usually by U.S.EPA or comparable methodology.

B. DATA QUALITY MANAGEMENT

The experience of earlier international multi-media studies in the Great Lakes Basin, particularly the Niagara River Toxic Committee Report (NRTC) (1), demonstrated the need for a careful and systematic program to ensure data quality and the utility of analytical results. Those involved in the NRTC Study strongly recommended the establishment of a data quality management program as one of the first actions of the Upper Great Lakes Connecting Channels Study.

The earlier studies found that commercial, government, and academic laboratories use different analytical methods, instruments, standards, levels of detection and reporting formats. Without external checks, there are no means to ensure that data generated by two or more laboratories would generate comparable data. Furthermore, agreement had to be reached among representatives from agencies having differing missions, goals and study requirements for a common protocol or strategy for data quality management. As part of such a strategy, the Management Committee agreed that, wherever possible, the number of laboratories providing analytical support would be minimized and laboratory facilities would be shared by the agencies in the study. This was an important step in minimizing potential variability in the data.

1. Activities

The Management Committee formed a Quality Management Workgroup (QMWG) from the agencies providing field and analytical service support. Consulting personnel experienced in statistical design and data quality analyses were also identified. The terms of reference for the Workgoup were as follows:

1) establish a quality management system for the UGLCC Study;

2) review and evaluate the suitability, completeness and competence of individual project quality assurance plans;

3) recommend quality assurance requirements for sampling, sample handling, analysis, management of project data and quality control data;

4) compile, review and report on the appropriateness of analytical and field protocols identified in the Quality Assurance Project Plan, as they became available;

5) provide guidance to other workgroups in the analysis and use of historical data as required by the Activities Integration Committee;

6) require and review periodic Quality Assurance (QA) reports from the individual workgroups; and

7) review draft project reports with respect to QA issues.

Throughout the Study, the QMWG maintained close contact with the Management Committee and the Activities Integration Committee. The QMWG Chairman or a representative participated in their meetings and provided verbal and written briefings on issues as they arose. A data quality management strategy was agreed upon (2). This included a project data quality plan document which was given to each project leader. This project plan was submitted to the workgroup by the principal investigators and was then reviewed by the QMWG. The review assessed the proposed project quality assurance and quality control procedures as well as, where feasible, the statistical design of the project. The data quality management strategy also included a series of thirteen interlaboratory "round robins" consisting of the analyses of "standardized" samples of blind concentration and composition. The results of the studies were provided to the Activities Integration Committee and the Management Committee such that corrective action could be taken as necessary.

It must be recognized that each agency has its own criteria for determining suitable field and laboratory procedures. In most cases these are chosen to meet the agencies' specific mandates. Within the time available to UGLCCS, it was not possible, and probably not advisable, to institute method changes to achieve standard procedures among the participants. The most that could be achieved was to:

a) encourage good project planning, including all necessary quality assurance activity;

b) encourage documentation of methods; and

c) initiate a limited number of round-robins, using such standards as were readily available to evaluate the accuracy of participating laboratories.

It was known from the start that many of the field techniques employed for sampling and sample handling were relatively untested, especially for the organic constituents, because they were part of exploratory research programs. There were questions about analytical procedures that might be employed, in terms of their ability to identify and quantify the many chemical constituents of interest in the water, sediment, biota and effluent samples. These issues were recognized early on by the other workgroups, and were the topic of much discussion.

Some difficulty was anticipated because the different jurisdictions employed a variety of control practices to a greater or lesser degree. There was concern that existing field and laboratory methods might not include the quality control and quality assurance protocols needed to verify proper application, and to document the level of quality achieved for UGLCCS. In the past, the impact of ongoing laboratory quality control activity in all these areas had been limited by the absence of a "top-down" management system to define responsibilities and ensure adequate documentation. Hence, Management Committee formally endorsed a modified U.S.EPA guidance document (3) as the basis for a quality assurance project plan to be filed for each project for initiating a verifiable QA process. The documentation and procedures required by the UGLCCS Project Plan guidance document is shown in the workgroup report (2).

2. Project Plan Review Findings

The magnitude of the study required intensive effort on the part of all workgroup chairmen to keep projects on track. Ultimately, most projects were implemented without adequate prior QA review, however, laboratory support for one project often provided data to serve other activities. A total of 30 project plans (out of 170 projects) were received from the workgroups, the majority dealing with biota and sediment. The workgroup QA project plans were distributed as received for review by teams of one or two QMWG members based on their expertise in field, laboratory, QA, sampling design, and related statistical factors. Project plans tended to follow the guidelines but were not necessarily complete in defining or justifying their methodology, data quality needs, or relationships to methodologies used by the other related projects.

Many project leaders had difficulty in providing detailed up-to-date descriptions of their field, laboratory or QA/QC procedures. This is not due to the absence of defined procedures, nor the lack of appropriate QA/QC activities: but, simply because the necessary documentation was not readily available. Some provided excellent documentation in one or more areas; but, there was not always a clear link between project needs and the specific technology used. Not all plans were evaluated for sampling design or other statistical aspects because some projects were essentially exploratory or were already in progress or even completed.

In general, the concept of a centralized quality assurance review on a project by project basis was new to many of the participants. Most project leaders had never experienced such a responsibility for providing the type of detail required in the QA review protocol. The normal relationship for most project leaders to their supporting analytical laboratories was that of a client to a service organization. As a result, significant difficulty was encountered in providing not only the requested detail but the type of material to be provided, its actual relevance to the UGLCCS, and the volume of material that was needed for review. Due to the large scope of the project, not all the members of the QMWG were fully familiar with specific laboratory practices, the analytical methods or the statistical methodology used by various organizations.

Delays in QA project plan reporting were encountered due to incomplete reports and the large volume of background information that had to be gathered, compiled and reviewed by disparate groups of professional individuals in both the field study and the QA review process.

C. INTERLABORATORY PERFORMANCE EVALUATIONS

1. Background

Field sampling procedures, sample handling and preservation, delays initiating analyses, sample matrix effects on the analytical process all affect data quality. However, there is no question that the analytical measurement is especially critical to the validity of project data. Traditionally, the single most serious source of variation between results from different laboratories is the control of standards and the instrument calibration process. For this reason the QMWG agreed to place most emphasis on the distribution of a series of check standards covering all of the UGLCCS parameters for which checks were available.

2. Approach

The QMWG recommended that interlaboratory performance evaluation quality control studies should be designed and carried out at least three times with test materials containing all constituents at low, medium, and high concentrations. Such studies would be presented and evaluated before, during and at the close of all analytical and field related activities. These studies were carried out in conjunction with a quality management strategy and in concert with an interagency split-sample program, and allowed management full control and assurance of data quality for the UGLCC Study. It was evident that this comprehensive program could not be issued in a timely manner (2). A reduced program was adopted that involved less frequent studies, use of only standard solutions, surrogate spikes and a limited number of natural reference materials.

The samples for the thirteen studies listed in Table IV-1 were prepared and distributed to twenty-six laboratories in different portions of the "round robins". The laboratories were requested to analyze for 36 inorganic and 50 organic parameters (see Table IV-1). Three reports for each interlaboratory study were generated by the QMWG:

a) a raw data summary to the participants (for verification);

b) a final data summary when the study was closed; and

c) a final laboratory performance evaluation report.

In addition, 3 status reports were prepared to advise MC and AIC chairpersons on extreme results. Extreme results were those results that deviated significantly from target values. Brief advisory reports reviewing the results of each interlaboratory performance assessment study from the QMWG to the MC/AIC, were

TABLE IV - 1

QC study parameters for interlaboratory performance evaluation of UGLCCS QC studies.

Study	Test Samples	Parameters	Substrate
QM-1	4 ampuls 4 ampuls 4 ampuls	Aroclors O.C. Insecticides* Chlorinated Hydrocarbons**	std solutions std solutions std solutions
QM-2	4 ampuls	16 PAHs	std solutions
QM-3	5 sediments	10 Metals	sediment CRM or RM
QM-4	4 waters	23 Major Ions & Nutrients	water CRM
QM-5	4 waters	7 Metals	water CRM
QM-6	4 sediments 2 ampuls	Chlorinated Hydrocarbons** Chlorinated Hydrocarbons**	sediment CRM or RM std solutions
QM-7	2 ampuls 2 ampuls 4 ampuls	Aroclors Chlorinated Hydrocarbons** Aroclors & Chlorinated Hydrocarbons**	std solutions std solutions spiking solutions & natural water
QM-8	4 ampuls 4 ampuls	Chlorinated Insecticides* Chlorinated Insecticides*	std solution spiking solutions & natural water
QM-9	4 waters	Mercury	water RM
QM-10	2 ampuls 4 ampuls	16 PAHs 15 PAHs	std solution spiking solutions & natural water
QM-11	4 waters	Cyanide	water RM
QM-12	4 waters	Total Phenol	water RM
QM-13	2 ampuls 2 oils 2 tissues	5 Chlorophenols	std solutions fish oils fish tissues

* HCB, (alpha, gamma) BHC' Mirex, pp'- DDE' pp - DDD, pp'-DDT, heptachlor epoxide, dieldrin, (alpha, gamma) Chlordane, oxychlordane.

** (1, 4, 1, 3, 1, 2) dichlorobenzene, (1, 3, 5, 1, 2, 4, 1, 2, 3) trichlorobenzene (1, 2, 4, 5, 1, 2, 3, 4) tetrachlorobenzene, pentachlorobenzene, hexachlorobenzene, hexachlorobutadiene, hexachloroethane, octachlorostyrene.

used by the UGLCCS management to implement the QA management strategy and to ensure that appropriate corrective action could be taken.

D. UGLCCS QUALITY ASSURANCE RESULTS

1. Percent Recoveries

The following results have been summarized from QMWG integrated reports evaluating interlaboratory performance for organics (4) and trace metals (5). As part of the QMWG recommendation for a QA/QC program for UGLCCS, values determined for samples should fall within a window of +/-25% of the design values.

Trace Metals

Figures IV-1 and IV-2 present graphically condensed results of the range and average values of percent recoveries of interlaboratory medians for all elements analyzed and all samples reported in sediments and waters, respectively.

For the sediment samples analyzed in QM-3, results for seven out of 10 elements, namely Pb, Zn, Hg, Cu, Ni, Co and Fe, were satisfactory because average recoveries for all samples tested were within +/-25% of the design values and the ranges of recoveries for all samples were within +/-25% of the design values. The performance for Cd and Se in these sediment samples were also satisfactory with average recoveries for all samples falling within +/-25% of the design values. However, the ranges of recoveries for all samples tested showed wide variations and fell outside the limits (+/-25%) of the design values (Figure IV-1). The interlaboratory results for Cr were less satisfactory with average recovery for all samples exceeding +/-25% of the design value. This was assumed to be due to incomplete digestion of the sediment samples.

For the water samples analyzed in QM-5 and QM-9 as shown in Figure IV-2, the interlaboratory comparability was excellent. All seven elements, (Cd, Pb, Zn, Cu, Ni, Co and Fe), determined in QM-5 and Hg in QM-9 were satisfactory with the ranges and averages of interlaboratory medians for all samples within +/-25% of the design values. The ranges of recoveries among test samples had wider variations for Zn and Hg than those obtained for the remaining elements.

Overall, comparing the precision of interlaboratory results for sediment and water samples, the less scattered results among test samples were obtained for water samples than those obtained for sediment samples, except for Hg. The wider variations of relative standard deviation (RSD) for Hg among test samples for water samples as compared with those for sediment samples, perhaps, was attributed to the lower concentrations of Hg in these water samples. In general, the interlaboratory comparability for the accuracy and precision of trace metals in sediment and water samples was satisfactory in most cases.

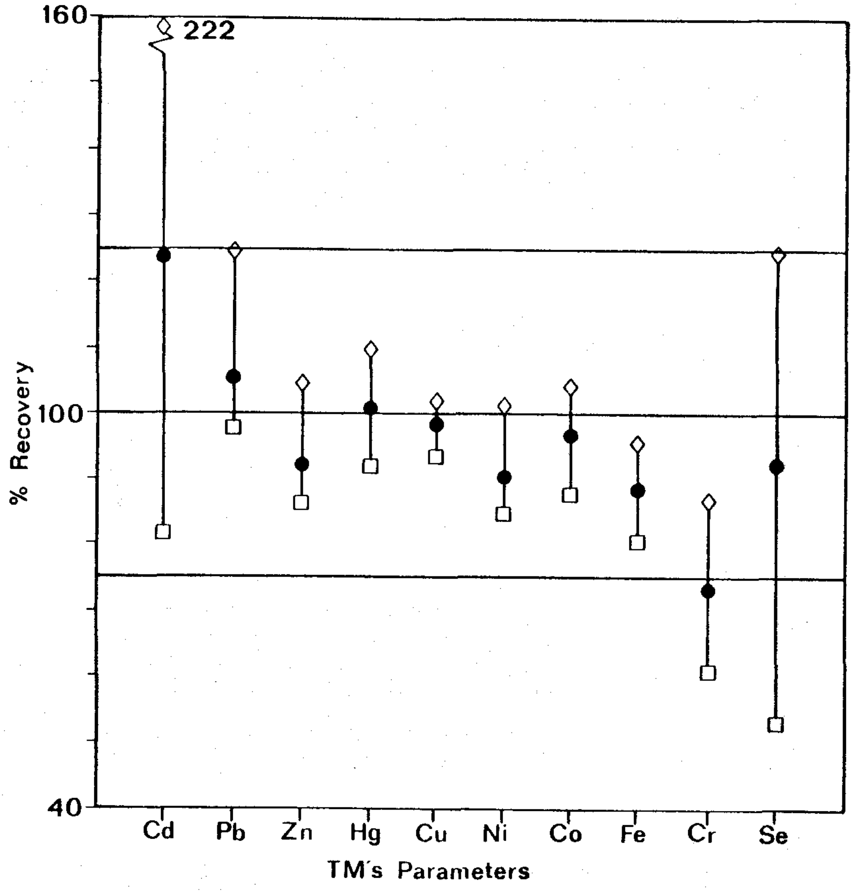
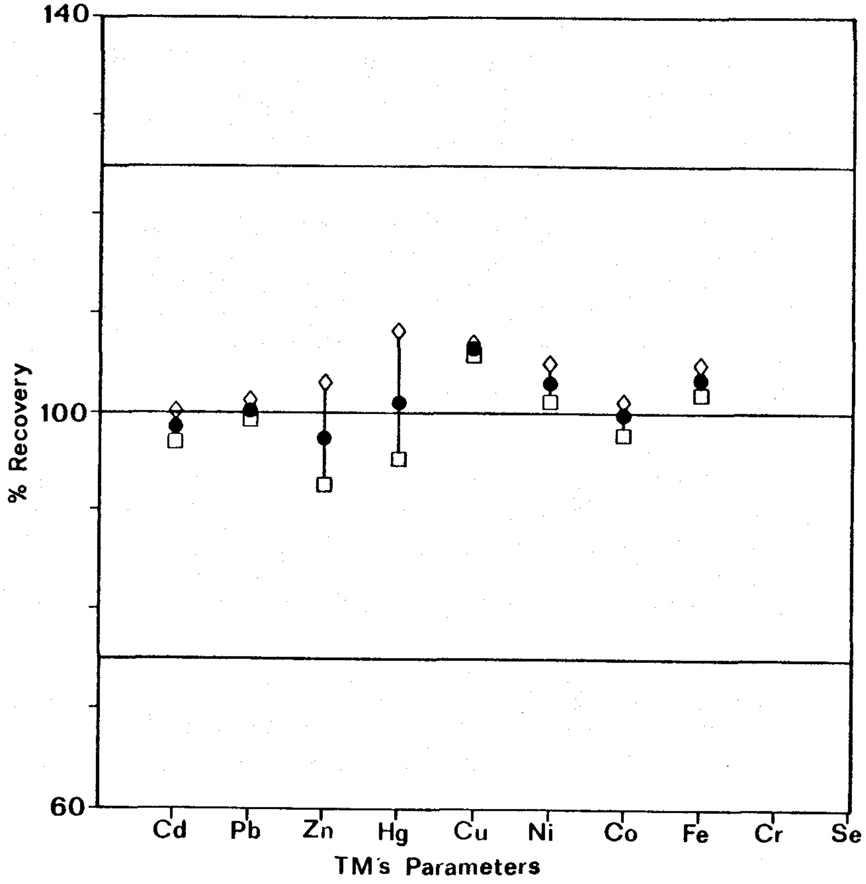


FIGURE IV-1. Percent recovery for trace metals (sediments).



◊ Max. ● Avg. □ Min.

FIGURE IV-2. Percent recovery for trace metals (waters).

Organic Parameters

i) OCs (Organochlorines)

The QMWG had set results within +/-25% of the design values for organic parameters as satisfactory. The agreement of interlaboratory medians for organochlorines was excellent. The results for all the samples were satisfactory within +/-25% of the design values for all OC parameters except sample 108 in QM-1 for p,p-DDD.

In order to detect the bias of interlaboratory results, the range and average of interlaboratory medians for all OC parameters in various studies were summarized. Figure IV-3 presents condensed results of average recoveries of interlaboratory medians for all samples in various studies. As can be seen from this figure, the interlaboratory results were compatable and satisfactory for all OC parameters in ampules of both QM-1 and QM-8. Furthermore, the interlaboratory results in QM-8 were more accurate than those in QM-1 for all OC parameters in most cases.

The percent average recoveries of OCs in spiked water samples in QM-8 were less accurate as compared with ampule samples in both QM-1 and QM-8 studies. However, the interlaboratory results for all OCs in QM-8 were still satisfactory within +/-25% of design values except for HCB.

ii) PCBs (Polychlorinated Biphenyls)

The agreement of interlaboratory medians in PCB test samples was excellent and percent recoveries of interlaboratory results were all satisfactory (within +/-25% of the design values) in both studies. The accuracy of interlaboratory comparability for PCBs in ampules and spiked water was very satisfactory in both studies.

iii) CHs (Chlorinated Hydrocarbons)

The results of CH analyses suggest that interlaboratory performance by participating laboratories, in most cases, improved in QM-6 and QM-7 as compared with the earlier QM-1 using some identical samples in various studies. In QM-1, some CHs were different by more than +/-25% of the design values; while all CHs were satisfactory within +/-25% of the design value in sample 606 of QM-6 and samples 703 and 704 of QM-7. These results suggest that the earlier interlaboratory studies helped the participating laboratories correct their internal quality control and that the quality of the test samples used for these evaluations was verified.

In order to evaluate the interlaboratory comparability, the range and average of percent recoveries of interlaboratory medians in

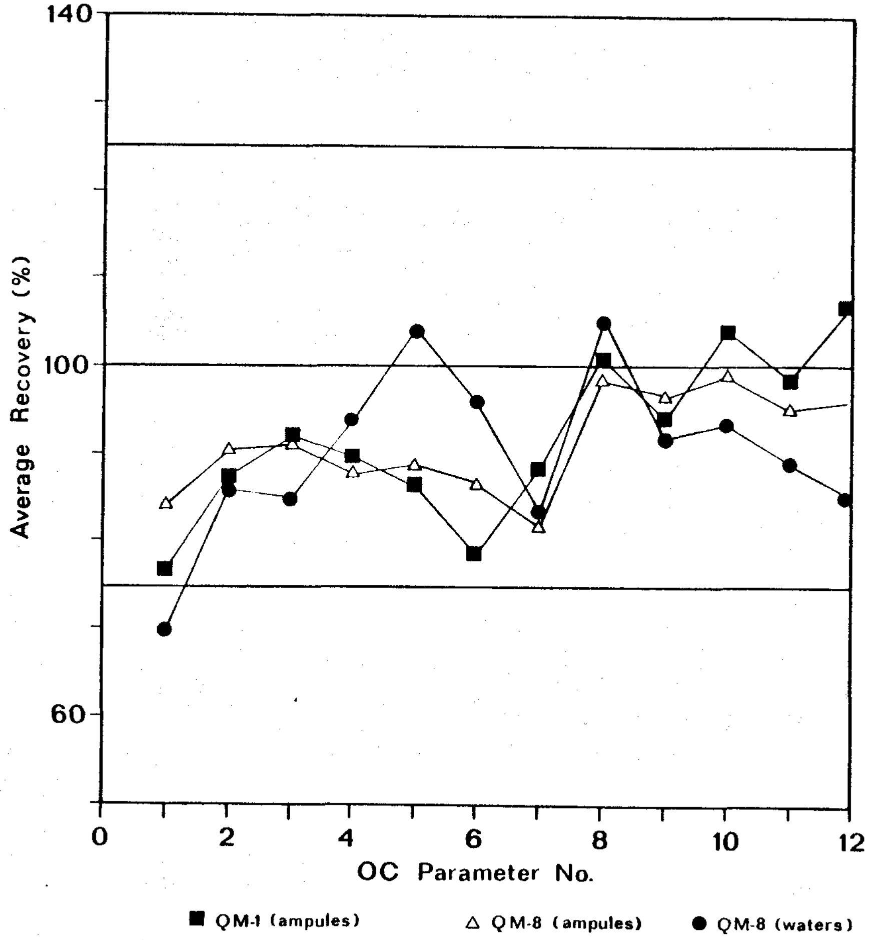


FIGURE IV-3. Average recovery (%) for OC's (various studies).

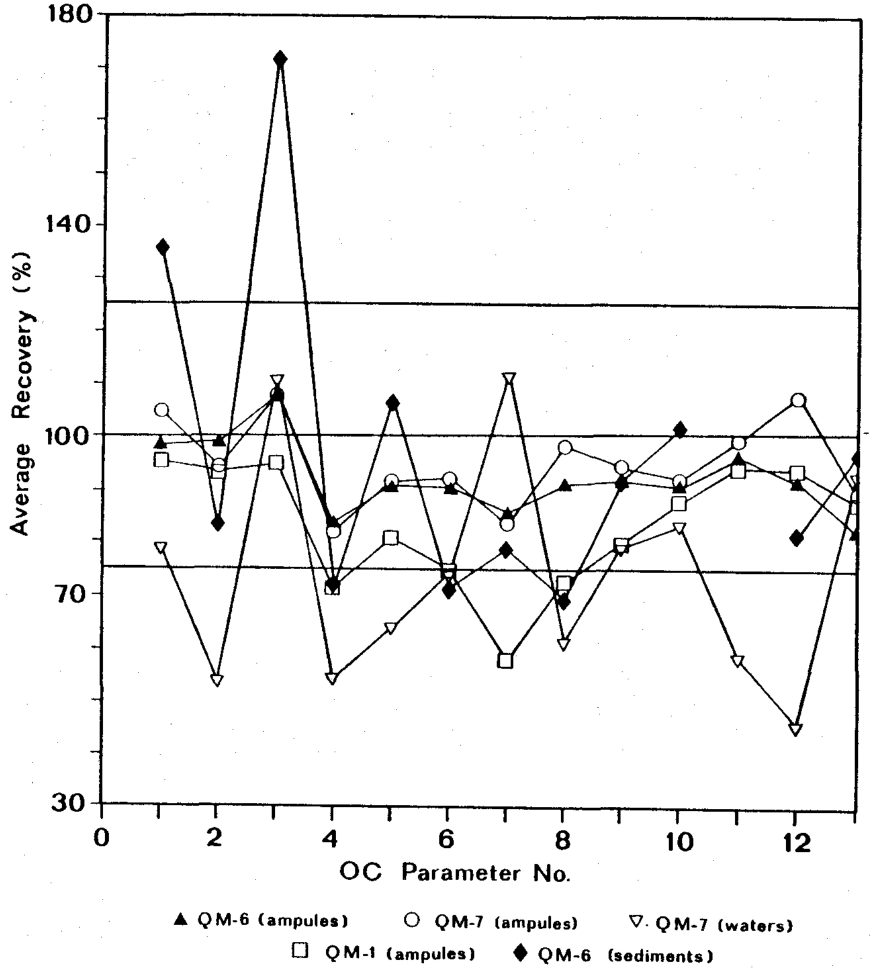


FIGURE IV-4. Average recovery (%) for CH's (various studies).

various studies were summarized. Condensed results of average recoveries of interlaboratory medians for all 13 CH parameters are shown in Figure IV-4.

As expected, the interlaboratory results for spiked waters (QM-7) and sediments (QM-6) were less satisfactory as compared with the ampule samples (QM-1, QM-6 and QM-7). Overall, only six out of thirteen parameters (1,4-DCB; 1,2-DCB; 1,2,4,5-TeCB; PeCB; HCB; and OCS) in water samples (QM-7) were within +/-25% of the design values. The performance of spiked waters for CHs (QM-7) was less satisfactory as compared with those of spiked waters for OCs (QM-8) and PCBs (QM-7). However, the interlaboratory results for sediments were less satisfactory as compared with ampule samples but were better than those in spiked water. Overall, seven out of 12 CH parameters were satisfactory within +/-25% of design values (HCE was not evaluated since a reference value was not available).

Poor quantitative recoveries of CHs from spiked waters were expected because of the volatility of most CHs, resulting in evaporative losses. In addition, the high water solubilities of some CHs also cause poor extraction recoveries.

iv) PAHs (Polycyclic Aromatic Hydrocarbons)

Figure IV-5 presents graphically the condensed results of percent average recovery of interlaboratory medians for all 16 PAHs in various studies. For the ampule samples, the interlaboratory results were satisfactory within +/-25% of the design values in most cases. Only three out of 16 parameters (fluorene, phenanthrene and chrysene) varied by more than +/-25% of the design value in QM-2 while all 15 PAH parameters were satisfactory within +/-25% of design values in QM-10. The performance of PAHs showed a significant improvement in QM-10 as compared with the earlier QM-2.

2. Overall Laboratory Performance

Acceptance Criteria

The key to administering information involving the laboratory performance data is the selection of acceptance criteria. The overall performance evaluation in this integrated report is based on percent biased of parameters analyzed and percent flagged of results reported. For the flags, the number of results reported by each laboratory excluding those with "ND" (not detected), "NS" (not separated; 2 parameters co-eluted), and "LT" (less than) codes, sum of results flagged with VH, H, L or VL, (very high, high, low, very low) for all parameters, and the percentages of results flagged were calculated. In addition, values less than detection that were flagged were included in the calculation of

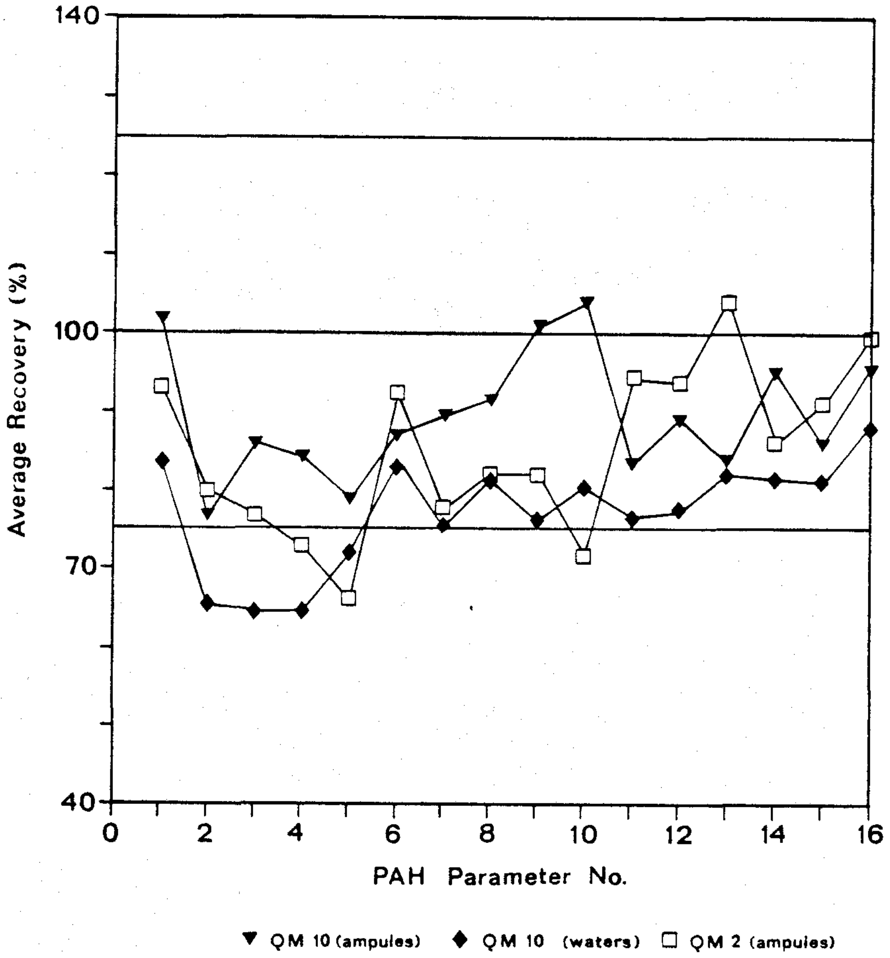


FIGURE VI-5. Average recovery (%) for PAH's (various studies).

the percent flagged. Similarly for the bias, the number of parameters analyzed by each laboratory, the sum of parameters biased with VH, H, L, VL based on average recovery for each set of samples and the percent of parameters biased were calculated. Note that the H and L parameters biased were counted as half of a VH or VL parameter.

To simplify the overall assessment of laboratory performance in various studies, the average of percent biased and percent flagged is calculated. The criteria or performance index provides a simple way to compare laboratory performance in various studies as shown below:

Average of Percent Biased and Percent Flagged	Comments
< 25%	Satisfactory (A)
26-50%	Moderate (B)
> 51%	Poor (C)

Trace Metals

Most laboratories provided consistent and satisfactory results for the interlaboratory studies for trace metals (5).

Organic Parameters

i) OCs

For the laboratory performance of OCs in various studies, few laboratories have achieved consistency for producing satisfactory results for both ampule and spiked water samples. Some other participating laboratories also produced satisfactory results but only participated in one study: either QM-1 for ampules or QM-8 for both ampules and spiked waters. However, for these OC interlaboratory studies, only one laboratory produced inconsistent and rather poor results for OCs in both ampules and spiked waters.

ii) PCBs

Three laboratories achieved consistency for producing satisfactory results for PCBs in both ampules and spiked waters. Although the PCB results for ampules were satisfactorily generated by all participating laboratories in most cases, poor results for spiked waters were produced by several laboratories. It was obvious that less satisfactory results for spiked waters were attributed to sample preparation involved with extraction, concentration and clean-up steps because the results for ampules were satisfactory within +/-25% of design values by all participating laboratories.

iii) CHs

The laboratory performance for CHs in various studies was less satisfactory as compared with those obtained for OCs and PCBs. Only one laboratory, which analyzed all the samples provided and most parameters requested, achieved the consistency for satisfactory results in all matrices (ampules, waters and sediments). On the other hand, there were more poor results generated by participating laboratories in either matrices in these CH interlaboratory studies than for other parameters.

iv) PAHs

Only one laboratory achieved the consistency for producing satisfactory results for PAHs in both ampules and spiked waters. However, less than satisfactory results were generated by only two laboratories in either ampules or spiked waters. The performance of one laboratory in QM-10 was very satisfactory for both ampules and spiked water as compared with that obtained in QM-2. This extensive improvement for this laboratory has demonstrated that the impact of these interlaboratory studies was very valuable in assisting participating laboratories to correct their internal QA/QC problems.

E. FINDINGS AND CONCLUSIONS

It is difficult to summarize the performance of laboratories because data quality varies with each parameter, matrix, and laboratory as well as over time. Furthermore, the acceptability of data for each laboratory depends on project objectives. In general, the large service laboratories performed consistently better than the smaller service laboratories and research laboratories did not perform as well as the routine laboratories.

It must be stressed that the QC samples in the interlaboratory performance evaluation studies for UGLCCS are generally easier to analyze than actual field samples. Most of these quality assurance samples were standard solutions at reasonably high concentrations and did not require special preparation. It is also recognized that many laboratories took extra care and performed repetitive analysis when dealing with the QC samples. Therefore, unsatisfactory performance in these interlaboratory studies may indicate a poorer quality of data for real samples in routine analysis.

The impact of these interlaboratory studies on laboratory operations is illustrated by a couple of examples. A large contract laboratory was identified as having severe analytical problems in several performance evaluation studies partly due to ineffective in-house QC. The laboratory took corrective actions. The data quality for one type of parameter (PAHs), when subsequently reevaluated, drastically improved. Three research laboratories and one large routine laboratory on separate occasions stated that the interlaboratory performance evaluation studies induced them to re-examine instrument calibration and the accuracy of the standards for chlorophenols, chlorobenzenes, PCBs and octachlorostyrene. Consequently, the analyst discovered poor in-house standards and improper calibration. Without these interlaboratory test samples, these laboratories would not have been aware of their internal biases.

The timeliness of QMWG follow-up on the findings of these studies was significantly impaired by the slow response of some of the participating laboratories. The reporting deadlines were frequently exceeded due to internal schedule conflicts. The actual number of laboratories providing results for any given test parameter depended on whether their UGLCCS project included that parameter. Hence, where severe scatter between laboratories was observed, it was not possible to decide whether this reflected poor control, or just the current "state of the art".

Many of the check samples were standards, and one would expect reasonably good recoveries and precision. In fact, for many of the organic tests, although a given lab frequently reported very similar results on the duplicate samples, the spread of results across labs was quite large. There is a definite need for an intensified effort by organic analysts for better control of standards, and the overall calibrations and quantification process. The findings in this area complement the findings of similar studies conducted by the Great Lakes Water Quality Board of the International Joint Commission.

The data quality management effort required intensive record keeping and imposed a significant additional sample load on the participating project managers and supporting analytical laboratories. The effort necessary to staff and organize the process precluded using the review as a preventative measure in most cases. However, it did flag facilities having quality assurance problems, precluded the use of data outside the specifications demanded by specific studies and allowed participating laboratories to make corrections to their standards and procedure during the course of the study. The data quality effort ensured better data for decision making both for this study and for subsequent environmental activities. It demonstrated clearly that joint studies require more than a sharing of equipment, personnel and laboratory space but also an active, ongoing data quality management program between the United States and Canada. There is insufficient time during the design and planning phase of large multi-agency co-operative studies to develop a common data management program that will assure a reliable and compar- able data base during the subsequent study. Agencies must recognize the importance of quality assurance documentation as an on-going requirement, not only for internal laboratory reviews but also for external scrutiny.

F. REFERENCES

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2. Quality Management Workgroup UGLCCS. 1987. Report of the Quality Management Workgroup. Revised draft, July, 1987. A.S.Y. Chau (Chairman), NWRI, Environment Canada, Burlington, Ontario: 26 p. + append.

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CHAPTER V

INTRODUCTION TO MODELING ACTIVITIES

A. INTRODUCTION

Mathematical modeling of ecosystems is a relatively young technique which, in simplest terms, seeks to simulate actual environmental conditions in a numerically quantifiable fashion. Ideally, a model is a dynamic conceptual framework which enables a clearer understanding of major factors affecting existing states within an ecosystem. Under certain conditions, some numerical simulations offer the added advantage of using data on existing environmental states, coupled with ecosystem process information, to enable predictions of future trends and tendencies. Quite logically, the predictive capability of such a tool is only as good as the conceptual framework of the model, the data set upon which it is based, the assumptions required to develop the model, and the extent to which the model has been both calibrated and verified.

Two types of models were developed in the UGLCCS. The first type of model is based on mass balance calculations. The second type of model is a process-oriented model. Both types of modeling efforts are valuable for indicating needed research, remedial and regulatory actions.

With sufficient data, mass balance calculations are useful for determining (1) whether an area is a source or sink of contaminants, and (2) the relative importance of known and unknown contaminant sources. Mass balance calculations were made for a number of water quality parameters in Lake St. Clair and the Detroit River (including the Trenton Channel, Table V-1). The mass balances calculated for these systems represent order of magnitude "snapshots" of contaminant fluxes since measurements were made during short time intervals only. Annual mass balances cannot be inferred from these calculations unless specifically noted.

TABLE V-1

Mass balance calculations performed on the Upper Great Lakes Connecting Channels.

Location	Date(s)	Parameters
St. Clair R.	Aug., Sept., Oct., 1985	Organics (concentration profiles only)
Lake St. Clair	July 21-29, 1986	Metals, Organics, Total Phosphorus
Detroit River	April 21-29, 1986 (SMB I)	Metals, Organics, Nutrients, Chlorides, Suspended Solids
	July 25 - August 5, 1986 (SMB II)	Metals, Organics, Nutrients, Chlorides, Suspended Solids
Trenton Channel	May 6-7, 1986	Metals, Organics, Nutrients, Chlorides, Suspended Solids
	August 26-27, 1986	Metals, Organics, Nutrients, Chlorides, Suspended Solids

Process-oriented models are based on mechanistic relationships (e.g. contaminant-sediment interactions) and represent a working hypothesis of how a dynamic system works. Process-oriented models are useful for (1) understanding the relative importance of processes that affect contaminant fate, and (2) given proper calibration and verification, for answering "what if" questions (e.g., if a particular contaminant is added to a system, where will it go, how long will it stay, what physical-chemical form will it be in, and what organism exposure might occur?). Models describing a variety of physical, chemical and biological processes were developed for the St. Marys River, the St. Clair River, Lake St. Clair, the Detroit River and the Trenton Channel (Table V-2).

TABLE V-2

Process models developed for the Upper Great Lakes Connecting Channels Study.

Location	Type of Model
St. Marys River	- 3-D steady state finite element hydrodynamic (upper river) - Steady state, depth averaged, mixing model (lower river) - Contaminant fate model (driven by hydrodynamic models, above)
St. Clair River	- Unsteady flow model with flow separation around islands - Steady state depth averaged mixing model - Contaminant fate model (water column only) - Contaminant fate model (TOXIWASP-based water and sediments)
Lake St. Clair	- Water level models (hydrodynamic and empirical) - Currents (predicts mean and daily currents) - Particle transport model - 3-D finite element flow field model - Waves and sediment settling and resuspension - Contaminant fate, 2-D model (TOXIFATE) - Contaminant fate, 2-D model (TOXIWASP-based) - Contaminant fate, 1 box kinetic model
Detroit River	- 2-D plume model of water and contaminant discharge from Detroit's sewage treatment plant
Trenton Channel	- 3-D hydrodynamic and toxicity transport model

B. METHODS

1. Mass Balance Calculations

Mass is a conservative property. As such, a material balance framework can be applied to a control volume (i.e., water body) where, assuming conservative behaviour and steady state conditions, the change in mass of the system can be described as:

$$D = W_{out} - W_{in}$$

W_{in} is the sum of all loads (flux) coming into the control volume (mass/time). W_{out} is the mass flux leaving the control volume. If all loadings into the system are accounted for and the mass flux leaving the system is known, then "D" should equal zero for a conservative substance. In general, if D is not zero, then the control volume is either a sink ($D<0$) or a source ($D>0$) of the substance. For substances that "leave" the system through volatilization or degradation it is important to note that a $D<0$ does not necessarily mean that the substance is accumulating in the control volume. A process-oriented calculation would be needed to define how much substance was lost through volatilization or degradation before an accurate estimate of accumulation could be made. Figure V-1 provides examples of mass balance calculations and interpretations based on various situations.

In the Connecting Channels where horizontal flow (advection) dominates, the W terms can be computed from:

$$W = Q * C$$

Where,
W is mass flux (M/T)
Q is the flow rate (L^3/T), and
C is the concentration (M/L^3).

There are two sources of error in calculating W. First, there are analytical errors associated with measurement of Q and C. Second, errors can be introduced by inadequate temporal and spatial sampling. Ideally, analytical errors would be non-existent and sampling of Q and C would be continuous at all locations. This is never the case, however, so W is always an estimate of the true load. Annual loads would ideally be calculated based on continuous measurements of Q and C throughout a year period. However, Q and C measurements might have been taken on a weekly basis only. Annual loads calculated with weekly information will be less certain than if the measurements were continuous.

Contaminant concentration data are sometimes reported as non-detectable or below the detection limit. This does not imply that the contaminant is not present in the sample, but merely that it cannot be quantified.

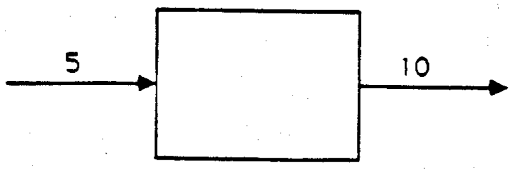
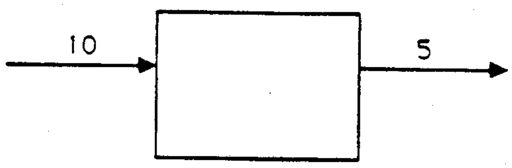
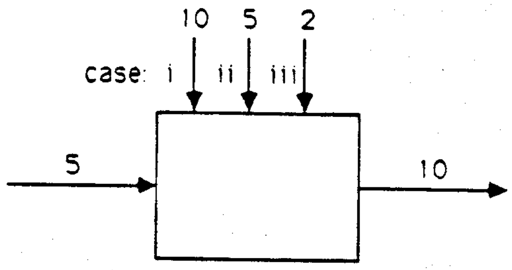
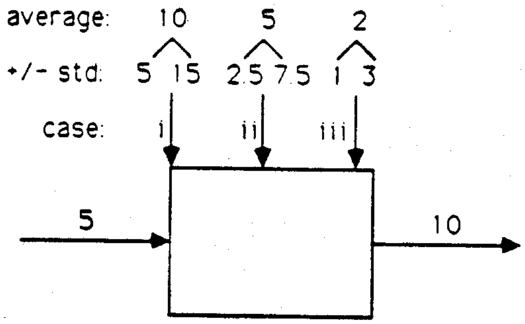
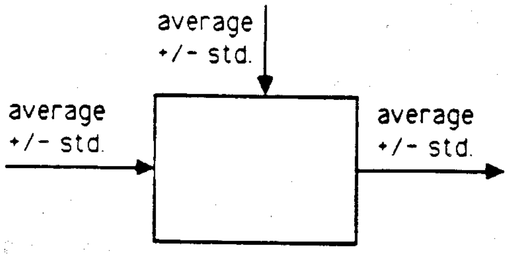
Situation	Cartoon	Interpretation
Upstream and downstream flux known; external loads unknown		Study area is a source of contaminant (net flux = 5).
Upstream and downstream flux known; external loads unknown		Study area is a sink for contaminant (net deposition = 5).
Upstream and downstream flux known; external loads known.		Case i Net deposition of 5; study area is a sink ii No net deposition iii Net export of 3; study area is a source
Upstream and downstream flux known; external loads approximated.		Case i No deposition - deposition of 5; ii In-place source of 2.5 - net deposition of 2.5 iii In-place source of 4 to 2
Upstream and downstream flux approximated; external loads approximated.		Can be difficult to interpret; depends on temporal resolution of samples.

FIGURE V-1. Mass balance calculation examples.

Given a high flow condition and non-detectable concentrations, a significant portion of a contaminant mass balance can be overlooked if non-detectable concentrations are treated as zero concentration. Therefore, a method for handling non-detectables in all mass balances was devised. Details of the method used are supplied in the Modeling Workgroup Report (1).

Comparability of point source sampling between Canada (3 to 6 day sampling composites) and the U.S. (24 hour composites) was an issue. An additional issue was the use of gross loadings (U.S.-effluent only) versus net loading (effluent minus influent-Canada). The loads used in mass balance calculations that follow were those that the Point and Nonpoint Source Workgroups furnished to the Modeling Workgroup. No modifications or corrections to their numbers were made by the Modeling Workgroup.

All mass balance calculations that could be made were summarized as shown in Figure V-2. With this type of diagram the relative importance of loads can be visualized, the relative contributions of U.S. and Canadian sources can be evaluated, unknown loads can be identified, and the source-sink question can be answered for the time period in question. In mass balance diagrams the width of the arrow shafts indicate the relative importance of the average load and loss terms. Average loading terms are subdivided into Canadian and U.S. contributions. A detailed breakdown of loading figures can be obtained from the Point and Nonpoint Source Workgroup reports. At the bottom of the figure is a box that provides an interpretation of the mass balance data. Statistical conclusions are given in this box although all data leading to the interpretation are not indicated.

2. Process Models

Process-oriented models represent working hypotheses of cause and effect linkages. These simulation tools can be used to investigate the relative importance of the various processes that control the linkages. As such, process models can provide a framework for identifying needed field measurements and experimental studies. Process models have the potential for being used in more than one system because they are theoretically based. The process models developed in this study range from purely physical models of water movement to temporally and spatially complex contaminant fate and behaviour models. Verification of the latter models have been difficult due to lack of necessary and sufficient data. Nevertheless, these models are based on well documented cause and effect relationships. Thus they can be used to speculate upon the possible fate of new contaminant introductions and related organism exposures in the Connecting Channels.

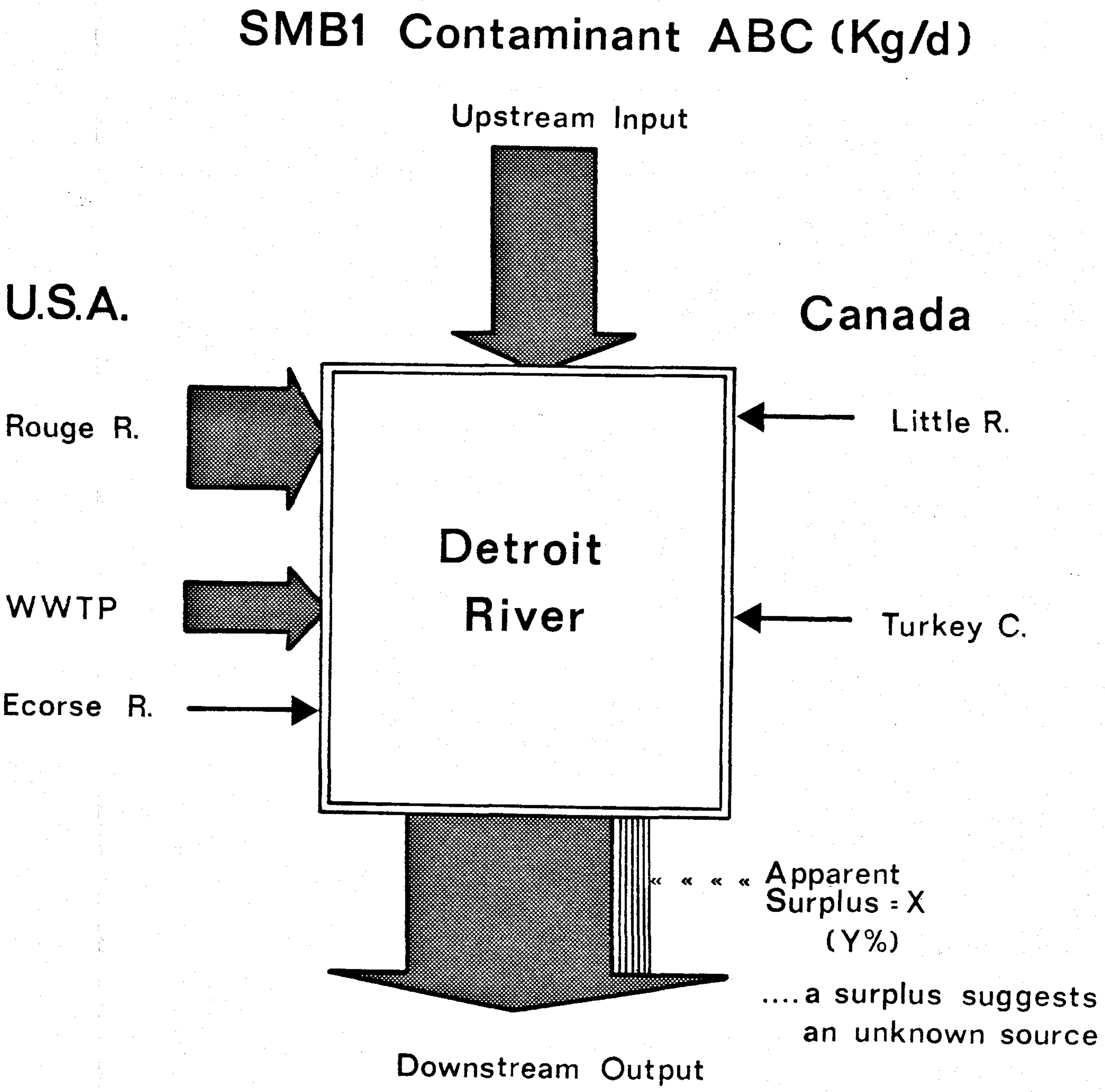


FIGURE V-2. Example of mass balance model presentations. (Detroit River Chapter VII only).

The output from process models is subject to uncertainty. Sources of uncertainty for these models include loading information, boundary conditions, initial conditions, parameter estimates (e.g., coefficient values used in process equations), and conceptual problems (e.g., are the boxes and arrows used the correct ones?). Although the Modeling Workgroup sought to conduct complete uncertainty analyses on all UGLCCS process models, time constraints and the computer resources needed for Monte Carlo-type simulations became limiting factors for most modelers. However, uncertainty analysis of models still may take place after the UGLCCS is over. Through sensitivity analyses, modelers were able to identify some parameters and processes that may require further research in order to improve contaminant fate models.

C. RECOMMENDATIONS

1. The goals of the study must be clearly defined. Recommendations for appropriate data collection and model development depend on it.

2. Goals fall into several categories: research, regulatory, remedial and political. The resource priority that each of these categories can expect to receive should be identified early on and be consistent with the goals of the study.

3. Goals must be realistic given time, personnel, financial, and laboratory capacity constraints. Realistic goals may not equate with ideal goals, but realistic goals promulgate realistic expectations.

4. Modelers are often asked to give direction to a study because models include the physical, chemical and biological processes of a system that are important for understanding its functioning and the behaviour of contaminants in it. By understanding the sensitivity of the system's behaviour to these processes, areas can be identified where data collection is most important. Modelers should be encouraged to develop "speculative" models as quickly as possible in order to perform these sensitivity analyses.

5. Monitoring and research requirements for any study should be identified in close cooperation with the modelers.

D. REFERENCE

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CHAPTER VI

ST. MARYS RIVER

A. STATUS OF THE ECOSYSTEM

1. Ecological Profile

Watershed Characteristics

The St. Marys River connects Lake Superior and Lake Huron. The river originates in Whitefish Bay on Lake Superior between Point Iroquois, Michigan and Gros Cap, Ontario and flows 112 km to Lake Huron. The lower St. Marys River has irregular shorelines and contains four large islands: Sugar, Neebish and Drummond on the American Side and St. Joseph on the Canadian side, as well as approximately 100 small islands less than 4 km^2 in area. Sugar Island separates the main river into the Lake George and Lake Nicolet channels (Figure II-2).

The surface geology of the southwestern St. Marys River valley is composed primarily of lacustrine sediments and moraines. On the southwestern edge of the valley, in Michigan, level lake bed plains are interrupted by gently rolling plateaus, low rounded ridges, sand dunes, bluffs, and marshlands. In Ontario, on the northeastern edge of the valley, knobby Precambrian rock is partially covered by a thin layer of till or lacustrine clay. Much of the bedrock of the basin consists of volcanic and granitic rocks of Precambrian origin in the north, and Ordovician and Silurian dolomites in the south.

The primary influence on surficial geology of the St. Marys River basin during recent times has been the fluctuating water levels. As recently as 3,000 years ago, crustal rebound lifted up rock ledges at Sault Ste. Marie to a level higher than the water level of Lake Huron. This changed the strait connecting Lakes Superior and Huron into the St. Marys River. The influence of fluctuating water levels on the St. Marys valley during the last 4,000 years has been to erode surface deposits, leaving remnant beaches, sand dunes, and other littoral features. Lacustrine clays form most of the soil of the area south of the Canadian Shield.

There are a number of watersheds that drain into the St. Marys River. By far the most important is the Lake Superior basin, which also includes the Goulais River on the Canadian side. Other drainage basins that discharge to the St. Marys River are much smaller. On the U.S. side, these include the Charlotte, Little Munuscong, Munuscong and the Gogomain Rivers. These drain about 64% of the immediate watershed. On the Canadian side are the Big Carp, Bar, Little Carp, Root, Garden, Little Garden and Echo Rivers.

Hydrology

Hydrologically, the St. Marys River may be divided into three major reaches: the upper river, extending from Whitefish Bay to the St. Marys rapids; the rapids; and the lower river, extending from the foot of the rapids to the De Tour Passage at Lake Huron. The upper river rapidly decreases in width in its 22.5 km of length and is characterized by sandy shores, with emergent wetlands occurring only in protected areas. The rapids separate the upper and lower river, and in an area 1.2 km long and 1.6 km wide, the river drops 6.1 m. The lower river is divided into two main outlets, Lake Nicolet and Lake George, and is slower moving.

Water currents of the river are highly variable and influenced by the quantity of discharge to the river from Lake Superior and the water level of Lake Huron. Current velocities are impeded by high surface water levels in the river's mouth at Lake Huron, by easterly or southerly winds, or by low barometric pressure. High surface water levels in Lake Superior result in greater discharge to the river and increased current velocities. Discharge to the river has been partially controlled by compensating gates at the Sault Locks since 1921.

Recorded outflow from the St. Marys River fluctuates greatly. The mean flow rate for the 124 years of record (1860 - 1984) is 2,200 m^3/sec, and have ranged from a minimum of 1,200 m^3/sec to a maximum of 3,700 m^3/sec. Since the completion of the Long Lake and Ogoki Diversions in the 1940s, in which some waters originally draining north into James Bay were diverted to Lake Superior, there has been an increase in the mean discharge by about 8%.

During the period April to October 1983, 74% of the total discharge measured at Sault Ste. Marie flowed through the Lake Nicolet reach. The balance flowed through Lake George.

Water levels of the St. Marys River are subject to three types of fluctuation: seasonal; long range, and short term. Seasonal fluctuations are over a period of one year. These are the most regular, with highest water levels occurring during the summer and lowest during the winter. There is about a 0.3 m change in water level during the year.

Flushing rates were calculated and found to average 1.31 lake (Nicolet) volumes per day. Because of this, and the hydrographic features of the lower river, materials in suspension or solution tend to be transported through the length of the St. Marys River in a short period of time.

Habitats and Biologic Communities

A series of narrow channels and broad lakes exist throughout the St. Marys River. The shorelines are without major areas of settlement except for the cities of Sault Ste. Marie, Michigan and Ontario. Rocky shores characterize the narrow reaches and clay, sand or mixed detritus-sediment combinations are found in shallow areas. The shorelines tend to be inhabited by emergent vegetation, sometimes uninterrupted for 3 to 5 km or more. The 12 km tract of hardstem bulrush and bur reed that extends northward from the Charlotte River is an example.

Annual production of biomass in these wetlands is dominated by three emergent plants: hard stem bulrush, giant bur reed and spike rush. Submerged species occur as a diffuse understory of low biomass. Growth that produces the emergent wetlands is vegetative and colonial, usually in monotypic stands. Areal surveys of the last three decades show that these stands tend to be long-lived, and relatively permanent features of the St. Marys shoreline. Rootstocks of the dominant species are present in the hydrosoil year round. They reach maximum biomass late in the growing season and degenerate in winter. Live rootstocks die back rapidly in the spring, yielding their food and nutrient reserves to new shoot growth. A tight cycling of nutrients results from this cycle, leaving little available for invading species.

Lake Superior and the St. Marys River are subject to important wind-driven forces, such as waves and seiches. Strong prevailing northwesterly winds cause formation of large waves which travel long distances before reaching Whitefish Bay and the headwaters of the river. Regions of wide expanse on the lower river have shorelines variously exposed to waves and currents. Shores with the most exposure have no emergent vegetation; the bottom is rock and shifting sand. Where emergent vegetation does occur, least protected sites have square bulrush or spike rush as the dominant vegetation. Most protected sites have hardstem bulrush and bur reed. The west shore of the St. Marys River lies in the lee of prevailing winds and emergent wetlands are more entrenched on this shore.

Upstream of the St. Marys fork at Mission Point and throughout Lake Nicolet and its downstream reaches, submerged wetlands spread as a meadow of low growing plants over bottom sediments wherever the river is broad, the substratum suitable and water clarity good. Twenty-two known species of plants occur in these wetlands.

Diatoms dominate the transient phytoplankton community and the species are characteristic of oligotrophic waters. Seventy-two species have been identified in the Lake Nicolet reach of the river. A mix of planktonic and benthic species has been found in the plume of the St. Marys River in Lake Huron. Benthic populations comprise as much as 40% of the total algal assemblage in terms of cell volume, while the remainder is planktonic. Chlorophyll a concentrations show that planktonic algal biomass varies only slightly from one end of the river to the other.

The species composition of benthic fauna changes from the upper river downstream with downstream communities exhibiting increased oligochaete abundance. Generally, the bottom fauna of the river is indicative of good water quality. However, pollution tolerant species are present near Sault Ste. Marie, Ontario as a result of contaminant loadings to the river. Ephemeroptera, Amphipoda and Mollusca are common and abundant and contribute substantially to the standing stock biomass. Mayflies may be the most abundant species of benthic invertebrates in the river. However, nymphs of two species, Hexagenia limbata and Ephemera simulans, are particularly abundant in areas of soft substrate. Hexagenia limbata is most abundant in portions of lakes George and Nicolet and in the lower river where fine sediments occur; Ephemera simulans is more common in the coarser sediments of Lake Nicolet and the upper river. The bottom of the shipping channel, because of dredging, is poor habitat for benthic macroinvertebrates.

Primary fish habitats in the St. Marys River have been classified as (i) open-water and embayments, (ii) emergent wetlands, (iii) sand and/or gravel beaches, and (iv) the rapids (1). Although most species are associated with only one habitat, some are found in more than one habitat and some use different habitats on a daily or seasonal basis. Rainbow smelt, spottail shiners, trout, common white suckers, rock bass, and yellow perch were collected in all habitats (2,3,4).

In general, the open water fish community is dominated by demersal species although two pelagic species, lake herring and rainbow trout, are abundant. Other fish found in open water areas are yellow perch, white sucker, lake whitefish, northern pike, and walleye. Smallmouth bass, chinook and pink salmon, and lake sturgeon are seasonally abundant in open water areas.

Liston et al. (4) collected 49 species of fish in the wetlands of the river which serve as spawning, nursery and feeding areas for many species, particularly yellow perch, northern pike, smallmouth bass, bowfin, longnose gar, brown bullhead, and walleye. A similar species mix was found in the sand and gravel beach zones together with some of the small bottom species found in the open water areas. Trout, perch, shiners, and juvenile walleye are common in these areas.

The fish community inhabiting the St. Marys rapids is discrete from the fish communities of other parts of the river. Thirty-eight species have been collected from the rapids (5), many of which are of interest to anglers, including lake whitefish, rainbow trout, lake trout, brown trout, brook trout, and chinook salmon. Important forage species in the rapids are longnose dace and slimy sculpin. Sea lamprey adults are present in the rapids during the spawning season (especially July) and appear to be increasing in number.

Local Ecological Relationships

i) Food Web and Trophic Structure

Emergent plants are by far the most productive component of the river system, some 200 times more productive than phytoplankton, and 40-50 times more productive than submerged plants. Periphyton on submerged shoots of emergent wetland plants have annual productivity of the same order as the phytoplankton. Thus, in the St. Marys system, food production for consumers is concentrated along the edges of the river in emergent wetlands and along the bottom in submerged plant communities.

Among secondary producers, zooplankton represent an important link between phytoplankton and higher trophic levels. Phytoplankton in pelagic zones of lakes and rivers have a low standing stock biomass, but constitute the basis of pelagic food webs. Zooplankton concentrate the energy available from phytoplankton biomass and are then available to fish and other planktivorous feeders.

The zooplankton community emptying into the river from Whitefish Bay consists of some 30 crustacean species. The winter zooplankton community consisted mostly of adult stages of *Diaptomus cicilis*, *Diaptomus ashlandi*, *Limnocalinus micrurus*, and immature copepodids of *Cyclops bicuspidatus tomasi*. During summer, immature calanoids, adult *Cyclops bicuspidatus tomasi* and Cladocera dominate the open water environment.

The zooplankton of the lower river is very similar in species composition to the summer community of the upper river, but far less abundant. The zooplankton density in emergent wetlands is more than an order of magnitude greater than the maximum densities found in open water.

The benthic macroinvertebrate community of emergent wetlands in the St. Marys River is taxonomically diverse with a total of 171 recorded species or taxa of aquatic insects. Chironomidae are the richest fauna, with 39 species, with Hemiptera, Odonata and Coleoptera also well represented. However, chironomids and oligochaetes numerically dominate the benthic macroinvertebrate community. Larva of the beetle Donacia sp. are phytophagus and develop within the stems of the macrophyte Sparganium eurycarpum. Larva of the moth Bellura sp. do the same in Scirpus spp. stems. Mayflies, Hemiptera and Odonata are found in more dense macrophyte stands.

Ichthyoplankton studies in the St. Marys River have identified 39 species. Fish larva collected in the river include larva from the river, the tributaries and Whitefish Bay. Rainbow smelt dominate all reaches of the river, spawning in small tributaries or along rocky shorelines. A marked succession of fish larvae is apparent and is the result of differential timing of reproduction by various species in response to environmental stimuli.

ii) Plant Nutrients and Dissolved Gasses

Data on alkalinity, pH, and dissolved oxygen are available for the St. Marys River from a number of sources. Alkalinity is typically 40 mg $CaCO_3$/L (or 0.8 milliequivalents/L), pH ranges between 7 and 8, and dissolved oxygen concentration varies seasonally. Dissolved oxygen concentrations throughout the river are adequate to support all forms of aquatic life and are well above the 5.0 mg/L U.S.EPA recommended limit.

Total nitrogen (TN) ranges from 0.262 to 0.668 mg/L and averaged 0.413 mg/L during 1982-83. Total phosphorus (TP) averages 13 ug/L. The ratio of TN to TP in the photic zone is a useful index for separating lakes into N-limited and P-limited categories. If the TN/TP ratio is greater than 10, algal production is likely to be phosphorus-limited. The average TN:TP ratio for the St. Marys River is 32 but varies during the growing season and always exceeds 10.

iii) Biological Links of the Great Lakes

Many of the fish species in the river undertake seasonal movements from one area to another. For some of these species these movements are only dispersal into adjoining habitats. However, for other species, such as chinook salmon, lake herring and walleye, these seasonal movements may be characterized as seasonal migration.

The parasitic sea lamprey is present within the St. Marys rapids. Twenty percent of the adults captured from Lake Huron tributaries in 1983 were taken at the powerhouse near the St. Marys rapids. Sea lamprey spawn in the St. Marys rapids, in tributaries to the river, and probably at lesser rapids located below Lake Nicolet and Lake George.

There are 172 known species of birds which frequent the St. Marys River and adjacent riparian areas (1). Waterfowl, colonial waterbirds and some raptors have traditionally been useful as indicators of water quality in the Great Lakes. Of these bird groups, species which breed, stage or overwinter on the river are particularly useful. A list of these species is included in Table VI-1. Duffy et al.(1), provide a detailed list of all the St. Marys River bird species.

Waterfowl nest along the shorelines and on islands within the St. Marys River. Census data from the 1980s are not available for most species that breed along the river. However, Weise (6) estimated a density of 8.9 pairs/km^2 of ducks at Munuscong Lake marshes during breeding season. Common goldeneye, mallard, blue-winged teal and black ducks nest in munuscong lake marshes while common mergansers, american coots, Canada geese and occasional northern pintails and common loons nest in emergent wetlands adjacent to the river.

Recent data from aerial surveys (6) show the highest absolute abundance of waterfowl in the river occurs during the fall migration period when virtually all the waterfowl species listed in Table VI-1 occur in the St. Marys River. During the October and November staging and migration period, the dominant species are redhead, scaup, ringnecked duck and mallard (6). The most common species which winter along the St. Marys River are common goldeneye, common merganser and mallard (7), and greater and lesser scaup.

The many islands of the St. Marys River provide nesting sites to colonial waterbirds (8,9). Herring and ring-billed gulls, common terns and great blue heron are present during the spring/summer breeding season. Nesting sites are found throughout the St. Marys River area, but only the herring gull winters here.

Bald eagles are year-round residents of the St. Marys River area. There are two active nests used by bald eagles, one on Sugar Island and one on the Munuscong Lake shoreline. In the winter, eagles are found in the area surrounding the north end of Sugar Island. Approximately 15 pairs of osprey breed on the river. This small but significant number of birds has stabilized since growing rapidly from 1 breeding pair in 1973.

The mammalian fauna of the St. Marys River area reflects the region's transitional position at the northern edge of the Great Lakes hardwood and the southern edge of boreal forests. Some 55 species of mammals inhabit the area, 46 small mammals and 9 large ones.

TABLE VI-1

Waterfowl, colonial waterbirds and raptors which are or could be used as important water quality indicators in the St. Marys River.

Scientific Name	Common Name
GAVIFORMES	WATERFOWL
Gaviidae	Common Loon
Gavia immer	
ANSERIFORMES	
Anatidae	
Branta canadensis	Canada goose
Anas discors	Blue-winged teal
Anas rubripes	American black duck
Anas platyrhynchos	Mallard
Anas acuta	Northern pintail
Anas strepera	Gad Wall
Aythya valisineria	Canvasback
Aythya americana	Redhead
Aythya collaris	Ring-necked duck
Aythya marila	Greater scaup
Aythya affinis	Lesser scaup
Bucephala clangula	Common goldeneye
Mareca americana	American Wigeon
Lophoelytes cucullatus	Hooded merganser
Mergus merganser	Common merganser
Mergus serrator	Red-breasted merganser
PELECANIFORMES	COLONIAL WATERBIRDS
Phalacrocoracidae	
Phalacrocorax auritus	Double-crested cormorant
CICONIFORMES	
Ardeidae	
Ardea herodias	Great blue heron
CHARADRIIFORMES	
Laridae	
Larus delawarensis	Ring-billed gull
Larus argentatus	Herring gull
Sterna hirundo	Common tern
Chlidonias niger	Black tern
FALCONIFORMES	RAPTORS
Accipitridae	
Pandion haliaetus	Osprey
Haliaeetus leucocephalus	Bald eagle
Buteo lineatus	Red-shouldered hawk
Circus cyaneus	Northern harrier
STRIFIFORMES	
Strigidae	
Bubo virginianus	Great horned owl

Associated with the river are beaver, muskrat, racoon, river otter, American water shrews and the northern water shrew. Muskrat are the most common and the two species of shrews are abundant. Nonriverine species of shrews, moles, mice, squirrels, chipmunks and hares abound. Badger and gray fox occasionally inhabit the area.

Mixed boreal forest and northern Great Lakes forest species of large mammals include numerous white tail deer, moose, black bear, bobcat, lynx, coyotes, red fox and gray wolves within the St. Marys Valley.

Climate

Area winters are cold and snowy, with total snowfall accumulation ranging from a minimum of 0.82 m to a maximum of 4.54 m. On average, permanent snow cover begins on November 21, and remains until April 7th. The 30 year (1950-1980) averages for precipitation (water equivalent) at Sault Ste. Marie, Michigan show an annual mean average of 0.85 m. Monthly variations are significant, with February being the driest month, having a monthly mean of 4.3 mm, while September is the wettest with a monthly mean of 9.9 mm.

The coldest month of the year in the region is January, which averages -10.4°C, while July is the warmest, averaging 17.5°C. Air temperatures are moderated throughout the year by the waters of Lake Superior which seldom freeze. Based on the thirty year period (1951-1980) the average first day of frost is September 27th and the average last occurrence is May 26th. Most summers pass without temperatures reaching 32.2°C and the highest temperature of record is 36.7°C, which occurred in 1888.

The water temperatures of the St. Marys River are near 0°C for four months of the year; annual temperatures of the headwaters in Whitefish Bay range from 0°C to 16°C. Ice forms on the St. Marys River with broad, shallow areas freezing first followed by the deeper, faster reaches.

2. Environmental Conditions

Water Quality

Water quality degradation has resulted from steel and paper mills and municipal sewage treatment plant discharges. Considerable progress has, however, been made since 1970 by Algoma Steel Corporation Ltd. in reducing ammonia-nitrogen, free cyanide, and phenol discharges; by St. Marys Paper in reducing suspended solids loading; and by the municipal sewage treatment plants in improving the removal of phosphorus and organic matter.

A system of transects across the St. Marys River between Whitefish Bay and the outlets of Lake George and Lake Nicolet has been used by the Ontario Ministry of the Environment to monitor water quality (Figure VI-1). Each transect was sampled at several locations from the Canadian shore to the U.S. shore. Transects are numbered by their distance in statute miles upstream (prefix - SMU) and downstream (prefix-SMD) of the Algoma Steel Terminal Basins' submerged diffuser outfall. About 20 samples for each water quality parameter were collected across each transect. The water quality parameters which were measured in most of the studies were phenols, cyanide, ammonia, phosphorus, heavy metals (such as total iron and zinc), and several polynuclear aromatic hydrocarbons (PAHs). In assessing the significance of contaminant concentrations in the St. Marys River, comparison can be made with the Ontario Ministry of Environment (OMOE) Provincial Water Quality Objectives (PWQO), the Great Lakes Water Quality Agreement (GLWQA) specific objectives and the Michigan Ambient Water Quality Standards (Table III-2, Chapter III).

i) Cross Channel Variations in Water Quality

In general, contaminants such as phenols, ammonia, cyanide, iron and zinc, attributable to Algoma Steel discharges, were found along the Ontario shoreline of the river with no transboundary pollution in the main channel upstream of transect SMD 2.6. Typical distribution of contaminants across the main portion of the river is shown in Figure VI-2. The cross channel variation at sampling transect SMD 2.6 indicates that the phenol, ammonia, zinc and iron concentrations increased from the stations located near the Michigan shoreline to those stations adjacent to the Ontario shoreline. Data from 1986-87 indicate that transboundary movement of iron, zinc, and ammonia did not result in exceedences of water quality standards in Michigan waters. However, the mean phenols concentration exceeded the GLWQA specific objective of 1 ug/L in Michigan waters.

Contaminants are confined to the Ontario shoreline as far as Sugar Island. The curving flow at the beginning of the Lake George channel creates a zone of high velocity towards the Sugar Island shoreline (10) because of the division of flow between the Lake Nicolet Channel, west of the island and the Lake St. George, northeast of the island. Secondary currents enhance the transverse mixing process across the Lake George Channel (11). Thus, contaminants attributable to upstream industrial discharges which were confined to the Ontario shoreline of the main portion of the river will be found along the Sugar Island shoreline of the Lake George Channel. Additional inputs of contaminants from the Sault Ste. Marie, Ontario East End Water Pollution Control Plant (WWTP) to those of upstream industrial discharges result in the persistence of contaminants in the downstream reaches.

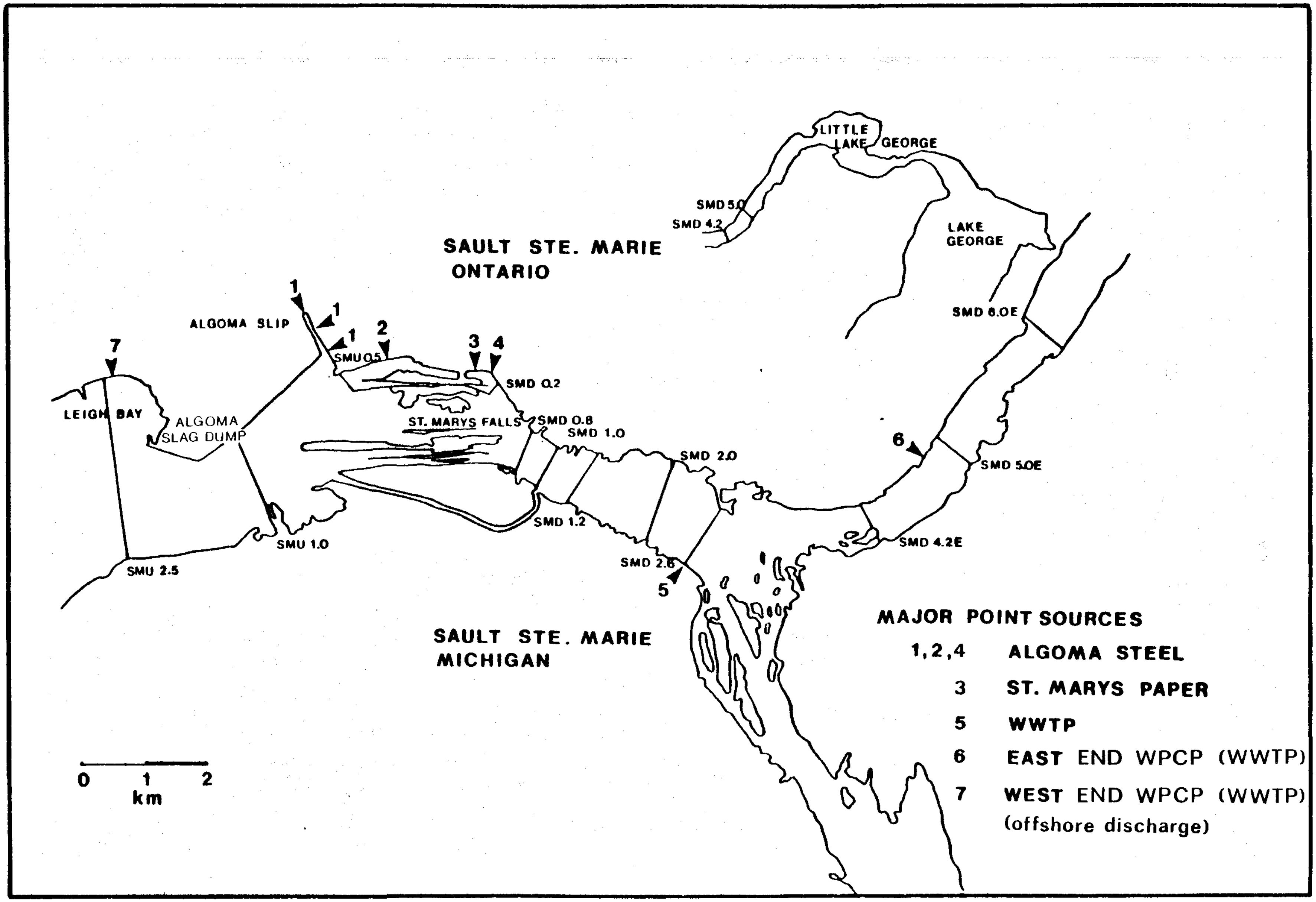

FIGURE VI-1. Sampling transects and major point source dischargers.

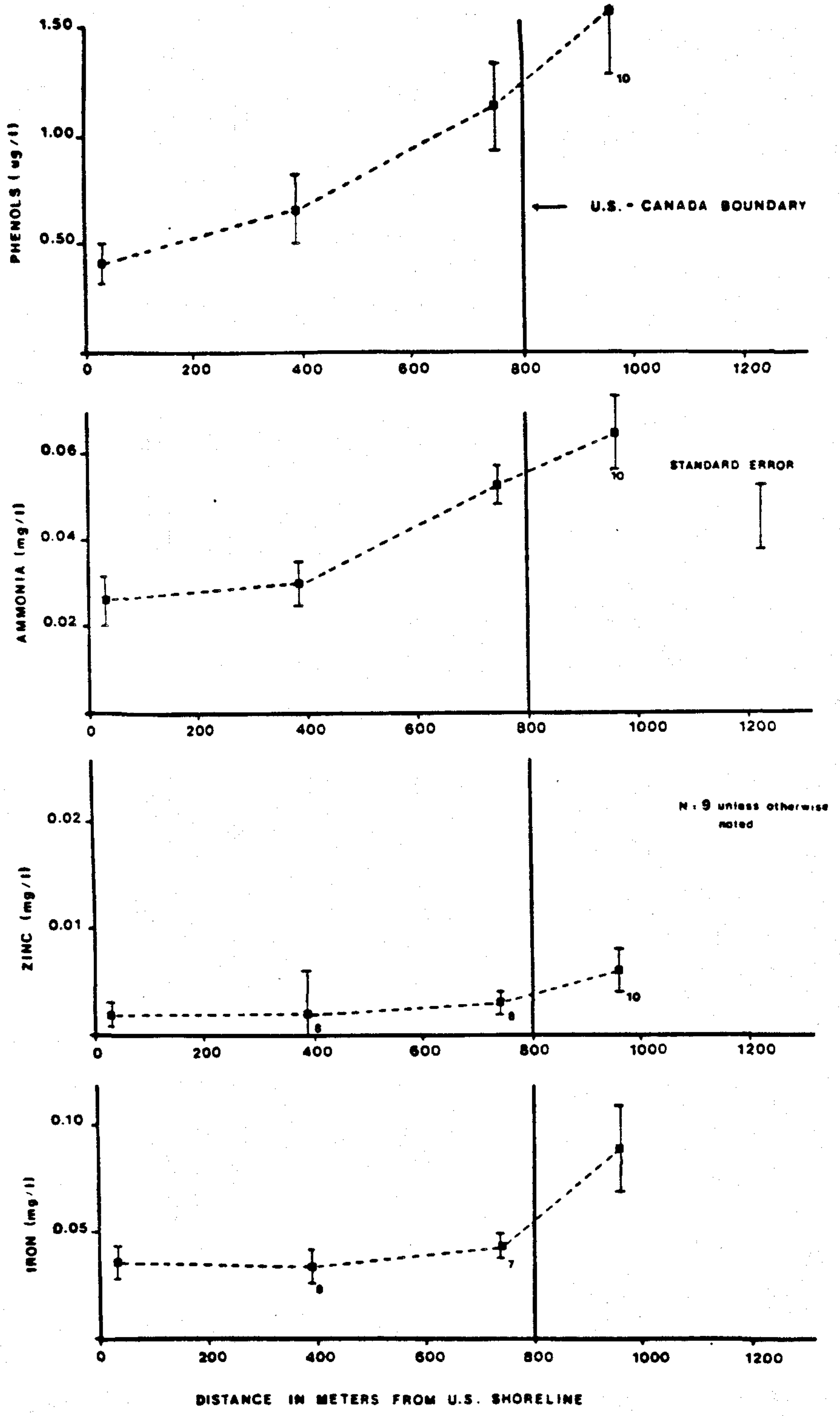

FIGURE VI-2. Distribution of contaminants across St. Marys River at transect SMD 2.6 (1986-87).

Hamdy and LaHaye (12) documented the transboundary pollution of ammonia in the Lake George Channel downstream from the East End WWTP. Ammonia concentrations increased by 20% in Michigan waters near Sugar Island.

ii) Longitudinal Variations in Water Quality

Bacteria:

In 1986, analyses for fecal coliform (FC), fecal streptococci (FS), E. Coli and P. aeruginosa in the St. Marys River indicated several problem areas. Geometric mean densities of FC along the Canadian shoreline were greater than the PWQO (100 organisms/ 100ml) at stations near storm sewers and major industrial outfalls. For example, at two stations (SMD 0.8 and 1.0) immediately below these outfalls and in the vicinity of some of the storm sewers, the mean FC densities over 3 days were 477 and 428/100ml. The corresponding densities for E. coli were 311 and 271/100ml; for FS, 24 and 13/100ml; and for PA, 4/100ml. At a further 1.5 km downstream, densities of FC were below the PWQO.

Bacterial densities were also elevated below the outfall of the Sault Ste. Marie, Ontario East End WWTP in the Lake George Channel. The mean densities over 3 days at two stations (SMD 5.0E and 7.9E) downstream of this facility were: FC, 184 and 182/100ml; E. coli, 120 and 153/100ml; FS, 24 and 19/100ml; and PA, 5 and 7/100ml.

Densities of fecal coliform and streptococci along the U.S. shore were below the respective PWQO at all stations, with the exception of immediately downstream of the Edison Sault Electric Company Canal (SMD 1.2). Compliance with Michigan's fecal coliform standard (200 cells/100ml) is determined on the basis of the geometric mean of any 5 consecutive samples taken over not more than a 30 day period. Because only 3 samples were collected from this site, comparison with Michigan water quality standards is not possible. However, the 3-day geometric means of E. coli, fecal coliform, fecal streptococci and P. aeruginosa were 1,149 organisms, 2,250 organisms, 233 organisms, and 20 organisms, respectively, per 100ml. The sources may be combined sewer overflows that discharge to the Edison Power Canal (see urban runoff section).

Phenols:

The redevelopment of the Great Lakes Power Limited hydroelectric generating station in 1982 resulted in changes in the distribution of river flow at the regulating works (Figure VI-3). The portion of total river flow along the Ontario shoreline increased from 21% to over 40% of the total river flow. This increase in flow is in part responsible for the reduction of river concentrations of phenols, cyanide and ammonia (12).

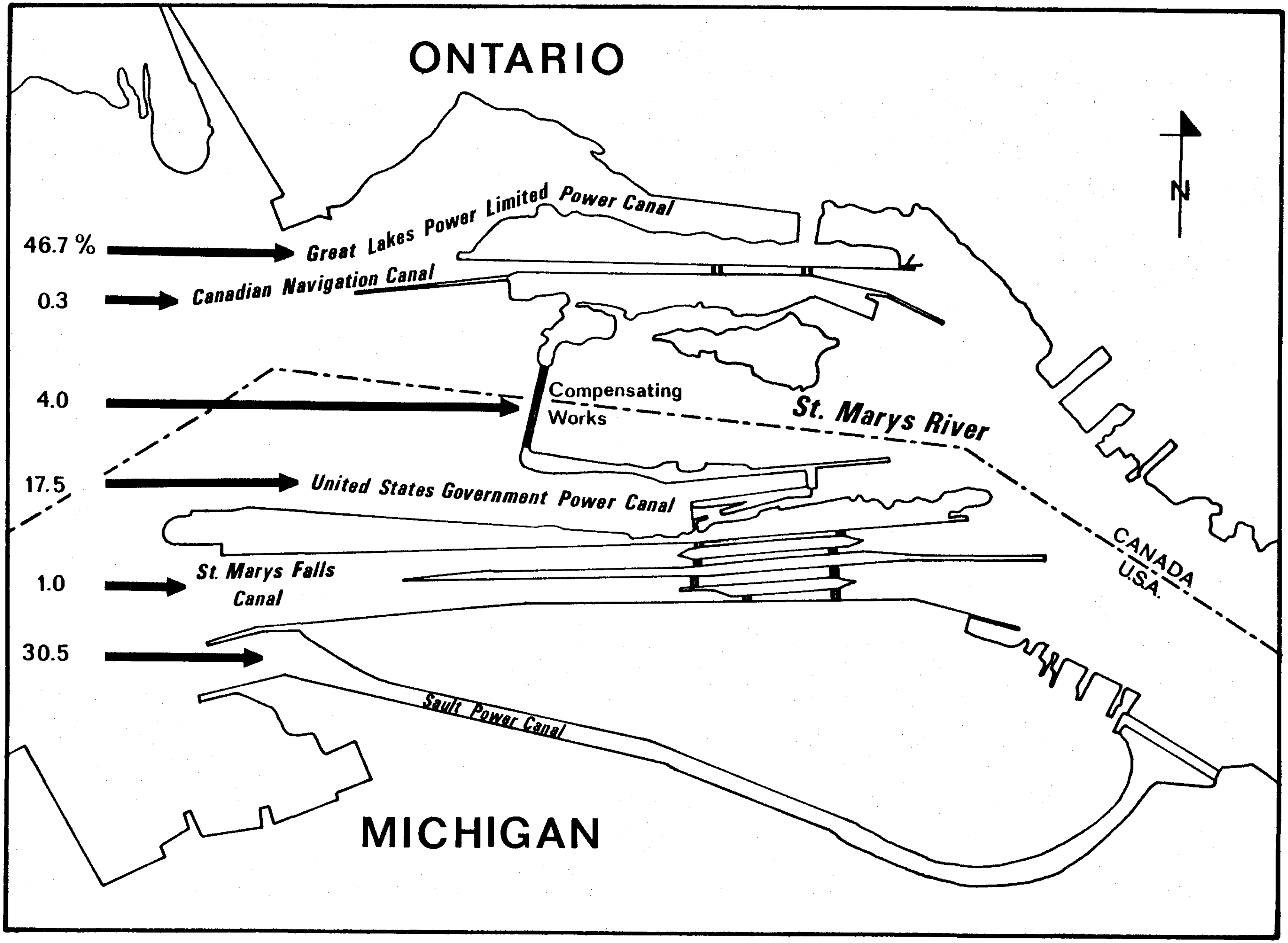

FIGURE VI-3. Average flow distribution (%) at the St. Marys River Rapids (2.2 x 10^3 m^3/s post 1982).

The year-to-year variations of total phenol concentrations measured at various distances downstream from the Algoma Steel discharges are shown in Figure VI-4. There is a downward trend of phenol levels over the years. Mean phenol levels 300 m downstream of the Algoma Terminal Basins outfall (at river range SMD 0.2) declined from 50 ug/L in 1973 to 15 ug/L in 1980 and to 1.2 ug/L in 1986.

In 1986, all stations downstream of Algoma Steel discharges had phenol levels approaching the PWQO and Great lakes Water Quality Agreement specific objective of 1 ug/L. However, phenols exceeded the objective in the Algoma Steel Corp. Slip (3.6 ug/L) and at the mouth of the Slip (3.4 ug/L) in 1986. The Algoma Slip is a ship loading and off-loading facility located upstream of the Terminal Basins and power canal.

In 1986-87, average phenols along the Michigan shoreline were below the PWQO and the GLWQA specific objective of 1 ug/L.

Ammonia:

The ammonia concentration distribution along the Canadian shoreline downstream of the Algoma Steel discharge, is illustrated in Figure VI-5. The 1986 levels along the Canadian shore exhibited significant decreases as compared to previous years. The calculated unionized ammonia concentrations were below the PWQO and GLWQA specific objectives of 0.02 mg/L.

The ammonia concentration increased downstream of the Sault Ste. Marie East End WWTP (see Figure VI-4, SMD 5.0). The impact of the WWTP effluent is localized, as concentrations at the Lake George Channel outlet were the same as those observed at the beginning of the Lake George Channel (0.046 mg/L) upstream of this facility.

Cyanide:

The distribution of free cyanide along the Canadian shore in 1974 and 1980 indicated peak concentrations 300 m downstream from the Algoma Steel discharge and uniformly low concentrations further downstream (Figure VI-6). The 1986 levels indicate a decline from the previous years, and uniformly low concentrations from upstream to downstream. All levels were in compliance with the PWQO of 0.005 mg/L and the U.S.EPA chronic AWQC of 0.0052 mg/L.

Heavy Metals:

During 1986-87 the concentrations of total iron in the St. Marys River ranged between 0.018 and 0.69 mg/L and no distinct longitudinal variations were noted. Just downstream of the Terminal Basin's outfall (SMD 0.2), the average concentration was 0.06 mg/L with a maximum of 0.69 mg/L. This maximum was one

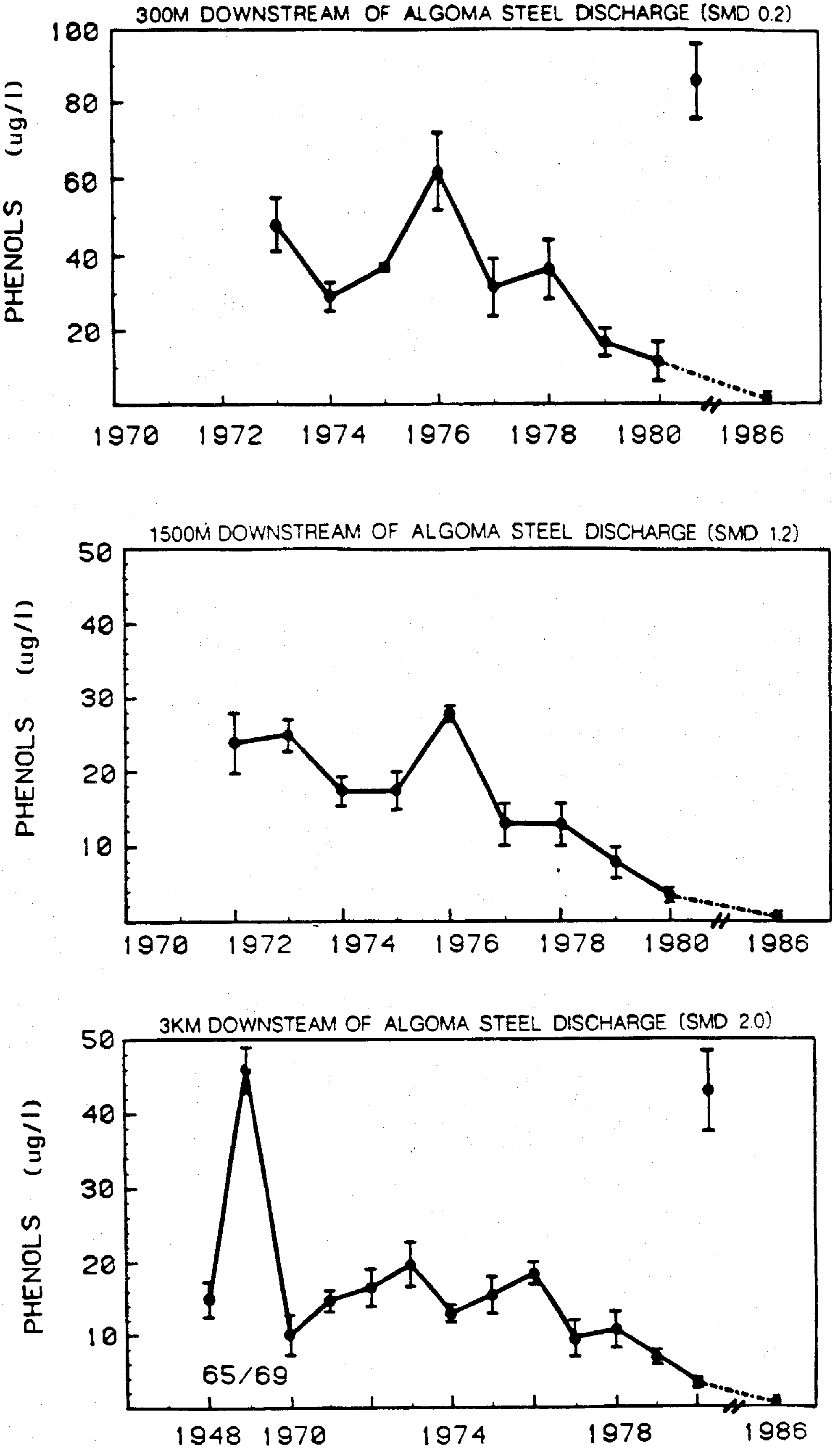

FIGURE VI-4. Phenol concentrations in the St. Marys River at various distances downstream of the Algoma Steel discharge along the Canadian shoreline.

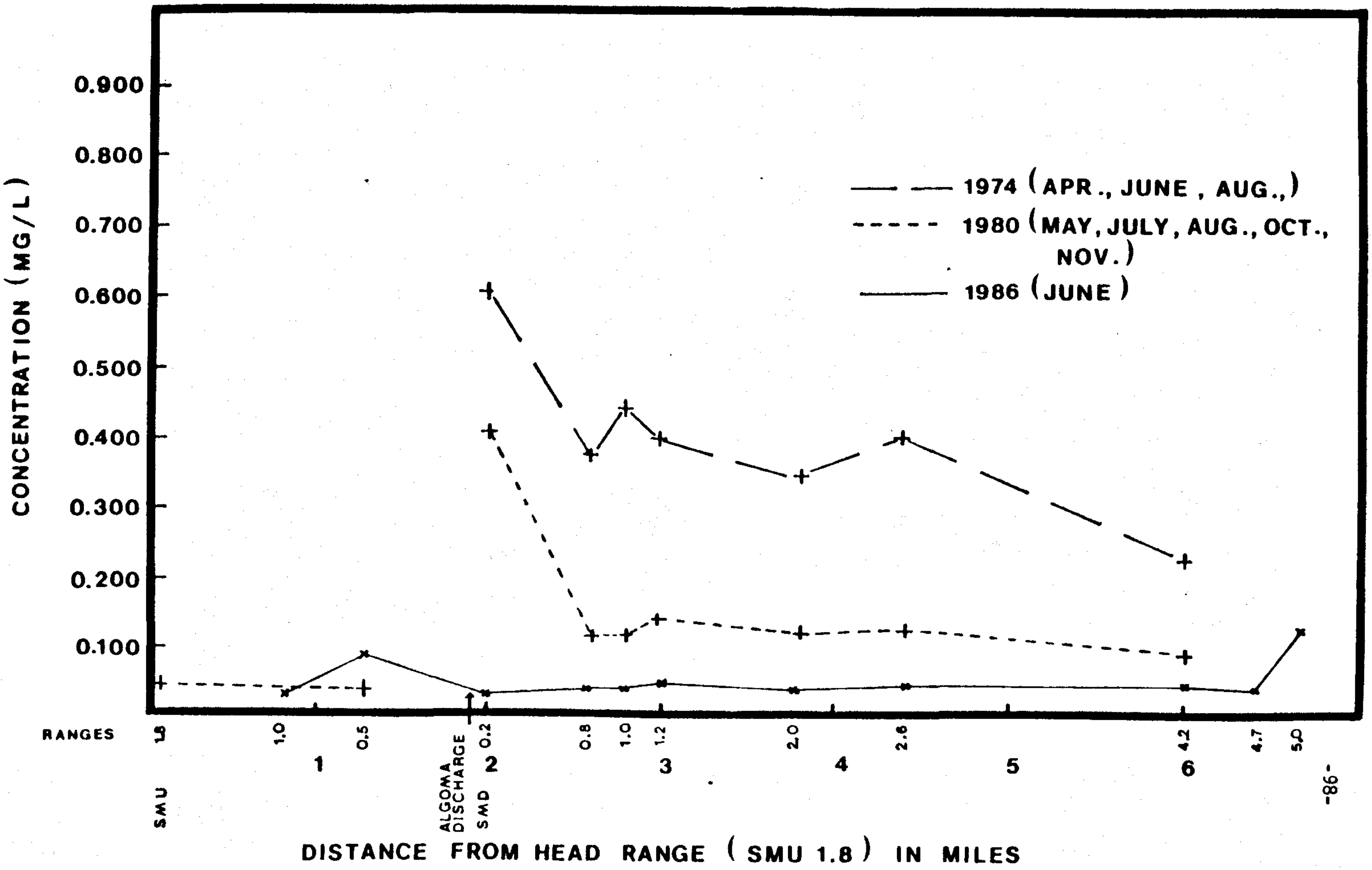

FIGURE VI-5. Ammonia distribution and yearly trends along the Canadian shore.

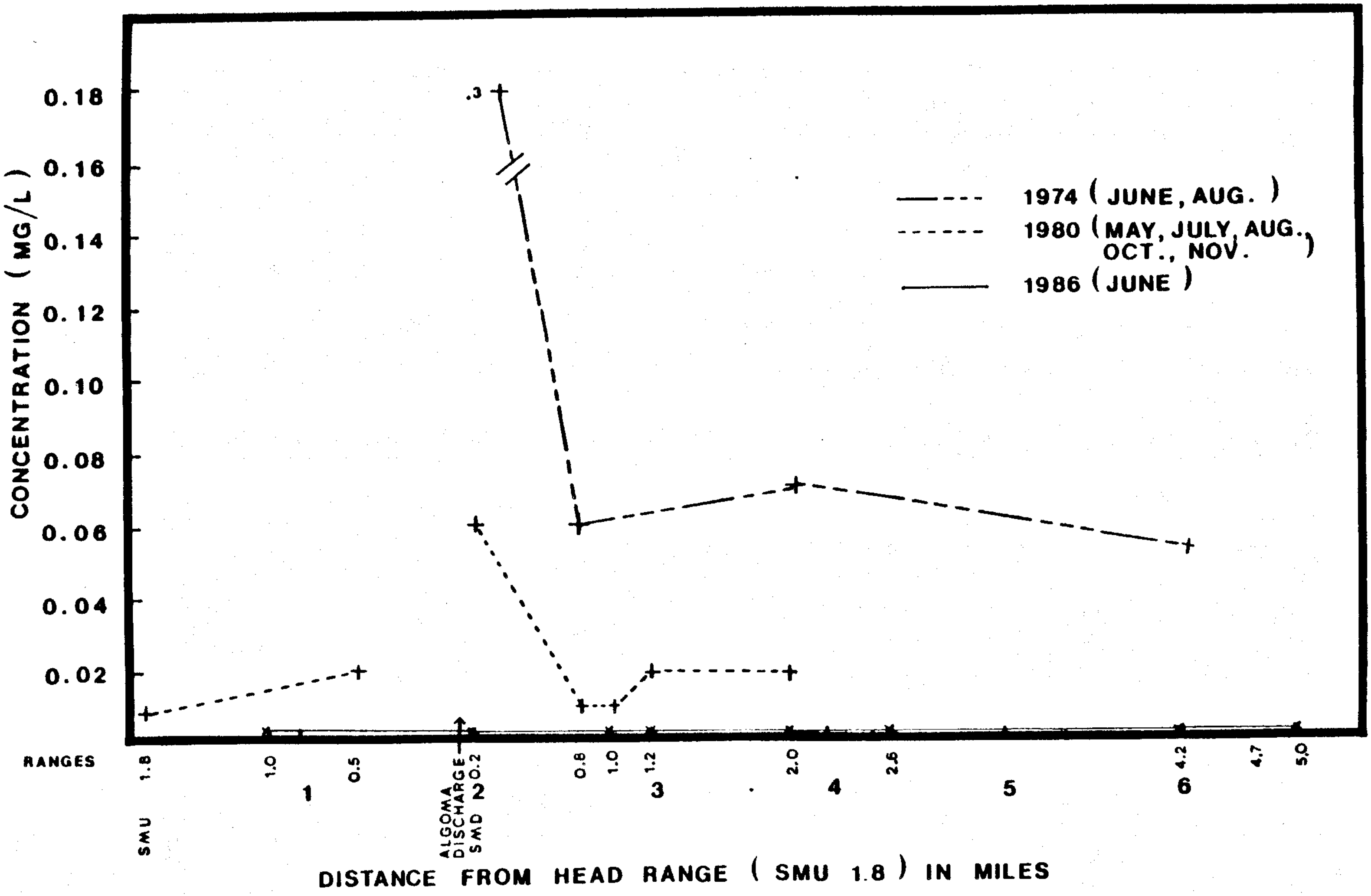

FIGURE VI-6. Cyanide distribution and yearly trends along the Canadian shore.

exceedence of the water quality objectives in 40 samples across the transect. In the Algoma Slip, iron exceeded the PWQO and GLWQA specific objective of 0.3 mg/L (average 0.445 mg/L with a maximum of 1.0 mg/L). All samples met the U.S.EPA chronic AWQC of 1 mg/L for chronic toxicity. Iron levels along the Michigan shoreline in 1986/87 ranged between .008 mg/L to 0.087 mg/L.

The elevated iron levels during the period 1970-74 decreased to levels in the range of 0.11 - 0.15 mg/L during the period 1976-1980 (10).

Total zinc levels in the St. Marys River along the Ontario and Michigan shorelines in 1986-87 displayed no distinctive longitudinal variations. Concentrations ranged between 0.001 and 0.009 mg/L, a decrease from 1980, when concentrations of 0.01 mg/L were prevalent. All these concentrations are below relevant water quality standards or guidelines.

Phosphorus:

In 1986-87, phosphorus levels along the Canadian shore ranged from 0.002 to 0.051 mg/L and from 0.005 to 0.014 mg/L along the Michigan shore. The highest level of phosphorus (0.051 mg/L) along the Canadian shore was noted just downstream of the Ontario Sault Ste. Marie East End WWTP (SMD 5.0). No elevated levels of phosphorus (relative to upstream levels) were noted downstream of the Sault Ste. Marie, Michigan waste water treatment plant (WWTP). Phosphorus levels were slightly higher along the U.S. and Canadian shores at Pointe Aux Pins (SMU 5.0) in 1986. The levels were 0.012 and 0.014 mg/L, respectively. However, all phosphorus levels in the St. Marys River met the PWQO of 0.03 mg/L with the exception of immediately downstream of the East End WWTP.

Polynuclear Aromatic Hydrocarbons (PAHs):

With the exception of polynuclear aromatic hydrocarbons (PAHs), trace organic contaminants such as chlorinated benzene and halogenated volatiles are not generally found in the St. Marys River. The environmental significance of PAHs in the St. Marys River cannot be determined due to the absence of surface and drinking water criteria for PAH compounds with the exception of the interim benzo(a)pyrene Ontario drinking water Maximum Acceptable Concentration (MAC) of 10 ng/L. For the maximum protection of human health from the potential carcinogenic effects of PAHs due to ingestion of contaminated aquatic organisms which may result in an incremental increase of cancer risk of 10^{-6} over a 70 year lifetime, a criterion of 31 ng/L for total PAHs was developed by the U.S.EPA (13). This is used as a yardstick to assess the significance of levels found in the St. Marys River.

Worldwide information on PAHs (14) indicates concentrations of benzo(a)pyrene range from approximately 0.1 to 100 ng/L. In Lake Erie, near Buffalo, Bass and Saxene (15) found 0.3 ng/L benzo(a)-pyrene and 4.7ng/L total PAHs. Williams et al. (16) extracted large volumes of municipal treated drinking water taken from 12 plants using Great Lakes water. The winter and summer concentrations (+/- 1 standard deviation) respectively were relatively high for pyrene (11.2 +/-20.0 and 3.9 +/- 10.2 ng/L) and fluoranthene (9.2 +/- 12.0 and 10.6 +/- 25.0 ng/L). Eadie (17) found 15 (+/- 9) ng/L of fluroanthene and 14 (+/- 6) ng/L of both pyrene and benzo(a)pyrene in filtered offshore waters of southern Lake Michigan. The concentration of these compounds on suspended particles was 2-4 ug/g. At a concentration of 1 mg/L of total suspended matter, greater than 75% of these PAHs were in the dissolved phase.

In 1985, large volume sampling was used to determine PAHs associated with the aqueous phase in the St. Marys river, focusing on the industrial and municipal areas of Sault Ste. Marie, Ontario (Table VI-2 and Figure VI-7). Total PAHs in samples taken from Leigh Bay (station #3) and off the Algoma Slag Site (station #4) were similar to the upstream background level of 4.0 ng/L (station #2).

Total PAH concentration increased downstream, reaching a peak concentration of 31.8 ng/L in the Algoma Slip. Benzo(a)-anthracene, which was absent in the upstream samples, was found at levels of 0.23 ng/L at Station #7 and 0.38 ng/L at Station #5. Benzo(a)pyrene was found only at station #5 (0.08 ng/L). Elevated total PAHs, relative to the upstream site, persisted downstream (station #10) at least 1km from the Terminal Basins' discharge. The PAH levels along the Michigan shore (3.2 - 3.6 ng/L) were similar to background concentrations (4.0 ng/L) indicating no transboundary pollution.

In order to provide insight into the partitioning of PAHs, concentrations in the whole water samples as well as those associated with the suspended particulates were determined as part of a centrifuge sampling program in 1986. Twelve stations along the St. Marys River from Leigh Bay to immediately downstream of the Sault Ste. Marie East End WWTP were sampled (Figure VI-8).

Oliver (18) found a significant correlation between octonol/water (K_{OW}) and organic carbon corrected partition coefficients (K_{OC}). Utilizing total organic carbon levels (Figure VI-9), suspended particulate levels (Figure VI-10), PAHs measured on suspended particulates (Table VI-3), and appropriate partition coefficients and assuming that equilibrium had been reached between the PAHs in the aqueous and particulate phases, estimates of both aqueous and whole water PAH concentrations were derived (Tables VI-4 and VI-5, respectively).

TABLE VI-2

PAHs associated with the aqueous phase from APLE sampling in the St. Marys River (1985).

	STATION									
PAHs (ng/L)	2	3	4	5	7	9	10	12	13	14
Phenanthrene	1.48	1.90	1.04	7.50	15.90	13.56	3.45	NA	1.51	1.82
Anthracene	0.18	0.29	0.06	0.88	1.70	1.86	0.36	NA	0.22	0.15
Fluoranthene	0.93	1.33	0.91	10.00	11.64	8.73	3.24	NA	1.33	0.94
Pyrene	0.26	0.40	0.15	1.30	1.59	1.57	0.54	NA	0.32	0.15
Benzo(a)anthracene	-	-	-	0.38	0.23	-	-	NA	-	-
Chrysene	-	0.2	-	0.34	0.33	-	-	NA	-	-
Benzo(b)fluoranthene	0.54	0.05	0.04	0.34	0.29	-	0.11	NA	0.06	0.05
Perylene	0.49	0.096	0.07	-	-	-	-	NA	-	-
Benzo(k)fluoranthene	-	-	-	0.20	-	-	0.07	NA	0.03	0.03
Benzo(a)pyrene	-	-	-	0.08	-	-	0.02	NA	0.02	-
Benzo(g,h,i)perylene	0.09	0.18	0.18	-	-	0.12	-	NA	0.05	0.03
Coronene	0.02	0.02	0.02	0.29	0.12	0.06	0.04	NA	0.02	0.02
TOTAL PAHs	3.99	4.46	2.47	21.31	31.8	25.9	7.83	NA	3.56	3.19

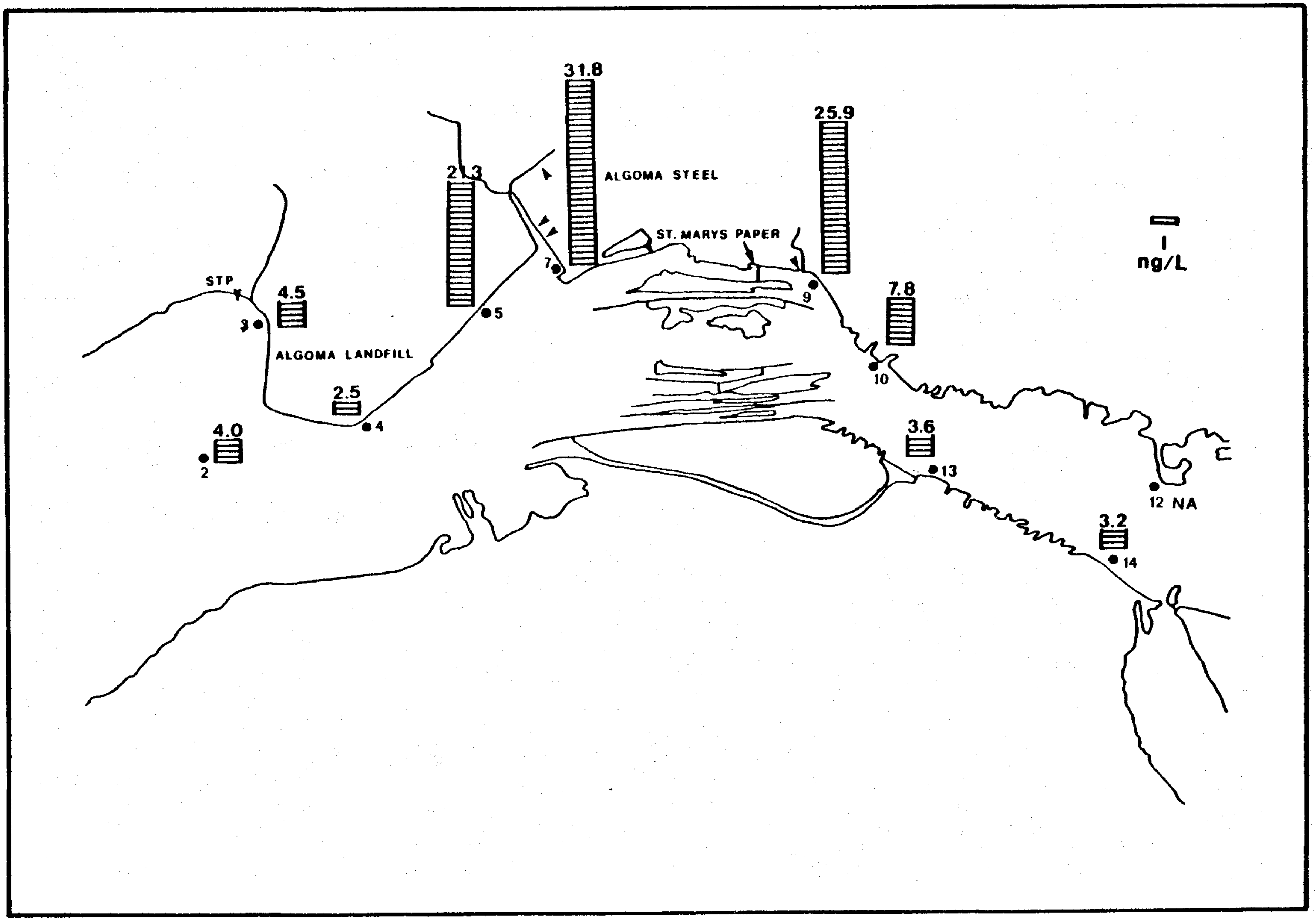

FIGURE VI-7. Total PAHs associated with the aqueous phase from APLE sampling (1985).

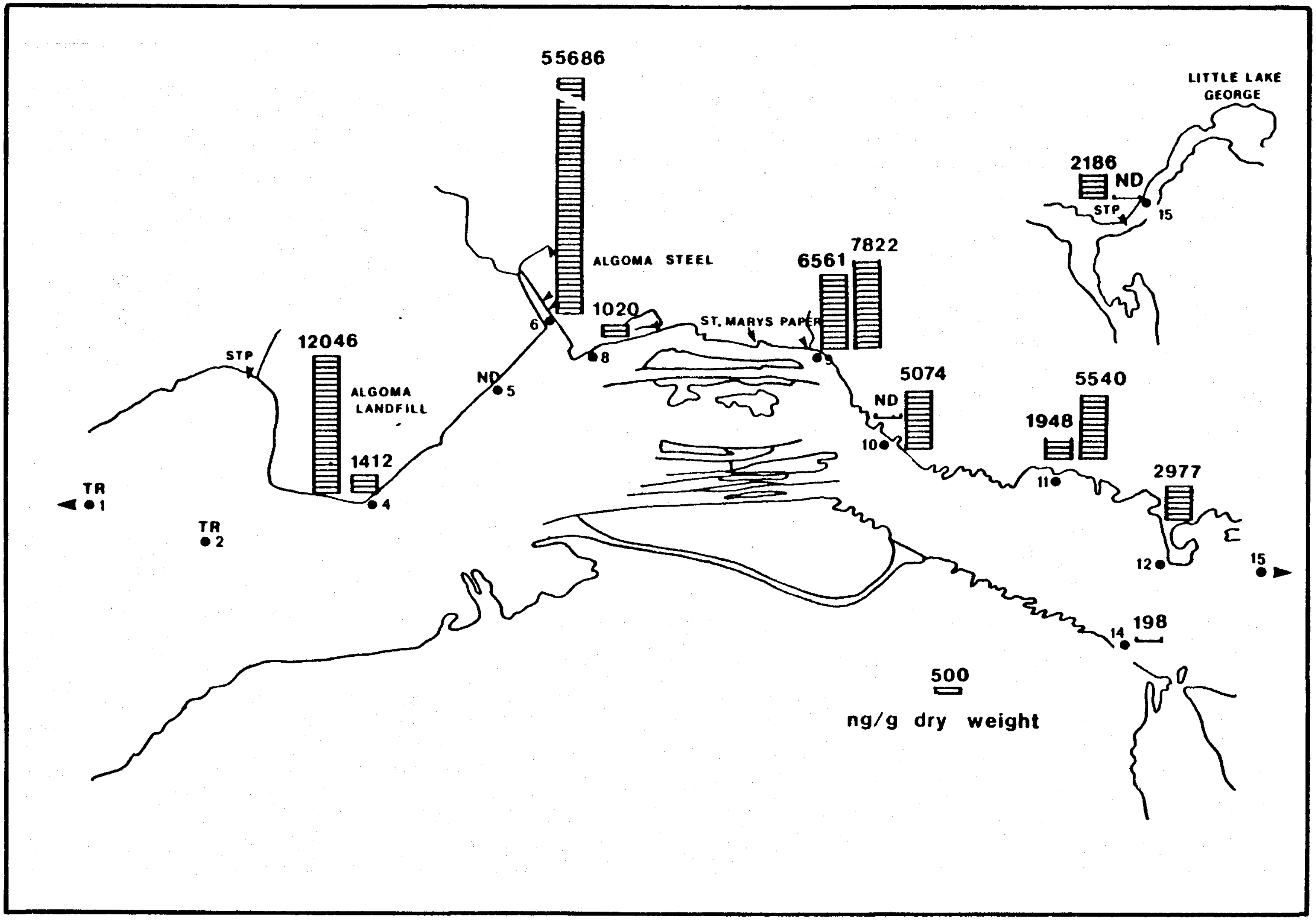

FIGURE VI-8. Total PAHs associated with centrifuged particulate matter (1986).

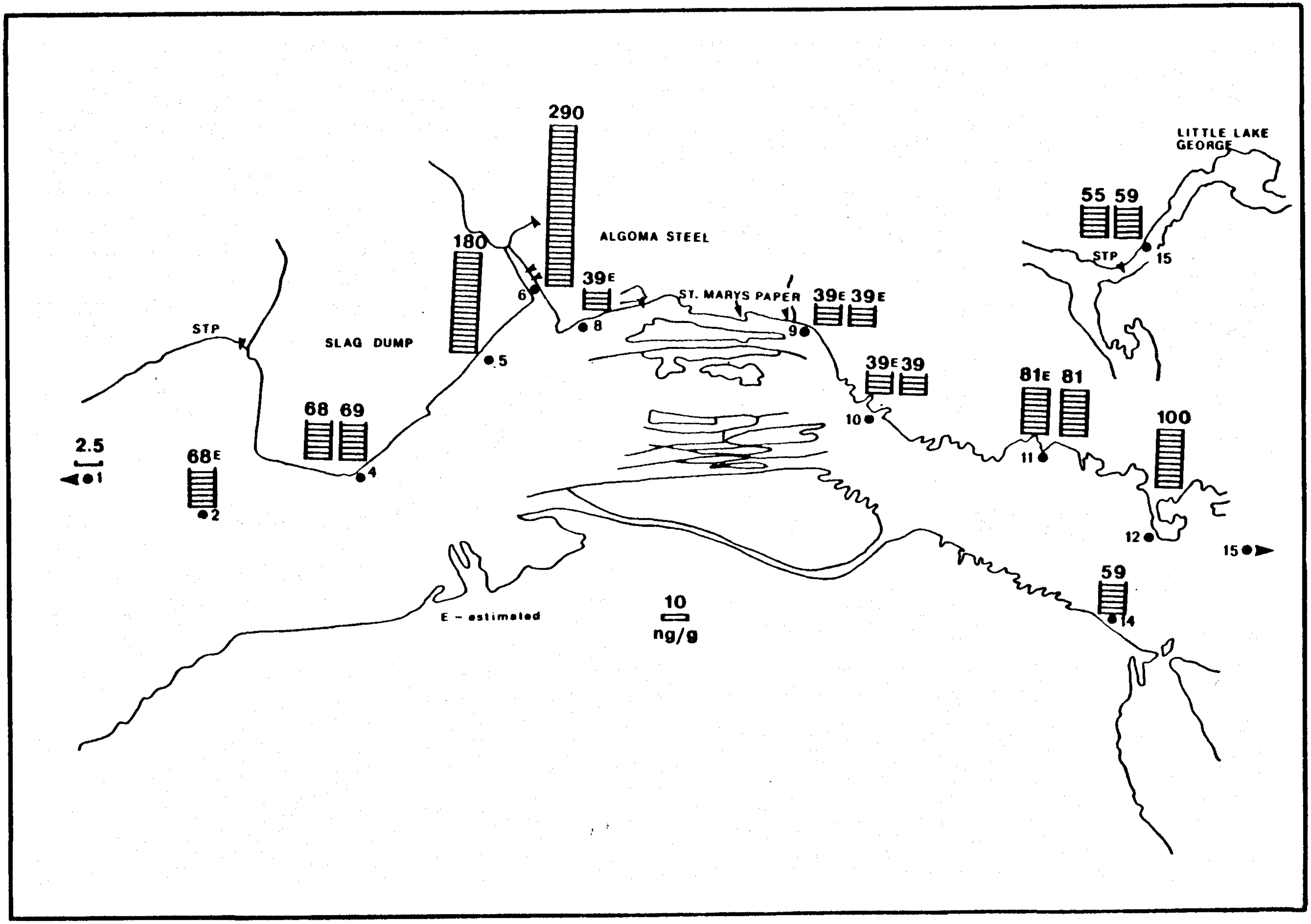

FIGURE VI-9. Total organic carbon levels in St. Marys River (1986).

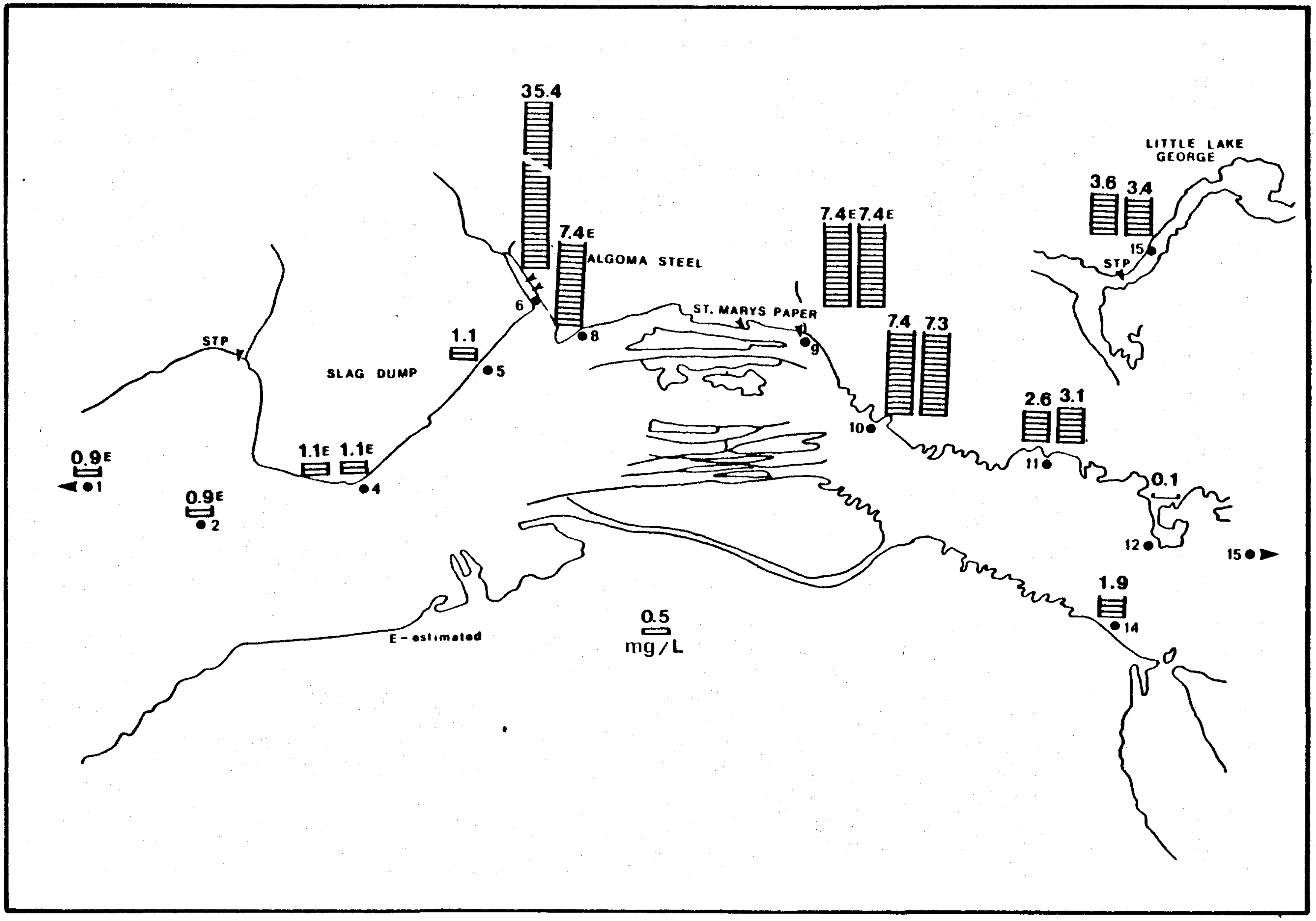

FIGURE VI-10. Suspended particulate levels in the St. Marys River (1986).

TABLE VI-3

PAHs associated with the centrifuged matter in the St. Marys River (1986).

STATION*

PAHs (ng/g Dry Weight)	MDL ng/g)	1	2	4		5	6	8	9		10		11		12	14	15	
			T	T	B	B	B	T	T	B	T	B	T	B	B	B	T	B
Naphthalene	50	ND	ND	ND	ND	ND	2,934	80	1,064	801	ND	ND	1,948	640	278	ND	184	ND
Acenaphthylene	50	ND	ND	ND	ND	ND	623	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acenaphthene	50	ND	ND	ND	ND	ND	1,086	TR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
9 H Fluorene	60	ND	ND	ND	ND	ND	303	TR	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	40	TR	ND	TR	189	ND	8,379	108	509	718	ND	ND	ND	447	ND	ND	189	ND
Anthracene	40	TR	ND	ND	ND	ND	2,444	120	ND	ND	ND	ND	ND	120	ND	ND	ND	ND
Fluoranthene	40	TR	ND	498	ND	ND	7,067	185	1,119	1,377	ND	1,358	ND	957	624	111	335	ND
Pyrene	40	TR	TR	479	290	ND	6,310	151	919	689	ND	1,262	ND	690	469	87	295	ND
Chrysene	50	TR	ND	7,995	233	ND	7,266	78	618	979	ND	TR	ND	538	362	ND	264	ND
Benzo(a)anthracene	50	TR	ND	1,337	286	ND	7,684	109	865	1,258	ND	1,035	ND	680	465	ND	408	ND
Benzo(a)pyrene	50		ND	593	ND	ND	3,882	67	465	650	ND	ND	ND	535	283	ND	ND	ND
Benzo(k) and Benzo(b)fluoranthene	50	TR	ND	1,144	330	ND	5,819	122	1,002	1,350	ND	1,419	ND	933	496	ND	511	ND
Dibenzo(a,h)anthracene	50		ND	ND	ND	ND	336	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	50		ND	TR	84	ND	822	TR	ND	TR	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-c,d)pyrene	50		ND	ND	TR	ND	731	TR	ND	TR	ND	ND	ND	ND	ND	ND	ND	ND
TOTAL PAHs		TR	TR	12,046	1,412	ND	55,686	1,020	6,561	7,822	ND	5,074	1,948	5,540	2,977	198	2,186	ND

ND - Not Detected, TR - Trace

* T - Sample taken 1.5 m below surface.
B - Sample taken 0.5 m off bottom.

TABLE VI-4

Estimated concentrations of PAHs associated with the aqueous phase in the St. Marys River (1986).

STATION*

PAHs (ng/L)	1	2	4		5	6	8	9		10		11		12	14	15	
		T	T	B	B	B	T	T	B	T	B	T	B	B	B	T	B
Naphthalene	NA	NA	NA	NA	NA	1,310.57	35.73	475.27	357.79	NA	NA	870.14	285.88	124.18	NA	82.19	NA
Acenaphthylene	NA	NA	NA	NA	NA	74.90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	NA	NA	NA	NA	50.80	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9 H Fluorene	NA	NA	NA	NA	NA	22.98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	6.55	NA	290.53	3.74	17.61	24.90	NA	NA	NA	15.50	NA	NA	NA	NA
Anthracene	NA	NA	NA	NA	NA	86.72	4.26	NA	NA	NA	NA	NA	4.26	NA	NA	NA	NA
Fluoranthene	NA	NA	2.50	NA	NA	35.42	0.93	5.61	6.90	NA	6.81	NA	4.80	3.13	0.56	1.68	NA
Pyrene	NA	NA	3.02	1.83	NA	39.81	0.95	5.80	4.35	NA	7.96	NA	4.35	2.96	0.55	1.86	NA
Chrysene	NA	NA	17.90	0.52	NA	16.27	0.17	1.38	2.19	NA	NA	NA	1.20	0.8	NA	0.59	NA
Benzo(a)anthracene	NA	NA	2.38	0.51	NA	13.66	0.19	1.54	2.24	NA	1.84	NA	1.21	0.83	NA	0.73	NA
Benzo(a)pyrene	NA	NA	0.54	NA	NA	3.54	0.06	0.42	0.59	NA	NA	NA	0.49	0.26	NA	NA	NA
Benzo(k) & Benzo(b)fluoranthene	NA	NA	0.23	0.07	NA	1.16	0.02	0.20	0.27	NA	0.28	NA	0.19	0.10	NA	0.10	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	0.11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	0.01	NA	0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-c,d)pyrene	NA	NA	NA	NA	NA	0.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL PAHs	NA	NA	26.57	9.49	NA	1,946.54	46.05	507.83	399.23	NA	16.89	870.14	317.88	132.27	1.11	87.15	NA

ND - Not Detected.
TR - Trace.
NA - Not applicable as PAHs were not detected on the centrifuged particulate matter (Table VI-3).

* T - Samples taken 1.5 m below surface.
B - Samples taken 0.5 m off bottom.

TABLE VI-5

Estimated concentrations of PAHs in whole water phase of the St. Marys River (1986).

STATION

PAHs (ng/L)	1	2	4		5	6	8	9		10		11		12	14	15	
		T	T	B	B	B	T	T	B	T	B	T	B	B	B	T	B
Naphthalene	NA	NA	NA	NA	NA	1,414.43	36.33	483.14	363.72	NA	NA	875.20	287.86	124.21	NA	82.85	NA
Acenaphthylene	NA	NA	NA	NA	NA	96.96	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthene	NA	NA	NA	NA	NA	89.24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9 H Fluorene	NA	NA	NA	NA	NA	33.71	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	6.76	NA	587.15	4.54	21.37	30.21	NA	NA	NA	16.88	NA	NA	NA	NA
Anthracene	NA	NA	NA	NA	NA	173.23	5.15	NA	NA	NA	NA	NA	4.63	NA	NA	NA	NA
Fluoranthene	NA	NA	3.04	NA	NA	285.59	2.30	13.89	17.09	NA	16.72	NA	7.76	3.19	0.77	2.88	NA
Pyrene	NA	NA	3.55	2.15	NA	263.19	2.07	12.60	9.45	NA	17.18	NA	6.49	3.01	0.71	2.92	NA
Chrysene	NA	NA	26.69	0.78	NA	273.48	0.75	5.96	9.44	NA	NA	NA	2.87	0.85	NA	1.54	NA
Benzo(a)anthracene	NA	NA	3.85	0.82	NA	285.68	1.00	7.94	11.55	NA	9.40	NA	3.32	0.87	NA	1.54	NA
Benzo(a)pyrene	NA	NA	1.19	NA	NA	140.96	0.56	3.87	5.40	NA	NA	NA	2.15	0.29	NA	NA	NA
Benzo(k) & Benzo(b)fluoranthene	NA	NA	1.49	0.43	NA	207.15	0.93	7.61	10.26	NA	10.64	NA	3.08	0.15	NA	1.94	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	12.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA	0.10	NA	29.15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indeno(1,2.3-c,d)pyrene	NA	NA	NA	NA	NA	0.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL PAHs	NA	NA	39.81	11.04	NA	3,891.94	53.63	556.38	457.12	NA	53.84	875.20	335.04	132.57	1.48	94.32	NA

T - Sample taken 1.5 m below surface
B - Sample taken 0.5 m off bottom
ND - Not detected
TR - Trace
NA - Not applicable as PAHs were not detected on the centrifuged particulate matter (Table VI-3)

Upstream samples (station #1 and #2) exhibited trace amounts of PAHs on the suspended particulates implying that PAHs may only be in the dissolved phase as found in 1985. In the vicinity of the Algoma Slag Site (station #4) the total PAHs associated with the suspended particulate amounted to 12,046 ng/g and 1,412 ng/g at 1.5 m below the surface and 0.5m off the bottom, respectively. These concentrations correspond to an aqueous phase having 27 ng/L and 9 ng/L in the water column, resulting in a whole water concentration of 40 ng/L. This level is above the criterion of 31 ng/L for total PAHs developed by U.S.EPA for the ingestion of aquatic organisms.

In a near-bottom sample from the Algoma Slip, in the vicinity of the 30" and 60" blast furnace sewer outfalls and downstream of East Davignon and Bennett Creeks, the total PAH concentration associated with the suspended particulate phase was 55,686 ng/g. This level, the highest observed in the study area, corresponded to an estimated whole water concentration of approximately 3,900 ng/L, greatly exceeding the U.S.EPA guideline for total PAHs of 31 ng/L. This high concentration may be related to both ongoing discharges as well as past losses, such as spills of coal tar.

At this location, measured concentrations for 12 PAH compounds in whole water (phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)-fluoranthene, benzo(a)pyrene, benzo(g,h,i)perylene, dibenzo-(a,h)anthracene, and indeno(1,2,3,c,d)pyrene) ranged from 504 ng/L to 2,520 ng/L. The upper range of these measured concentrations is similar to the concentrations estimated from the levels associated with suspended particulates for the 12 PAHs (2,258 ng/L). The estimated and measured concentration of benzo(a)-pyrene in the whole water phase in the Algoma Slip locations exceed the interim Ontario drinking water MAC of 10 ng/L. There are no drinking water intakes downstream from the industrial discharges.

Immediately downstream of the Terminal Basins' discharge (station #9), total PAH concentrations associated with the suspended particulates at 1.5 m below the surface (6,561 ng/g) and 0.5 m off the bottom (7,822 ng/g) were similar due to vertical mixing. The estimated total PAH concentrations (naphthalene, phenanthrene, fluoranthene, pyrene, chrysene, benzo(a)pyrene, benzo(b,k)fluoranthene, and benzo(a)anthracene) associated with the aqueous phase were 508 ng/L and 399 ng/L in the samples taken at the surface and 0.5 m off bottom, respectively. The predicted total concentration for the 12 PAH compounds in the aqueous phase of surface water in 1986 was 33 ng/L. This was similar to the measured PAH concentration (same 12 compounds at station #6) of 26 ng/L in 1985. The estimated whole water total PAH concentrations were 556 ng/L and 457 ng/L in samples taken at 1.5 m below the surface and 0.5 m off the bottom, respectively. Both of these estimated levels exceed the U.S.EPA AWQC Human Health Criteria (fish consumption only) for total PAHs of 31 ng/L. The estimated concentration of benzo(a)pyrene associated with the whole water phase averaged 5 ng/L, lower than the interim Ontario MAC of 10 ng/L.

At station #11, located in a sheltered embayment, the total PAHs associated with the centrifuged particulate matter were much greater at the bottom than at the surface, reflecting the characteristics of depositional zone. Compounds attributable to industrial discharges were found in the sample taken 0.5 m off the bottom. The estimated concentration of total PAHs in the aqueous and whole water phases for this sample were 318 ng/L and 335 ng/L, respectively. This level greatly exceeds the U.S.EPA AWQC Human Health Criteria (for fish consumption) for total PAHs of 31 ng/L.

Generally, these elevated PAH levels associated with the suspended particulates persisted downstream of the Terminal Basin's discharge as far as the Sault Ste. Marie East End WWTP in Lake George Channel (Figure VI-8). At station #15, downstream from the Sault Ste. Marie East End WWTP the concentration of total PAHs associated with the suspended particulate matter at the surface was 2,186 ng/L. PAHs at 0.5 m off the bottom were not detected. This reflects the buoyant nature of the WWTP effluent. The estimated total PAHs associated with the whole water phase was 94 ng/L.

Along the U.S. shoreline, downstream of the Edison Sault Electric Company Canal, the concentration of total PAHs associated with the suspended particulates was 198 ng/g. The estimated concentration of total PAHs in the aqueous and whole water phases was 1.11 ng/L and 1.48 ng/L, respectively, considerably lower than levels identified along the Canadian shoreline.

Biota

The OMOE and the U.S. Fish and Wildlife Service (U.S.FWS) have monitored biota from various trophic levels in the St. Marys River since the early 1970s with the aim of defining the health of the river ecosystem. The St. Marys River Biota Workgroup Report synthesizes the published information together with the unpublished results of investigations conducted as part of the UGLCC Study (19,20,21).

i) Phytoplankton

Chlorophyll a showed very similar concentrations in the upstream and downstream reaches of the St. Marys River with a mean value of 0.78 mg/m^3 (4). Similarly, primary productivity studies using Carbon 14 techniques showed relatively low carbon assimilation, ranging from 5.5 to 57.9 mg C/m^2/d. Based on chlorophyll a concentrations, primary productivity and species composition (mainly diatoms) Liston et al. (4) concluded that the phytoplanton community of the river is similar to that of Lake Superior.

ii) Macrophytes and Macroalgae

Production:

Unpublished estimates of total primary production for the St. Marys River made by Duffy et al. (1) show the contribution of emergent plants (4,710 tonnes/yr), is about 20 times that of phytoplankton and periphyton combined but only about 3 times that contributed by submerged plants. Thus, the emergent and submerged plant communities are the major primary producers in the St. Marys River (1,20).

Biomass Drift:

Observations of plant detritus drift in the St. Marys River (1,21,22) indicated a general pattern. In the spring a pulse of plant detritus from the emergent wetlands and from the submerged plant communities further offshore is initially retained and utilized in-situ. Eventually, a portion of the detritus is dispersed to offshore and downstream areas by currents and wave action·

The living component of plant drift constitutes a small fraction of total plant biomass drift as compared to the detritus component. The total living plant biomass entering the St. Marys River from Whitefish Bay in April to October 1986 was approximately 1,555 tonnes wet weight and 77.7 tonnes ash-free dry weight. During the same time the combined total leaving the river through the St. Joseph Channel below Lake George and the outlet of Lake Munuscong was 10,362 tonnes wet and 518 tonnes ash-free dry weight (23).

The drift of detritus and living plant material may be an important mechanism for the redistribution of food resources within the river. However, the drift of plant material containing contaminants may also facilitate the dispersal of contaminants within the river and their transport from the river into Lake Huron.

iii) Benthic Invertebrates

The St. Marys River supports a diverse benthic invertebrate community composed of more than 300 taxa (1). Chironomidae and Oligochaeta are the most numerically abundant. The Ephemeroptera and particularly the burrowing mayflies (Hexagenia and Ephemera) are also abundant, and they may be the most important benthic invertebrates in the river because of their central role in trophic interactions. The Chironomidae are more strongly represented numerically in the upper and middle reaches of the river, while the Oligochaeta and Ephemeroptera are more abundant in the lower river (2,3,6,21,24). Overall, the abundance of benthic invertebrate is highest in the middle reaches of the river, and slightly higher near the head of the river near Whitefish Bay than in the lower reach near Lake Huron (1).

The benthic macroinvertebrate community of the St. Marys Rapids and Lake Nicolet Rapids (5,25) is typical of those found elsewhere in rapids or rocky streams and differs substantially from communities found in other portions of the river (1).

The navigation channels in the river are not intensively colonized by benthic invertebrates (1,2,4). Only Oligochaeta and Chironomidae are common in this habitat and both taxa generally occur only in low densities. Vessel induced turbulence and the removal of soft substrates by dredging are probably responsible for the poor benthic invertebrate community typically observed in the navigation channels.

Studies of impairment in the benthic communities in the St. Marys River were conducted in 1967 (26), 1973 (10), 1974 and 1975 (27), 1983 (28), and 1985 (29,30). Generally, zones with impaired benthic communities corresponded with the occurrence of visible oil and elevated levels of other contaminants in the sediment. Specifically, an inverse relationship between the abundance of Hexagenia nymphs and visible oil in the substrate was noted. Impact zones were restricted to the Ontario portion of the St. Marys River and were found immediately downstream of the discharges of Algoma Steel, St. Marys Paper, and the East End WWTP and in the depositional zones of Lake George. In Michigan waters and all portions of the river upstream of point source discharges, benthic communities were unimpaired. No impacts from transboundary transport of contaminants were apparent along the Michigan shoreline.

To better determine zones of impact, cluster analysis was performed on the 1985 data using various physical, chemical, and biological components of the benthic system (29). Seven major clusters were distinguished and four pollution impairment zones were identified.

1. SEVERE:

This zone is found in the Algoma Slip area and in embayments downstream from the industrial and municipal discharges along the Ontario shoreline of the river. This zone is characterized by extreme tubificid dominance (i.e., L. hoffmeisteri and immatures without capilliform chaetae), pollution tolerant chironomids, low numbers of taxa and high total densities, or communities with either very low total densities and low numbers of taxa, and/or high densities of nematodes with few other taxa.

2. MODERATE:

This zone, mainly confined to the Ontario shoreline, is approximately 500 m wide, extending 4 km downstream from the industrial and municipal discharges. Tubificid dominance with high densities of nematodes and facultative chironomids, absence of polychaete worms, reduced numbers of taxa and high total densities are the major characteristics of this zone.

3. SLIGHT:

Some recovery was apparent with increased distance from industrial and municipal discharges; however, complete recovery was not apparent until the lower section of Lake George. Nematode and polychaete dominate with moderate densities of tubificids and some nontolerant groups are present.

4. UNIMPAIRED:

This zone was found in the upper reaches of the river and along the Michigan side of the river. Communities tended towards chironomid dominance, with several nontolerant groups (e.g. Ephemeropterans and Trichopterans) present, together with low tubificid densities and high numbers of taxa.

The macroinvertebrate community impairment zones are summarized in Table VI-6 and illustrated in Figure VI-11. It is important to realize, however, that areas of the St. Marys River defined as "unimpaired" by benthic community structure analysis may nevertheless be unsuitable or "impaired" habitats to *Hexagenia* when oil is present even in a physically suitable substrate. This organism has a central role in the food webs.

Over the years only slight improvements have been noted in the benthic community in the Ontario waters of the St. Marys River.

Sediment Quality-Benthic Macroinvertebrate Contamination:

Persaud *et al*. (31) examined contaminant concentrations in benthic invertebrates and in corresponding sediments at four stations, located downstream of the discharges of Algoma Steel, St. Marys Paper and the East End WWTP (Figure VI-12).

The <63um size fraction of the sediments includes the very fine sand, silt and clay components. This size range is normally ingested by benthic invertebrates (32). Most chemical contaminants were associated with this fraction. Sequential chemical extractions on the <63um sediment identified six geochemical phases.

TABLE VI-6

Characteristics of benthic community zones in the St. Marys River (1985).

	ZONES			
	Unimpaired	Slight	Moderate	Severe
Common Taxa	Immat.Tubificids w/o chatae *Nematoda Procladius Bezzia *Manayunkia Spirosperma Cricoptopus Pisidium Chironomidae Polypedilum Chironomus Helisoma Amnicola limosa Hyallela Hydracarina Valvata sincera	*Immat.Tubificids w/o chaetae *Nematoda *Manayunkia Nemertea Stylodrilus Pisidium Spirosperma Immat.Tubificids with chaetae	*Immat.Tubificids w/o chaetae *Nematoda Nais variabilis	*Immat.Tubificids w/o chaetae *Nematoda *Chironomidae
Mean No. Taxa	27-40	23	15	12
Mean Total Density (No/m2)	56,000-201,000	192,000	259,000	71,000
Substrate	Variable Silty-Coarse Sand	Coarse Sand w or w/o Silt	Organic Silt	Silt
Water Depth(m)	1-13.7	2.5-14	1-16	1.5-8.5
Macrophytes	Variable	Absent or Sparse	Variable	Usually Absent
Visible Oil	Absent-Very Strong	Absent-Very Strong	Slight-Very Strong	Absent-Very Strong
Current	None-Moderate	Slight-Moderate	None	None-Strong

* Dominant Taxa

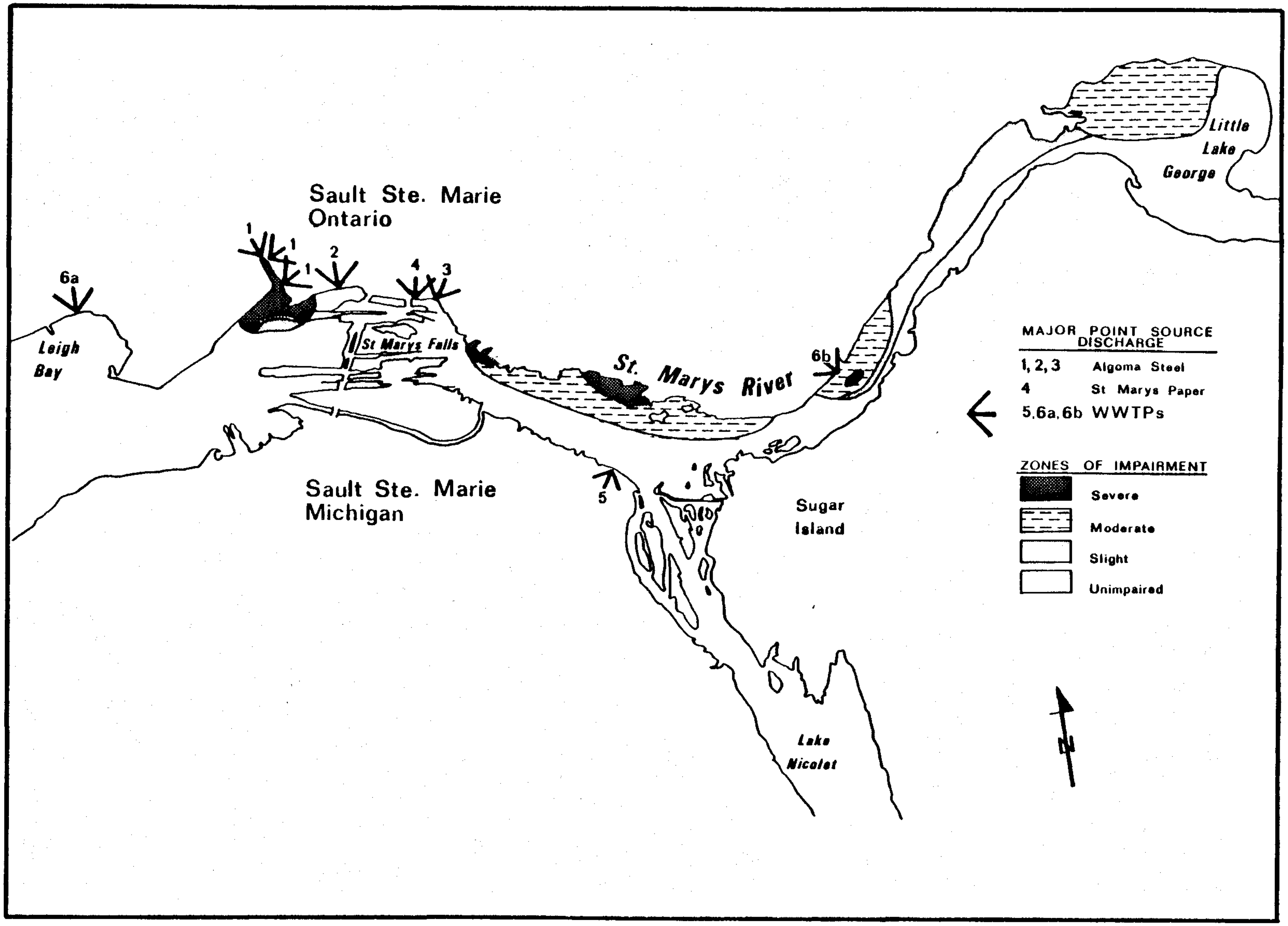

FIGURE VI-11. Distribution and zones of impairment of benthic fauna (1985).

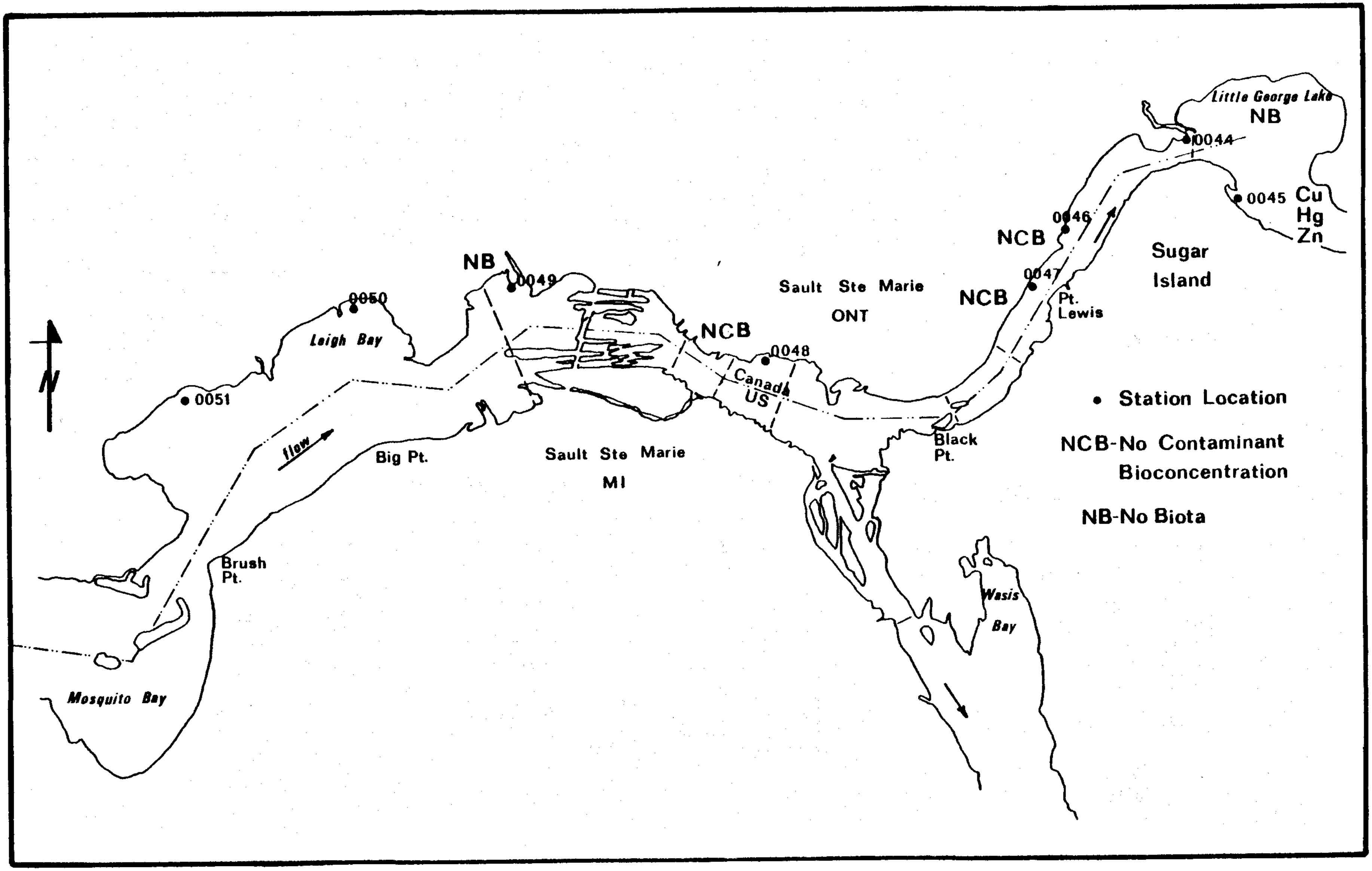

FIGURE VI-12. St. Marys River station locations and parameters showing bioconcentration factors greater than 1.0.

In the St. Marys River, 77% of the copper, 96% of the cadmium, 94% of the lead, 84% of the zinc, 23% of the manganese, and 12% of the iron was in potentially available forms. With the exception of Fe and Mn, most of the potentially available metals were associated with the organic/sulphide fraction. The largest fraction of Fe and Mn was held in the residual phase.

Table VI-7 shows the levels of metals in benthic tissue and sediment and the ratio of the tissue/sediment values referred to as bioconcentration factors. The sediment metal values used in these tables were the "available" metal concentrations obtained from the sequential extraction data. Bioconcentrations factors of copper, zinc and mercury were greater than one only at a station located in Little Lake George (station #45) which had the lowest bulk sediment contaminant levels. The uptake of these three metals was found to be inversely proportional to the organic matter content of sediments, especially the solvent extractables (oil and grease). In areas with high levels of organic matter, uptake was very low, despite the fact that the concentrations of metals were generally at their highest in the sediment. Also, copper and zinc concentrations in organisms appeared to be related to specific geochemical fractions.

These data show that contaminated sediments can be a source of contaminants to benthic organisms. The high levels of contamination and the concentration of certain contaminants in the tissue of these organisms raises concerns related to the potential for transfer of these contaminants to higher organisms that feed on these species. Toxic effects could also result in the complete elimination of benthic organisms or reduction in species diversity and individuals to a few tolerant organisms.

Recently, increased emphasis has been placed on determining the concentrations, distribution and availability to biota of polynuclear aromatic hydrocarbons (PAHs) in river water. In 1985 uncontaminated clams were exposed in cages along the nearshore of the St. Marys River for three weeks. Clams placed in areas downstream from the Canadian discharges accumulated significantly higher levels of PAHs than clams exposed at the upstream locations (Figure VI-13). PAHs accumulated in clams exposed along the U.S. shoreline, but generally at lower levels than along the Canadian shoreline. Caged clams introduced in the Algoma Steel Slip accumulated the highest levels of total PAHs. The degree of accumulation of compounds in decreasing order of magnitude in the Slip were: phenanthrene; fluoranthene; pyrene; acenaphthene; fluorene; naphthalene; anthracene; chrysene/benzo(a)anthracene; and benzo(a)pyrene. Benzo(a)pyrene in clams was well below the proposed IJC objective (33) of 1 ug/g for organisms serving as a food source for fish.(34)

TABLE VI-7

Concentrations of metals in sediment (ppm dry weight) and in benthic tissue (ppm dry weight, gut corrected) and corresponding bioconcentration factors in the St. Marys River.

SAMPLING STATION	COPPER			ZINC			LEAD			CADMIUM		
	S	BT	BCF	S	BT	BCF	S	BT	BCF	S	BT	BCF
45	23.1	22.5	1.0	118.7*	131.3	1.1	54.4*	2.4	0.0	1.0	0.3	0.3
46	166.9*	24.0	0.1	730.3*	115.8	0.2	217.4*	0.2	0.0	3.5*	0.3	0.1
47	89.4*	11.4	0.1	493.8*	107.5	0.2	157.1*	1.2	0.0	2.0*	0.3	0.2
48	168.1*	17.0	0.1	947.3*	110.7	0.1	619.3*	6.8	0.0	4.5*	0.3	0.1

SAMPLING STATION	IRON			MANGANESE			MERCURY			ARSENIC		
	S	BT	BCF	S	BT	BCF	S	BT	BCF	S	BT	BCF
45	6,272.3	1,030.2	0.2	64.9	39.6	0.6	0.1	0.5	5.0	NA	NA	NA
46	15,043.8	258.2	0.0	197.1	12.0	0.1	0.6	0.3	0.5	34.3	18.0	0.5
47	8,949.2	715.1	0.1	128.0	8.5	0.1	0.4	0.1	0.3	NA	NA	NA
48	13,280.3	104.2	0.0	362.4	-1.2**	0.0	0.6	0.0	0.0	NA	NA	NA

S = *Sediment*, BT = Benthic Tissue, BCF = Bioconcentration Factor, NA = Data Not Available

* Exceedes OMOE guidelines for the open water disposal of dredged materials.
** Negative values are the result of extremely low levels of Mn in benthic tissue compared with sediment values.

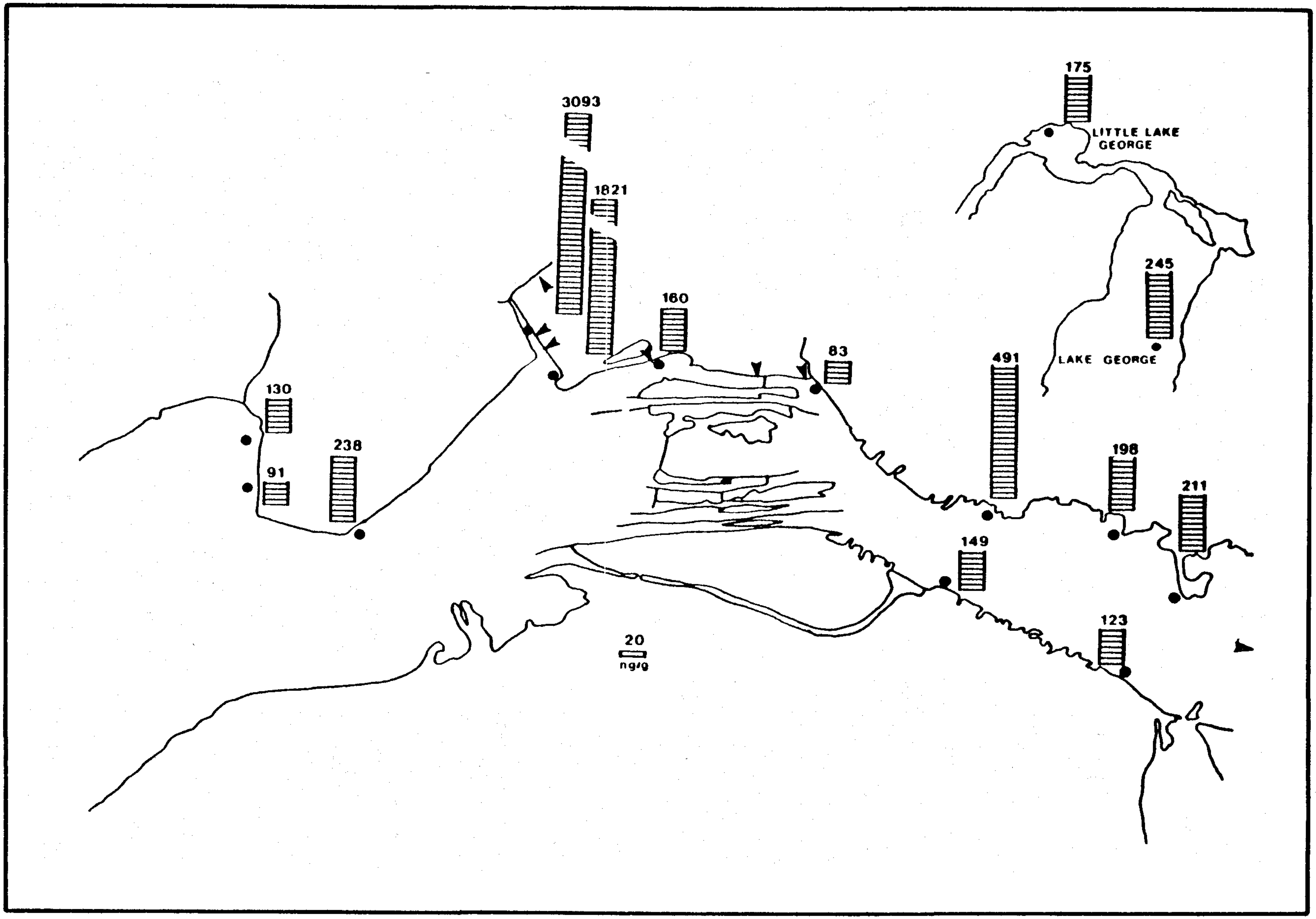

FIGURE VI-13. Total PAH concentrations (ng/g) in caged clams (<u>Elliptio complanata</u>)(1985).

iv) Contaminants in Fish

Sport fish in Ontario waters of the river are tested regularly by the OMOE for dorsal fillet concentrations of selected contaminants (mercury, PCBs, mirex, organochlorine pesticides, and 2,3,7,8-TCDD). As shown in Table VI-8, dieldrin, heptachlor, mirex and 2,3,7,8-TCDD were not detected in any fish samples. PCBs, DDT and lindane were below consumption guidelines. Concentrations of chlordanes, hexachlorobenzene and octachlorostyrene were also low, but there are no guidelines for these parameters.

Only mercury is found in fish in excess of the Canadian federal government guideline for fish consumption in the St. Marys River. Usually, only large specimens of certain species of sportfish contained sufficient mercury to warrant the Ontario government to issue consumption advisories (Table VI-9). There were no fish comsumption advisories issued by the Michigan Department of Public Health for 1988. Data for trend purposes are limited and indicate that trends in mean concentrations of mercury in walleye and northern pike since 1977 are not significant. Mean concentrations of mercury in rainbow trout declined by about 60% between 1978 and 1985.

Young-of-the-year yellow perch collected near Sault Ste. Marie, Ontario contained PCBs, but these concentrations (average 25 ppb) were well below the GLWQA specific objective (100 ppb) for the protection of birds and animals which consume fish (35) and the Ontario and Michigan fish consumption guidelines. No detectable levels of chlorophenols or chlorinated aromatics were found in these fish. Preliminary analysis of whole fish (36) indicate that white sucker and brown bullhead from the North Channel of Lake Huron contained detectable levels of naphthalene, acenaphythylene, acenaphthene, phenanthrene, anthracene, fluoranthene and pyrene. These concentrations were similar to those found in these species from other industrialized areas of the Great Lakes, such as Hamilton Harbour and the St. Lawrence River.

v) Contaminants in Birds

The early 1980s saw a marked resurgence in the number of young produced per active nest of both ospreys and bald eagles. In 1986 and 1987, bald eagles successfully nested on the Munuscong Lake shoreline and produced two young each year.

Limited data are available for current contaminant levels in birds. Monitoring has generally been limited to eggs, owing to the susceptibility of embryos to the effects of toxic organic compounds which bioaccumulate. Common tern eggs that were collected in 1984 from Lime Island had very low or undetectable concentrations of organochlorine compounds (U.S.FWS, unpublished data). The exceptions were p,p-DDE and PCBs. The mean DDE concentrations in 10 eggs was 1.8 ug/g and for PCBs, 0.9 ug/g.

TABLE VI-8

Contaminants in dorsal fillets of sport fish from Ontario waters of the St. Marys River.

Contaminant	Concentration (ppm wet wt.)	
	Consumption Guideline*	Observed Range
Mercury	0.5	0.4-1.30
PCBs	2.0	ND-1.260
Chlordanes (Alpha & Gamma)	NA	ND-0.045
Dieldrin	0.3	ND
DDT and metabolites	5.0	ND-0.486
Heptachlor	0.3	ND
Endrin	0.3	NA
Lindane (Gamma-BHC)	0.3	ND-0.001
Mirex	0.1	ND
Hexachlorobenzene	NA	ND-0.011
Octachlorostyrene	NA	ND-0.009
2,3,7,8-TCDD	0.000020	ND

ND-Not Detected NA-No Data Available

Note: * Health and Welfare Canada guidelines and Great Lakes Quality Agreement specific objectives for the protection of human consumers of fish.

Ontario Ministry of the Environment (OMOE) data (A. Johnson pers. comm.) for individual dorsal fillets of various species collected from the St. Marys River below the rapids, Lake George, St. Joseph Channel and St. Joseph Island since 1982.

TABLE VI-9

Species of sportfish from Ontario waters of the St. Marys River with fillet concentrations of mercury in excess of the Canadian Government Guideline for Fish Consumption (0.5 ppm).

Location	Species*	Size	Hg Concentration Range (ppm)
St. Marys R. (below rapids)	White Sucker	>35 cm	0.5 - 1.0
	Longnose Sucker	>30 cm	0.5 - 1.0
	Walleye	>45 cm	0.5 - 1.0
Lake George	Northern Pike	>65 cm	0.5 - 1.0
	Lake Trout	>55 cm	0.5 - 1.0
	Walleye	45-55 cm	0.5 - 1.0
	Walleye	>55 cm	1.0 - 1.5
St. Joseph Channel	Northern Pike	>75 cm	0.5 - 1.0
St. Joseph Island	Walleye	45-55 cm	0.5 - 1.0

* from "The 1988 Guide to Eating Ontario Sport Fish" (34).

The highest PCB concentration was 7.3 ug/g, a level which could have subtle intrinsic (to the egg) and extrinsic effects in terns. Mercury and selenium levels were not above reasonable background levels reported in bird eggs.

The Canadian Wildlife Service collected herring gull eggs from Pumpkin Point in 1985 and 1986. Only DDE and PCBs exceeded 1 ug/g in 10 egg composite samples, (Dr.C. Weseloh, personal communication). PCBs had the highest concentration, 22 ug/g, in 1985 and 14 ug/g in 1986. Although this is below the perceived toxicological threshold for herring gulls, it is important to recognize that a resistant species with a relatively high body (or egg) burden can be a source of significant contamination if consumed by other predators, such as raptors or mammals.

The concentration of 2,3,7,8-TCDD was also measured in herring gull eggs. Levels were considered in the background range at 4 pg/g in 1985 and slightly above background at 16 pg/g in 1986. Other dioxin-like compounds, including the highly toxic, non-ortho PCB congeners were detected in bullheads and walleye from the St. Marys River in 1984 (U.S.FWS, unpublished data). It is thought that these dioxin-like PCB congeners account for the majority of toxic effects in Green Bay Forster terns (37). Bird samples collected from the St. Marys River have not been analyzed for these congeners.

Bottom Sediments

i) Physical Characteristics

Physical characteristics of sediment samples taken during 1985 from the St. Marys River (38) indicated that sediment composition was strongly related to flow velocities. Sediment composition varied across the river according to the flow distribution. Upstream from the Sault locks, medium and fine sand constituted 80% of the particles. This sediment texture is attributed to the high river velocities in the channel where coarse material settled first and fine materials (silt and clay) remained in suspension and settled in embayments along the Ontario shoreline of the river.

A typical sediment composition from below the rapids at transect SMD 2.6, 4 km downstream of the Algoma Steel discharges is illustrated in Figure VI-14. The Michigan shoreline is characterized mainly by coarse and medium sand which represents about 63% of the sediment composition. Along the Ontario shoreline, where several embayments exist, the sediment is composed of silt (82%). In the mid-river, fine and very fine sand and silt constituted about 90% of the sediment composition. This particle sorting is attributed to the river flow distribution in the lower river where 69% of the total river flow is along the Michigan

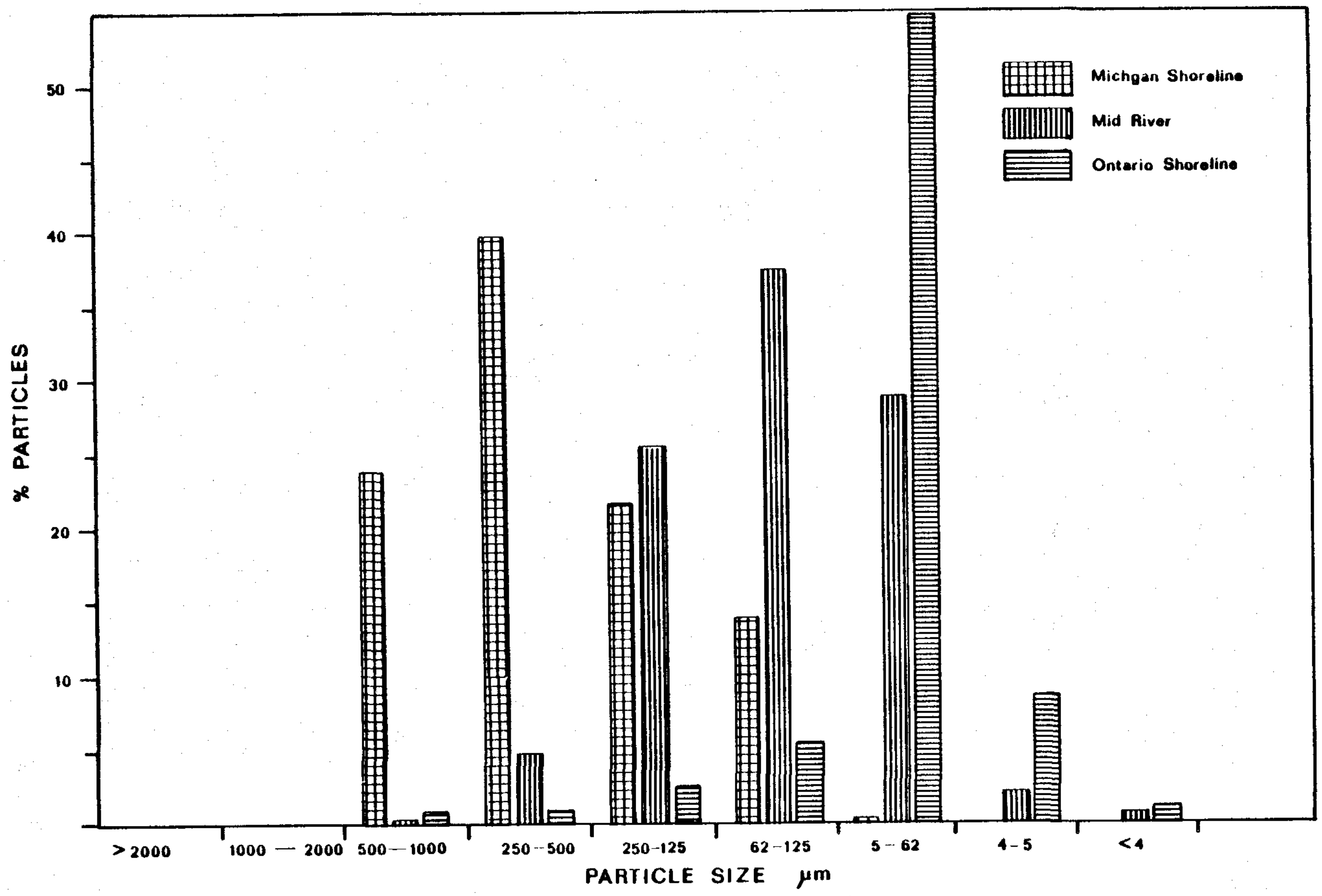

FIGURE VI-14. St. Marys River typical particle size.

shoreline and 31% is along the Ontario side.

ii) Sediment Transport

No bedload transport study was conducted in the St. Marys River. However, sedimentation rates were determined using Cs-137 measurements on two 1985 core samples from Lake George (OMOE stations #100 and 102). The peak of radionuclide Cs-137 occurred at approximately the 15 cm sediment depth in Lake George (Figure VI-15). The testing of large-scale nuclear weapons in the northern hemisphere started in 1954, increased significantly around 1958-59, and peaked during 1962-64. Since then the fallout of debris has decreased markedly. Consequently, in the dating of the sediment, the peak of Cs-137 is referred to the 1962-64 fallout peak activity of the atmospheric testing. This would correspond to a sedimentation rate of 0.22 $g/cm^2/yr$ (0.7 cm/yr) and 0.19 $g/cm^2/yr$ (0.53 cm/yr), or an average of 0.6 cm/yr. Results for sediment mixing for the two samples were 1.3 g/cm^2 (4.7 cm) and 1.7 g/cm^2 (5.8 cm).

In 1986 a joint U.S.EPA and OMOE seismic survey was conducted in portions of the St. Marys River including Lake George and Little Lake George. Preliminary seismic data indicate that the combined thickness of glacial deposits and unconsolidated sediments overlying bedrock exceeds 30 m in Lake George. The thickness of recently deposited sediment in this lake is in the order of 1 m. The data indicate that Little Lake George is also an active depositional area. There is about 0.3 m of sediment over bedrock and glacial deposits.

iii) History of Contamination

The concentrations of PCBs and DDT in the Lake George core taken in 1986 at station #102 are shown in Figure VI-16 (39) together with sediment dates estimated from the Cs-137 profile. The production of PCBs in the United States began in 1929 and peaked in 1970. In the core samples, PCBs are first detected in the segment corresponding to the 1950s and reach their maximum concentration in the early to mid-1970s. DDT usage in the U.S. began in 1944, peaked in 1959, and was banned in 1971. DDT first appears in the mid-1950s part of the core and reached its highest concentration in the early to mid-1960s. The peak concentration of PCBs and DDT in the core occurred approximately 5 years after peak production or usage of the chemicals. The major sources of PCBs and DDT in the area are likely remote and nonpoint, thus, time delays in their transfer to the St. Marys River sediment are likely. The low concentrations of these contaminants in the cores is further support for diffuse remote sources.

The concentration of total PAHs, particularly the PAH, benzo(a)-pyrene, in the sediment core are plotted versus depth and date in Figure VI-17. The PAH concentrations are three orders-of-mag-

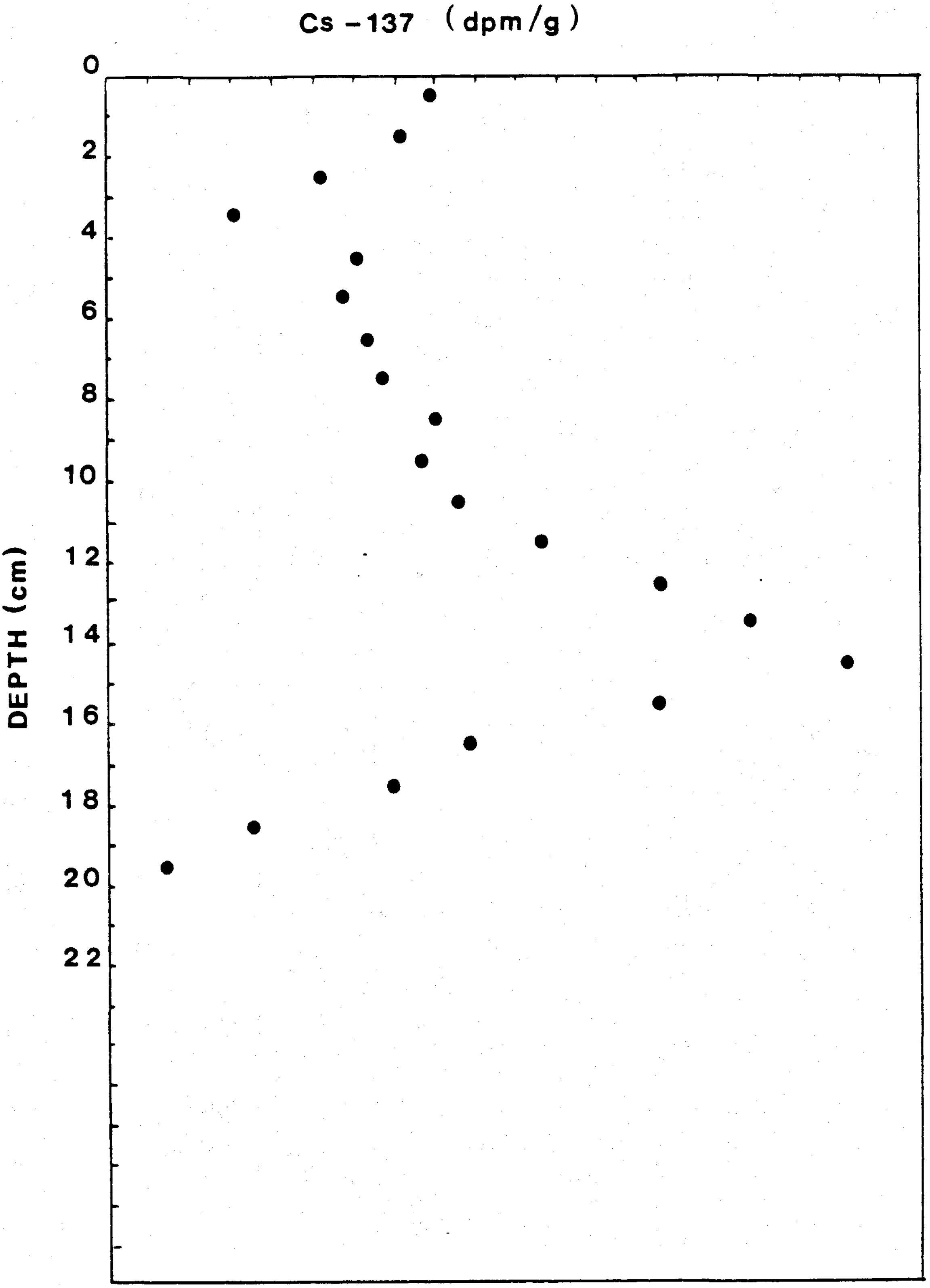

FIGURE VI-15. Variation with depth of ^{137}Cs in Lake George sediments.

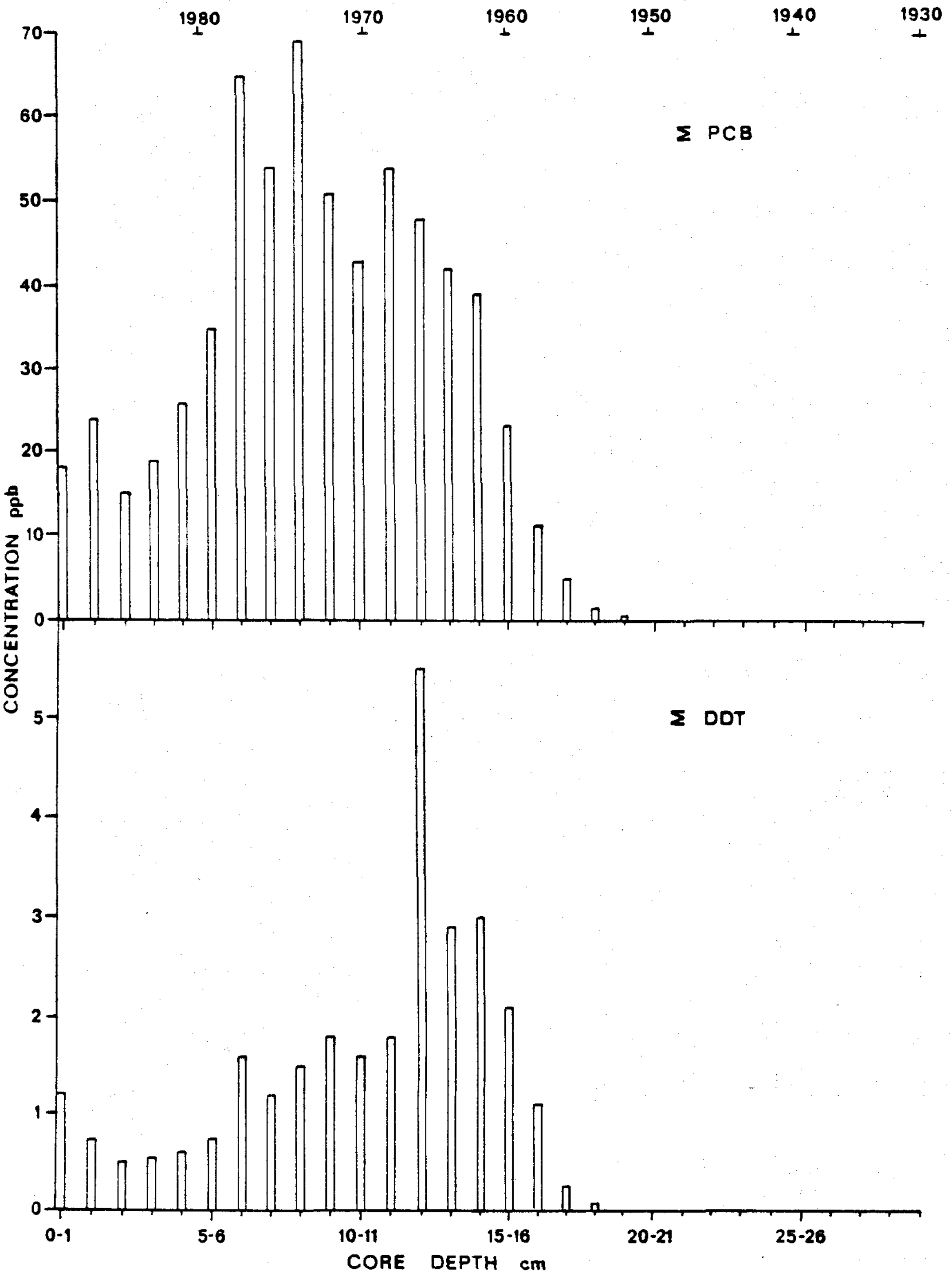

FIGURE VI-16. Total PCBs and DDTs in Lake George sediments (station 102, 1986).

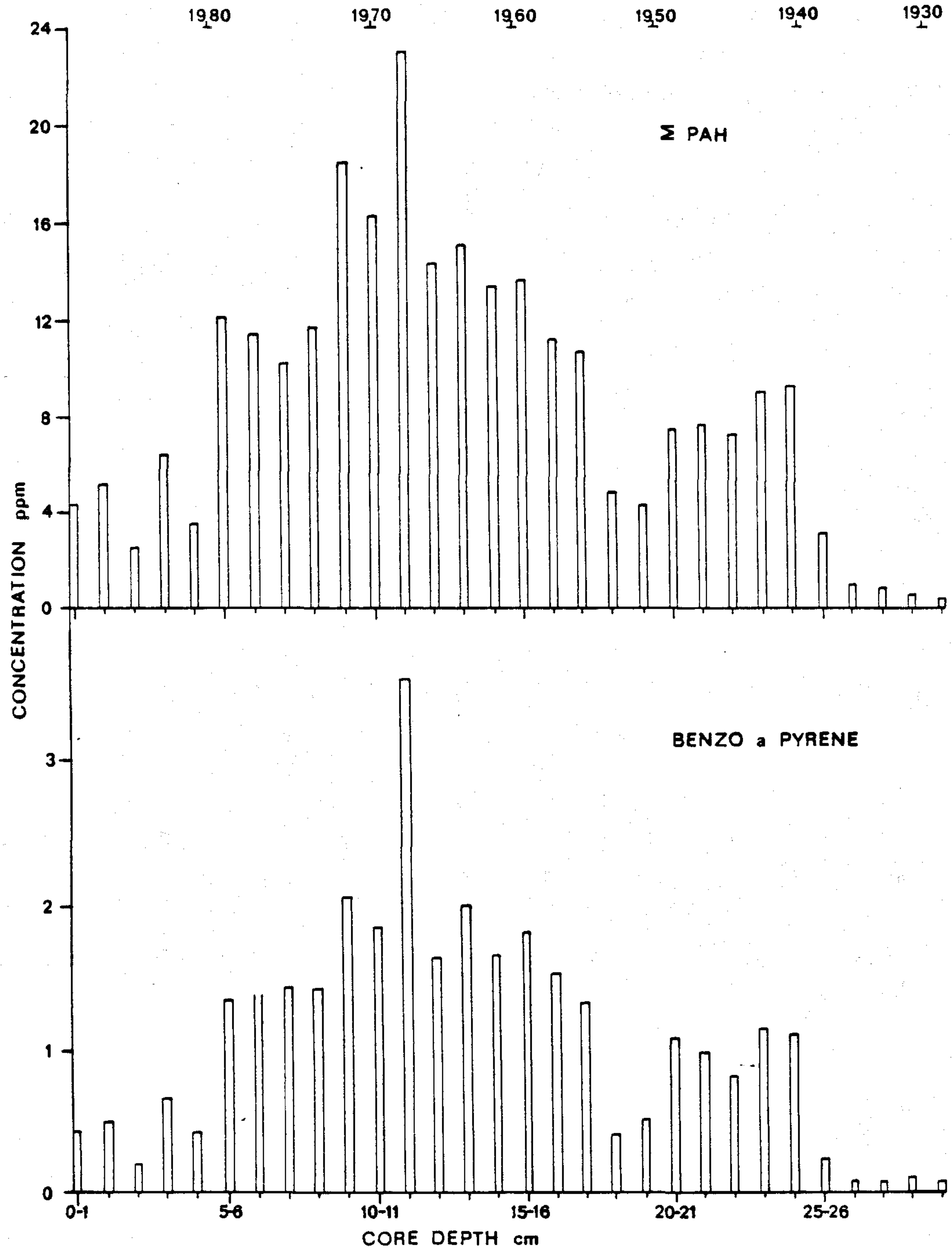

FIGURE VI-17. Total PAH and benzo(a)pyrene in Lake George sediments (station 102, 1986), core depth related to year by ^{137}Cs dating.

nitude higher (ppm versus ppb) than those of the chlorinated organics, indicating major PAH sources in the area. The Algoma Steel Mill in Sault Ste. Marie is likely the principal source of these chemicals to the river, because PAHs are known to be by-products of the coking process. Virtually the same concentration profile was found for total PAHs and for benzo(a)pyrene. The core concentration profile shows that PAH discharges in the area increased substantially in the early 1940s, probably due to increased steel production during World War II. A small lag in steel production occurred in the late 1940s to early 1950s, followed by a sharp increase in the late 1950s, peaking during the late 1960s or early 1970s. The pattern of PAH concentrations in the core segments is in excellent agreement with historical steel production in the area. Much lower concentrations of PAHs are found in the more recent sediments. This is probably due to a combination of lower steel production and improved pollution control.

Changes occurring in the relative distribution of PAH compounds at various core depths are illustrated in Figure VI-18. At a depth of 29-30 cm, corresponding to about 1930, indeno-(1,2,3,c,d)pyrene and benzo(g,h,i)perylene were the major PAHs in the sediment. Benzo(a)pyrene was below the detection limit at this core depth. During the peak of industrialization (1968, 11-12 cm) benzo(a)pyrene was the most dominant PAH but the other 4 and 5-ringed PAHs, pyrene, benzo(a)anthracene, chrysene, benzo-(b)fluoranthene and benzo(k)fluoranthene were also present at high concentrations relative to the other PAHs. In recent surficial sediments (0-10 cm, 1968) naphthalene and phenanthrene represent a significant fraction of the total PAHs, together with the 4- and 5-ringed PAHs. The concentrations of naphthalene and phenanthrene in the core are much less variable than benzo(a)-pyrene, indicating that they may originate from a different source.

Results for heavy metals in the core from Lake George (OMOE station #102) are presented in Table VI-10 (40). Only the first 20 cm of the core were analyzed. Distributions of Ni, Co, V and Cu were relatively uniform with depth but Zn, Pb and Cr were not. Zinc increased gradually from 185 to 410 ug/g between 4 and 12 cm and then decreased back to 139 ug/g at 20 cm depth (Figure VI-19). Lead peaked at 94 ug/g in the 10-11 cm segment and decreased to 39 ug/g at 20 cm of depth. Chromium peaked at 189 ug/g in the 15-16 cm section. Using the estimated sedimentation rate of 0.7 cm/yr for this sample, zinc, lead and chromium reached peak concentrations in the river around 1968-70.

The distribution of oil and grease in the core (Figure VI-19) was different than for total PAHs and zinc. Oil and grease increased gradually from 2,700 to 3,580 ug/g between 0 and 7 cm depth, increased drastically to 8,190 ug/g in the 7 to 8 cm segment (mid-1970s) and then decreased gradually to 360 ug/g at 30 cm.

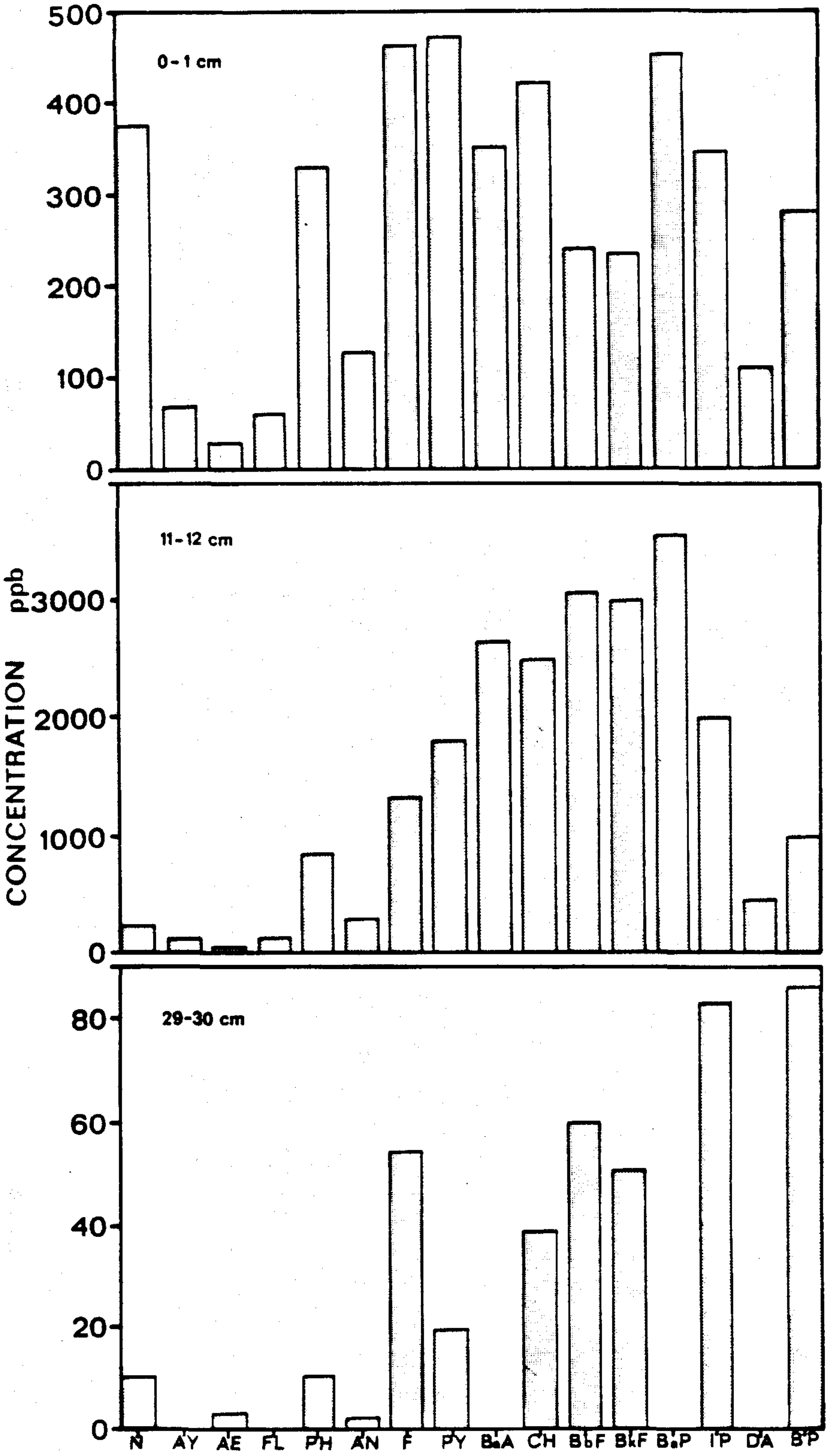

FIGURE VI-18. Vertical distribution of PAHs in Lake George sediments (station 102, 1986).

TABLE VI-10

Results from metal analyses in a sediment core sample collected during 1986 at OMOE station 102 in Lake George (ug/g, dry weight).

Depth cm	Ni	Co	Cr	V	Zn	Cu	Pb
0-1	41	18	95	59	199	35	41
1-2	41	16	107	50	191	34	37
2-3	45	17	95	57	193	35	39
3-4	42	91	91	54	185	35	35
4-5	44	17	99	60	238	35	48
5-6	44	20	98	54	259	34	51
6-7	44	17	100	60	328	35	61
7-8	43	18	102	57	332	35	61
8-9	43	17	99	57	369	41	75
9-10	44	18	104	60	365	38	82
10-11	45	19	111	60	384	39	94
11-12	42	19	121	65	410	39	89
12-13	42	17	123	68	407	37	78
13-14	39	18	141	63	379	33	72
14-15	41	18	184	68	334	34	71
15-16	39	18	189	63	257	29	62
16-17	39	17	152	67	227	33	57
17-18	43	16	117	62	188	33	48
18-19	41	16	94	63	154	34	42
19-20	40	16	89	63	139	37	39

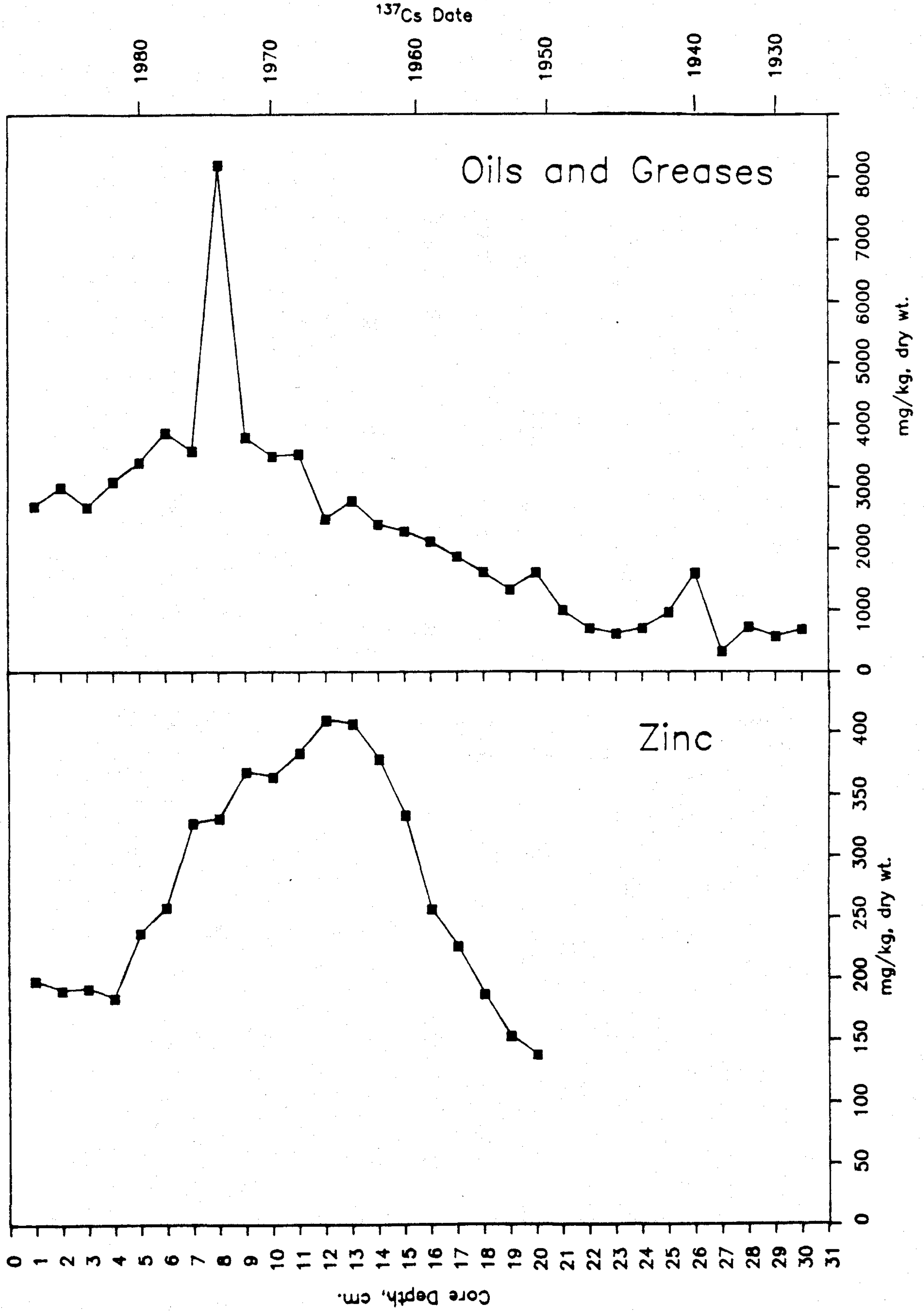

FIGURE VI-19. Oils and greases, and zinc in Lake George sediments (station 102, 1986).

In summary, results from the core sample reflect the effectiveness of the ban on DDT and PCB and the reduction of total PAHs, oil and grease, zinc, chromium and lead loadings to the St. Marys River over the past 20 years.

iv) Spatial Distribution of Contaminants in Surficial (Recent) Sediments

During 1985, the U.S.EPA and FWS collected sediment samples from 125 stations (Figure VI-20) covering the entire St. Marys River (41). The OMOE collected sediment samples at 71 river stations (Figure VI-21) and 8 Canadian tributaries (38).

In comparing the levels of contaminants in sediments, comparison is made to the OMOE Guidelines for Dredge Spoils for Open Water Disposal and the U.S.EPA Guidelines for Pollutional Classification of Great Lakes Harbor Sediments (Table III-4, Chapter III). These guidelines are not based on biological effects and, therefore, will not provide insight into impacts on the river ecosystem. However, their use provides a comparison of relative concentrations. There are no ecologically based sediment guidelines.

Hesselberg & Hamdy (38) found that oil and grease, loss on ignition (total volatile solids), cyanide (CN), arsenic (As), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn) exceeded both U.S.EPA and OMOE guidelines in 20% or more of the samples in at least one group of samples (Table VI-11). Concentrations of chromium, copper, and iron (Fe) most consistently exceeded both U.S.EPA and OMOE guidelines.

The percent of samples exceeding both U.S.EPA and OMOE guidelines in the vicinity of industrial discharges, as well as further downstream, are shown in Table VI-12 (33,34,35,36,37,38,39,40,41, 42). Percents were calculated using the lowest of U.S.EPA moderately polluted or OMOE guidelines for each contaminant. It is apparent from Table VI-12 that the area near Algoma Steel, the City of Sault Ste. Marie, Ontario, and Little Lake George represent the most contaminated areas in the St. Marys River. However, as shown by the spatial distribution of zinc and oil and grease in surficial sediments during 1973 and 1983 (42), both the areal and downstream extent of heavily polluted sediments has decreased (Figures VI-22 & 23). This coincides with the core data from Lake George (Figure VI-19).

Contaminant concentrations in Lake George sediment samples were lower overall. However, over 20% of the samples exceeded the guidelines for most contaminants except for PCBs and cadmium. Lake Nicolet sediment samples exhibited a much lower frequency of contaminants exceeding guidelines but As, Cr, Cu, Fe, Ni and Zn still exceeded guidelines in 14% or more of the samples. In Lake Munuscong and Lime Island Channel a surprising percent of samples

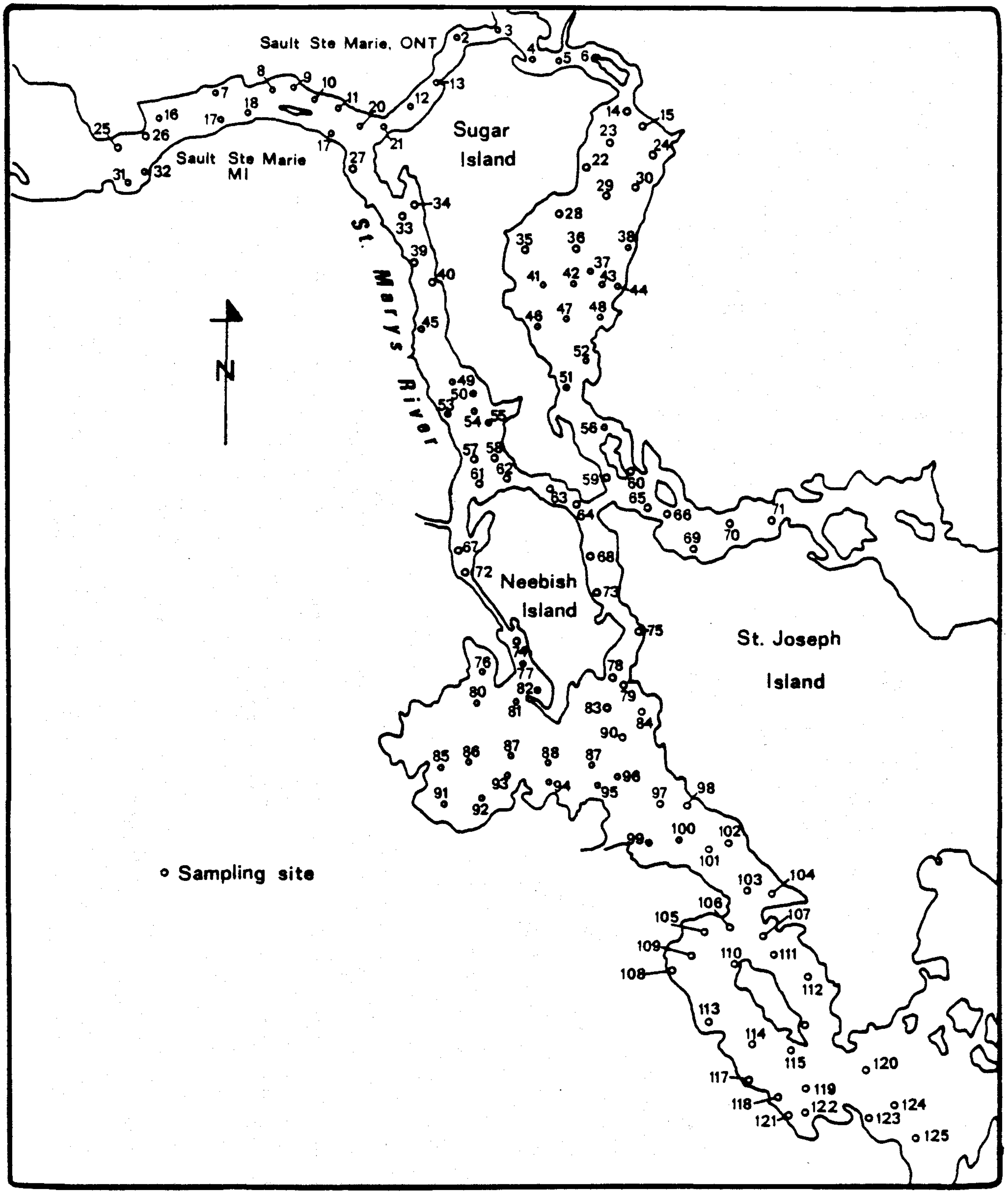

FIGURE VI-20. U.S. EPA/FWS St. Marys River 1985 sediment sampling sites.

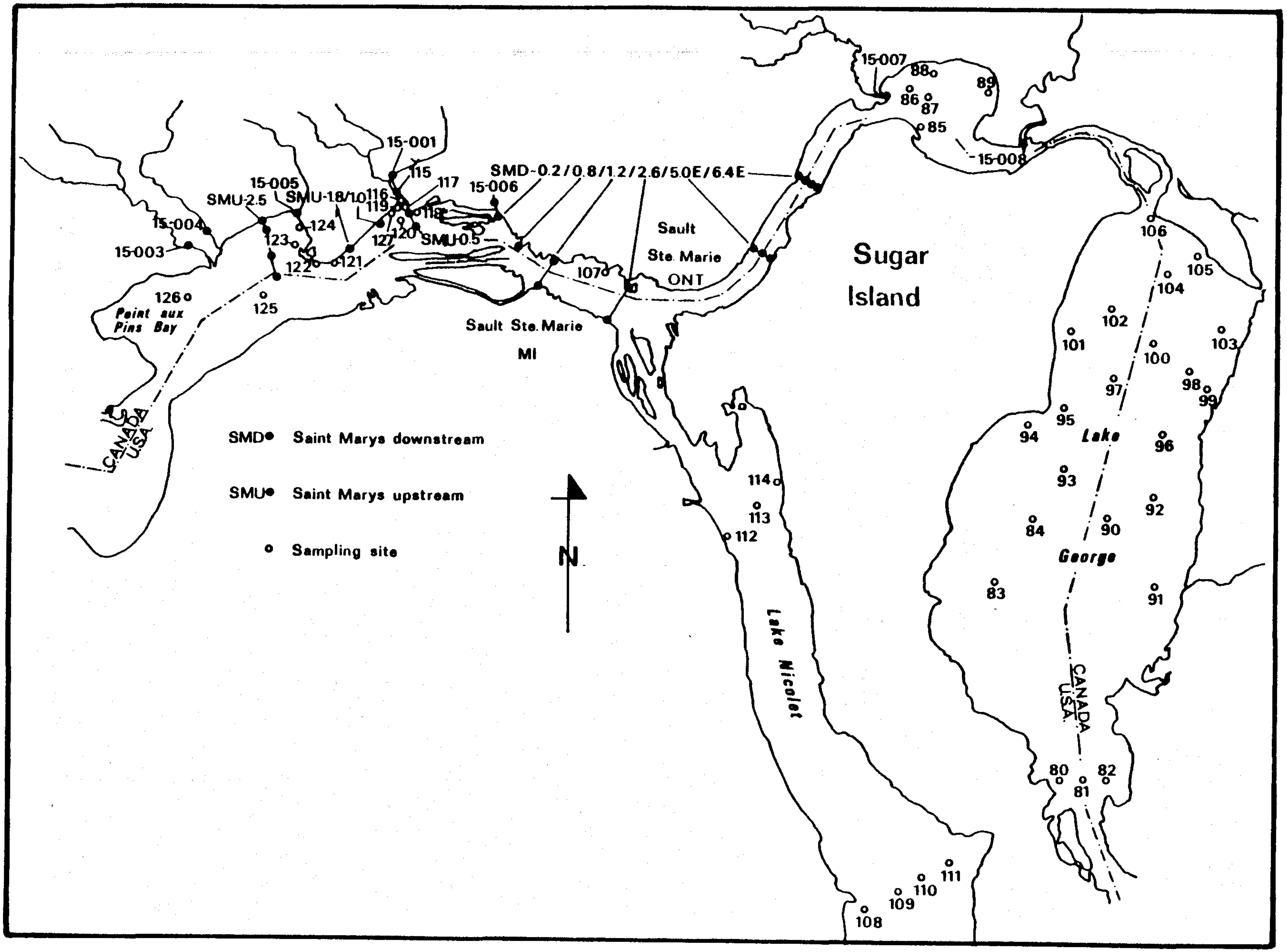

FIGURE VI-21. MOE 1986 St. Marys River sediment sampling sites.

TABLE VI-11

Percent of sediment samples collected from the St. Marys River during 1985 by U.S.EPA, USFWS, or OMOE that exceeded moderately polluted U.S.EPA and/or OMOE sediment pollutation guidelines given in mg/kg, except where noted.

Sources of Samples	Total Samples	Oil and Grease	Percent Loss on Ignition	P	TKN	Cyanide	PCBs	As	Cd	Cr	Cu	Fe%	Pb	Hg	Ni	Zn
		% Exceeding U.S.EPA Moderately Polluted Guidelines														
Guidelines		1000	5	420	1000	0.1	1*	3	<6*	25	25	1.7	40	1	20	90
U.S.EPA 1985	19	5	5	63	10	100	0	0	0	44	17	26	0	0	32	0
U.S.EPA/FWS 1985	125	17	18	NA	NA	78	1	NA	0	56	34	NA	11	0	34	18
OMOE 1985	71	42	28	45	35	NA	0	58	0	58	49	44	34	0	21	49
		% Exceeding OMOE Guidelines														
Guidelines		1500	6	1000	2000	0.1	0.05	8	1	25	25	1	50	0.3	25	100
U.S.EPA 1985	19	0	5	0	0	100	0	0	0	44	17	47	0	0	32	0
U.S.EPA/FWS 1985	125	10	12	NA	NA	78	27	NA	4	56	34	NA	9	1	19	17
OMOE 1985	71	38	21	0	NA	NA	14	31	3	58	49	66	23	1	6	46

NA - Not analyzed or not available

* - Heavily polluted

TABLE VI-12

Percent of samples by area at or exceeding U.S.EPA moderately polluted or OMOE sediment pollution Guidelines.

Area Location	Agency Samples	No. Samples	Oil and Grease	Loss on Ignition	Total PCBs	As	Cd	Cr	Cu	Fe	Pb	Ni	Zn
Algoma Steel	U.S.EPA/FWS	8	25	38	12	NA	0	50	38	NA	38	12	38
Sault Ste. Marie	OMOE	9	56	55	11	89	0	78	67	89	44	22	56
Little Lake George	U.S.EPA/FWS	4	50	50	50	NA	50	50	50	NA	50	50	50
	OMOE	5	100	60	20	100	20	0	100	100	60	4	100
Lake George	U.S.EPA/FWS	24	21	12	17	NA	0	33	29	NA	21	25	29
	OMOE	22	45	32	0	72	5	64	59	95	32	36	59
Lake Nicolet	U.S.EPA/FWS	15	0	7	33	NA	7	33	NA	NA	7	7	7
	OMOE	7	14	0	0	29	0	29	14	29	0	14	14
Lake Munuscong	U.S.EPA/FWS	30	0	0	30	NA	0	77	37	NA	0	43	0
	OMOE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lime Island Channel	U.S.EPA/FWS	21	19	5	0	NA	0	76	52	NA	0	62	19
	OMOE	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA = Data not available or not analyzed

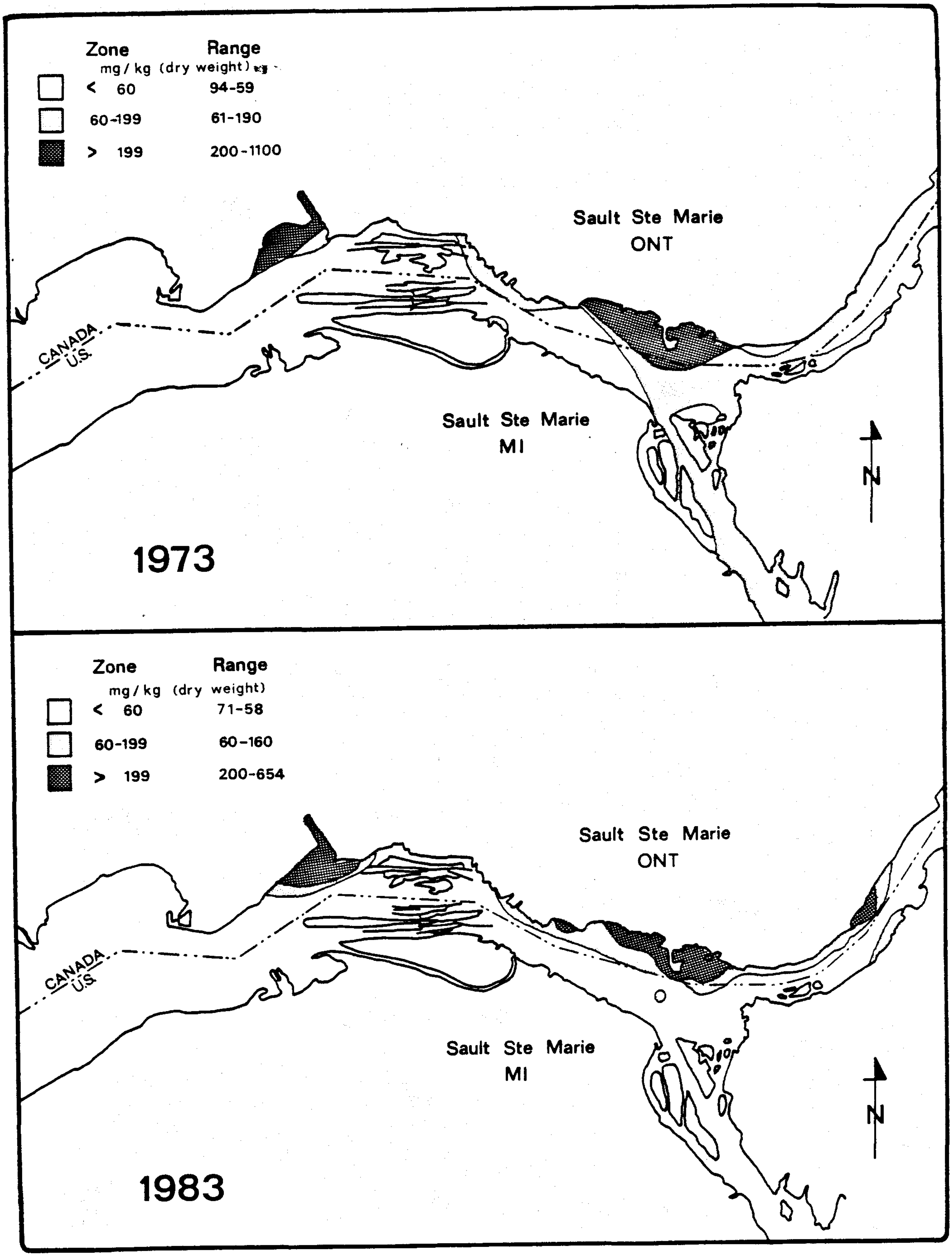

FIGURE VI-22. Distribution of zinc in the St. Marys River surficial sediments.

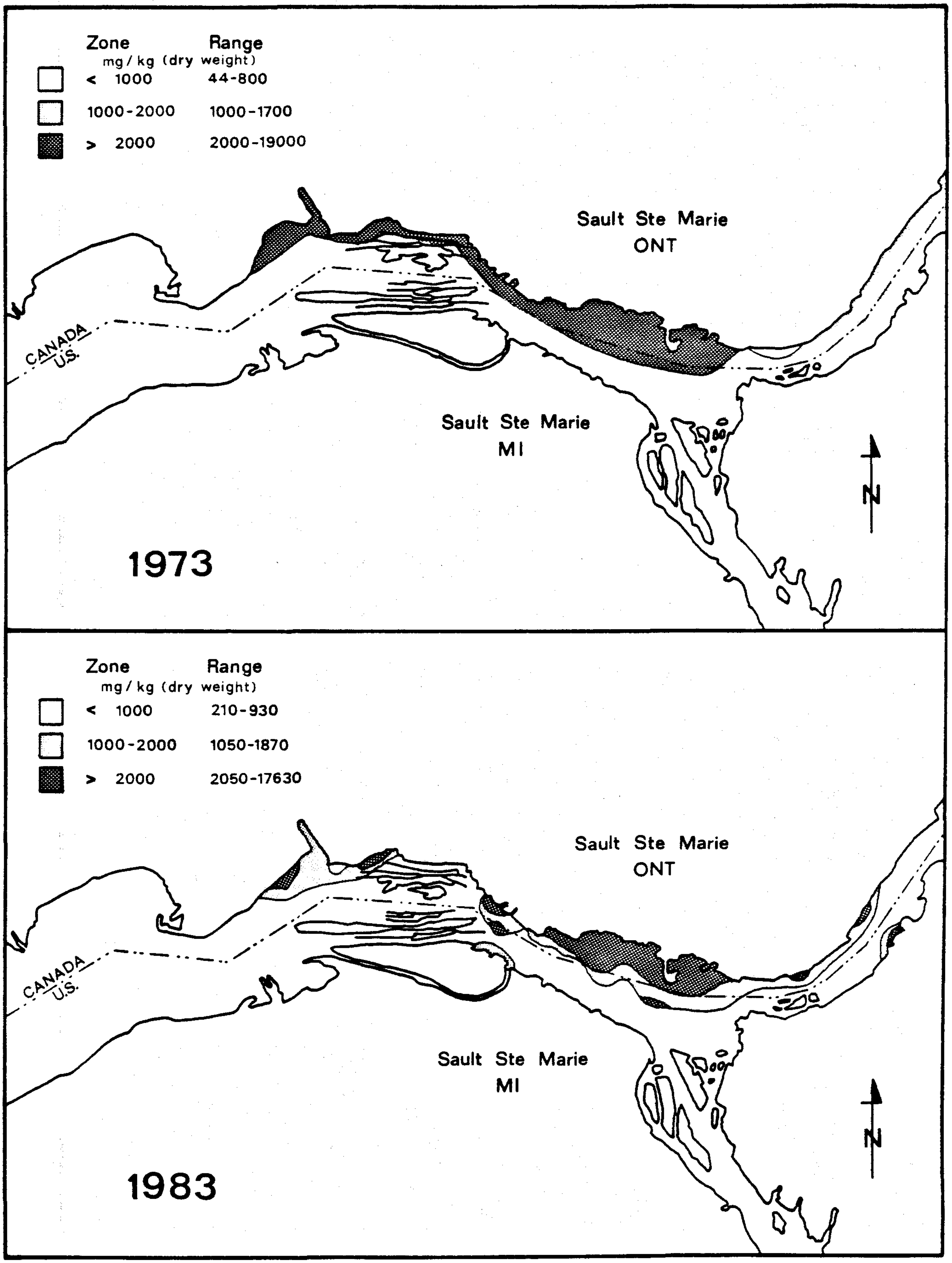

FIGURE VI-23. Distribution of oil and greases in the St. Marys River surficial sediments.

exceeded guidelines for Cr, Cu, and Ni. It appears these elements settled out with the sediment in the slower moving waters.

Most chlorinated organic contaminants had low concentrations in the sediment. PCBs exceeded OMOE guidelines in the upper river; however, no more than 1% of the total samples exceeded the U.S. EPA moderately polluted guideline.

The distribution of PAH compounds (Figure VI-24) indicated that sediment from the Algoma Slip contained the highest levels of total PAHs (711 ug/g). Individual compounds, notably acenaphthene, phenanthrene, anthracene, fluoranthene, pyrene, dibenzothiophene and carbazole in the Algoma Slip area were also the highest levels in the river as shown in Table VI-13. A semiquantitative analysis of samples collected during a coal tar spill investigation in Bennett Creek during 1987 indicated that total PAH concentrations (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benzo(a)anthracene, benzo(b,k)fluoranthene, (benzo(j)fluoranthene, benzo(e)pyrene, benzo(a)pyrene, perylene, indeno(1,2,3-c,d)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)-perylene) were approximately 3,300 ug/g. Bennett creek flows into the Algoma Slip. The Algoma Steel and/or Domtar Inc. operations are likely the major source of PAHs to the slip and Bennett Creek and subsequently to the St. Marys River.

As a result of the strong association of PAHs with silt and clay, higher concentrations of PAHs were found in the embayments downstream from the Terminal Basins than those observed in non-embayments immediately downstream from the discharge.

Along the Michigan shore, with the exception of a location immediately downstream from the Edison Sault Electric Company Canal, total PAHs were similar to background levels (Figure VI-24). Total PAH concentrations immediately downstream of the Edison Sault Electric Company Canal (334 ug/g) may be the result of historical inputs from a coal stockpiling operation on the shore.

Few guidelines are available for PAHs in sediments. However, the IJC has (1983) (33) proposed an objective of 1 ug/g for benzo(a)-pyrene. This concentration was exceeded along the Ontario shoreline in samples from the east end of the Algoma Slag Site to as far downstream as the beginning of the Lake George Channel and also below the Edison Sault Canal in Michigan.

Tributaries may also contribute contaminants to the river system. In the vicinity of Algoma Steel and the City of Sault Ste. Marie Ontario, tributaries such as East Davignon and Fort Creeks are likely sources of As, Cr, Cu, Fe and oil and grease. Fort Creek is also likely a source of Ni, Pb, Zn and total PCBs. The levels of Cr, Ni and Fe in McFarland Creek, a tributary to Little Lake

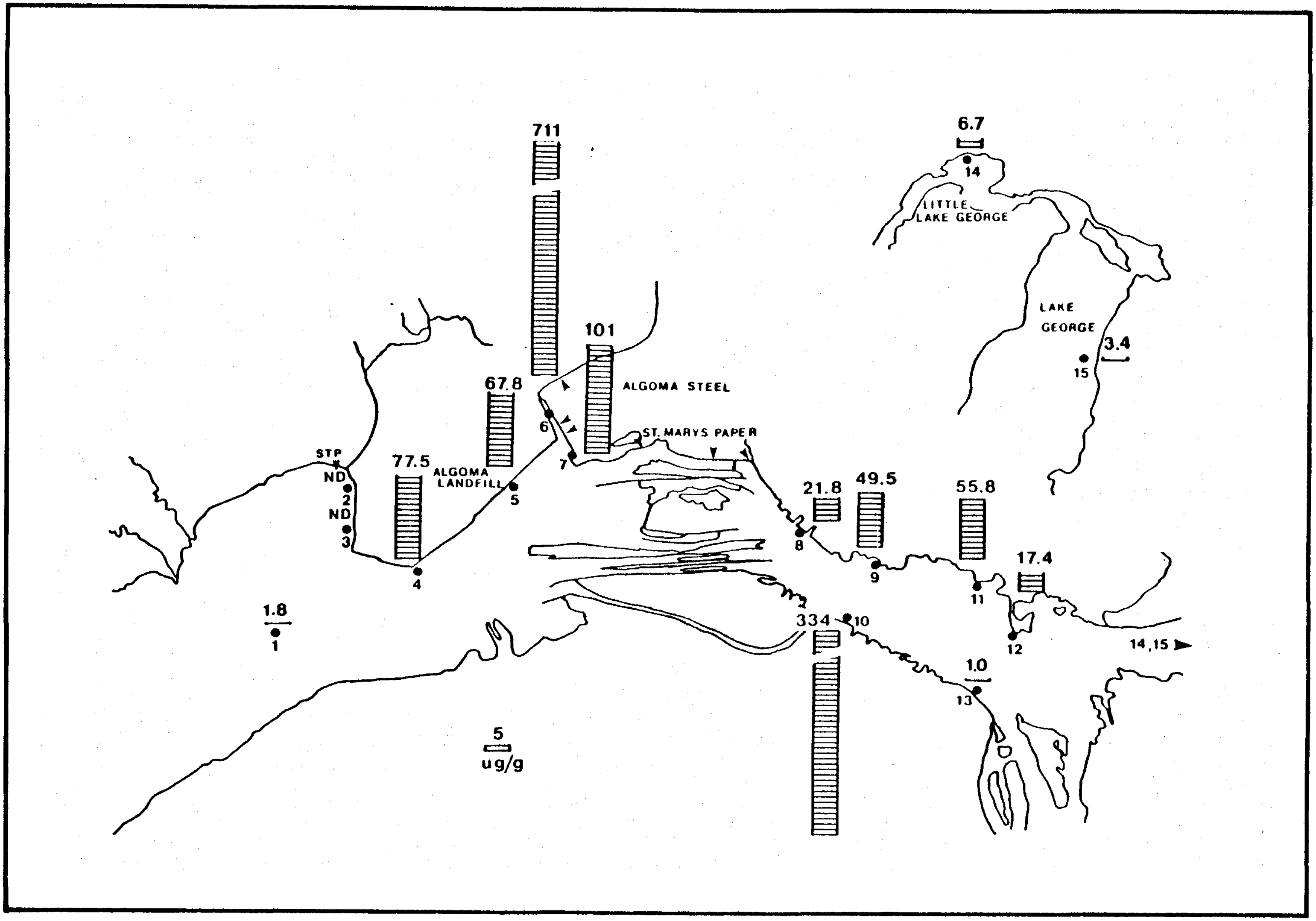

FIGURE VI-24. Total PAHs in surficial sediments in the St. Marys River (1985).

TABLE VI-13

PAHs in sediments in the St. Marys River, 1985 (ug/g).

COMPOUNDS	STATION														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Naphthalene	ND	ND	ND	0.06	3.4	29	33	0.06	5.9	0.69	6.6	1.7	0.03	0.13	0.125
Acenaphthylene	0.2	ND	ND	0.08	0.93	4.8	0.42	0.42	0.55	4.6	0.52	0.55	ND	0.18	0.07
Acenaphthene	ND	ND	ND	ND	1.1	19.5	0.93	ND	0.18	0.62	0.17	ND	ND	ND	ND
Fluorene	ND	ND	ND	ND	2.3	28.5	1.9	0.06	0.47	3.4	0.36	0.17	ND	ND	0.03
Phenanthrene	0.07	ND	ND	0.86	13	185	14	0.29	3.9	25	2.2	1.1	0.09	0.4	0.25
Anthracene	0.1	ND	ND	ND	4.5	37	3.5	0.22	1.4	10	1.0	0.52	0.03	0.18	0.07
Fluoranthene	0.14	ND	ND	4	11	135	13	0.53	6.4	30	3.7	1.7	0.12	0.59	0.425
Pyrene	0.09	ND	ND	3	5.6	71.5	7.4	0.32	3.6	17	2.2	1.1	0.07	0.36	0.27
Chrysene	ND	ND	ND	3.4	1.1	9.3	1.5	0.26	1	9.9	1.0	0.45	0.02	0.14	0.06
Benzo(a)anthracene	0.21	ND	ND	18	4.2	32	5.5	1.3	4.6	36	4.2	2.1	0.09	0.55	0.28
Benzo(b,k)fluoranthene	0.44	ND	ND	16	4.8	32.5	4.3	5.5	6.2	67	11.0	2.8	0.13	0.97	0.325
Benzo(j)fluoranthene	ND	ND	ND	1.1	0.9	5.5	0.64	1.8	1.1	17	3.0	ND	ND	0.16	0.06
Benzo(e)pyrene	0.24	ND	ND	7.4	2.6	16.0	2.1	4.3	3	37	7.0	2	0.08	0.56	0.18
Benzo(a)pyrene	0.35	ND	ND	9.2	3.5	24.5	2.8	4.3	4.4	48	8.4	1.9	0.11	0.71	0.21
Perylene	ND	ND	ND	2.2	1	7.3	0.74	1.4	1.2	11	2.3	0.55	0.032	0.33	0.11
Indenol(1,2,3-c,d)pyrene	ND	ND	ND	3.6	1.2	5.3	0.82	0.7	1.1	4.9	0.69	ND	0.04	0.34	0.07
Dibenzo(a,h)anthracene	ND	ND	ND	1.5	0.55	2.3	0.35	ND	0.46	2.5	ND	ND	ND	0.11	0.025
Benzo(g,h,i)perylene	ND	ND	ND	3.5	1.1	4.5	0.82	0.2	0.88	1.7	0.21	ND	0.04	0.31	0.065
Benzothiophene	ND	ND	ND	ND	0.45	3.8	0.39	ND	0.31	0.06	0.26	ND	ND	ND	0.06
Quinoline	ND	ND	ND	ND	0.07	0.46	0.12	ND	ND	ND	ND	ND	ND	ND	0.03
Dibenzothiophene	ND	ND	ND	ND	1.8	24.5	1.7	ND	0.59	2.3	ND	0.14	ND	ND	0.15
Acridine	ND	ND	ND	0.58	0.71	8.7	1.3	0.08	0.61	1.2	0.22	0.16	0.08	0.25	0.195
Carbazole	ND	ND	ND	0.28	0.8	14	1.7	ND	0.81	2.2	0.3	0.1	0.04	0.26	0.186
Benz(a)acridine	ND	ND	ND	2.7	1.2	10.2	1.5	0.13	0.84	5.7	0.49	0.31	ND	0.13	0.186
Dimethyl benz(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(b)chrysene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anthanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Coronene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total PAHs	1.84	ND	ND	77.5	67.8	711	100.5	21.8	49.5	334	55.82	17.4	1.0	6.66	3.42

George, represented a moderately polluted sediment according to the U.S.EPA Dredging Guideline. The levels were 38 mg/kg, 25 mg/kg and 19,000 mg/kg, respectively.

In 1985, U.S.EPA collected 19 samples of bottom sediment from 18 Michigan tributaries. The samples were analyzed for a broad range of conventional pollutants, metals, pesticides, PCBs and other organic chemicals (43). Various benthic organisms were present in most samples and there was no obvious evidence of pollution. Analyses for conventional pollutants, metals, aromatics, DDT and metabolites, phthalate esters, PCBs, and PAHs indicated that, although some parameters resulted in the sediment being classified as moderately polluted (U.S.EPA guidelines), most were classified as nonpolluted. The results of this study indicate that Michigan tributaries are not a significant source of contaminants to the St. Marys River. Samples collected from streams which drain the City of Sault Ste. Marie, where contaminant sources are most likely, were generally free of significant contaminant concentrations. Exceedances of specific U.S.EPA guidelines are believed to be the result of natural sources.

B. SPECIFIC CONCERNS

Table VI-14 summarizes contaminants of concern in the St. Marys River by matrix. The following discussion provides more detailed information on the areas or species impacted. In general, where the same contaminant was measured in all matrices (e.g., PAHs) the zones of environmental impact were similar.

1. Water

Degradation of the water quality in the St. Marys River resulting from industrial and municipal discharges is a concern for citizens of Sault Ste. Marie, Ontario and Michigan. Generally the concerns are focussed on the possible combined toxic effect of ammonia, cyanide and heavy metals (e.g. zinc); excessive amounts of oil and grease as a result of discharges or spills; phenols which continue to exceed the objective, albeit in a small zone downstream from the industrial discharges; and PAHs because of the carcinogenic nature of certain PAH compounds.

Water quality impairment in the St. Marys River is mainly restricted to a narrow band along the Canadian shore, downstream of Algoma Steel and St. Marys Paper effluent discharges. Partial recovery from the effects of these industrial inputs takes place throughout the St. Marys River downstream, however, discharges from the Sault Ste. Marie, Ontario East End WWTP delay the complete restoration of satisfactory water quality with respect to several contaminants (i.e. phenols, ammonia, cyanide) until Lake George. There is some transboundary pollution in the Lake George Channel.

A band of phenols which slightly exceeds the PWQO and the GLWQA specific objective of 1 ug/L was noted along the Canadian shore for a distance of 3 km below the Terminal Basins discharge. Although ammonia and cyanide levels are within their respective objectives throughout the St. Marys River, the combined effect of these contaminants may result in toxic conditions.

In the St. Marys River, measured PAHs associated with the aqueous phase of the water column increased downstream from Leigh Bay, reaching a peak concentration in the Algoma Slip. Although PAHs are commonly reported as a group, the toxicity and relative carcinogenicity of individual substances vary greatly as shown in Table VI-15. In the aqueous phase, 95% of the PAH compounds measured in the St. Marys River were considered to be not or weakly carcinogenic. Estimated concentrations of PAHs associated with the whole water phase exceeded the U.S.EPA AWQC for Human Health Criteria (for fish consumption) of 31 ng/L for total PAHs from the Algoma Slag Site to downstream of the Sault Ste. Marie, Ontario East End WWTP. Estimates of PAHs associated with both the whole water and aqueous phase that are considered noncar-

TABLE VI-14

Summary of contaminants of concern in the St. Marys River.

	MATRIX					
			BIOTA			
CONTAMINANT	WATER	SEDIMENT	BENTHOS COMM.	OLIGO-CHAETES	CAGED CLAMS	SPORT FISH
Bacteria (Fecal coliform)	E					
Phosphorus	E		I			
Ammonia	P		I			
Cyanide	P					
Heavy Metals						
- Chromium		E	I			
- Copper		E		P		
- Lead		E				
- Mercury		E		P		E
- Nickel		E				
- Zinc	P	E		P		
- Iron	E	E				
Phenols	E		I			
Oil and Grease	P	E	I			
PCBs, total		P				P
PAHs, -total	P				P	
- Benzo(a) pyrene	E	E	I(?)		P	

Notes:

E = exceeds available guideline
P = present above background
I = impacted by contaminant indicated

TABLE VI-15

Carcinogenic activity of individual PAHs.

Individual PAHs	Carcinogeric	Potential
Naphthalene	*	**
Acenaphthylene	-	Inactive
Acenaphthene		
Fluorene	-	
Phenanthrene	-	Inactive
Anthracene	-	Inactive
Fluoranthene	-	
Pyrene	-	Inactive
Benzo(a)anthracene	-	Disputed
Chrysene	+/-	Disputed
Benzo(b)fluoranthene(2,3-benzfluoranthane)	++	
Benzo(k)fluoranthene(8,9-benzfluoranthane)	-	
Benzo(a)pyrene(1,2-benzpyrene)(3,4-benzpyrene)	+++	High Active
Dibenzo(a,h)anthracene(1,2,5,6-dibenzanthracene)	+++	Moderate
Benzo(g,h,i)perylene	-	Moderate
Indeno(1,2,3-c,d)pyrene(o-phenylene pyrene)	+	
Benzo(e)pyrene(4,5-benzpyrene)(1,2-benzpyrene)	-	Inactive
Perylene		
Benzo(j)fluoranthene(7,8-benzfluoranthene)	++	
Coronene	-	
Acridine	-	
Dibenzo(a,h)acridine(1,2,5,6-dibenzacridine)	++	Slight
Carbazole	-	Slight
Benzo(a)carbazole	-/+	High
Quinoline	+	
Benzo(f)quinoline	-	
Dibenzthiophene		
Benzo(2,3)phenanthro(4,5-b,c,d)thiophene		

* Source: National Academy of Sciences (1972): Particulate Polycyclic Organic Matter; Washington, D.C.
Indications are "-" for not carcinogenic, "+/-" for uncertain or weakly carcinogenic, "+" for carcinogenic and "++, +++" for strongly carcinogenic from (44).

** Source: Polynuclear Aromatic Carcinogens, Dipple, Anthony in Chemical Carcinogens, p., 245-307.

cinogenic constitute greater than 80% of total PAHs at all sites monitored along the St. Marys River. PAH levels along the U.S. shoreline were similar to the background or upstream levels indicating no transboundary pollution.

2. Sediments

Bottom sediments of the St. Marys River exhibited contaminant concentrations that exceeded both the OMOE and U.S.EPA dredged material disposal guidelines. The parameters of concern are arsenic, cadmium, chromium, cyanide, copper, iron, lead, mercury, nickel, zinc, nutrients, and oil and grease. Most of these contaminants, together with chlorinated organics and PAHs, are of concern due to bioconcentration and the potential for toxic effects.

Sediments along the Ontario shore near Algoma Steel and Sault Ste. Marie and in Little Lake George were the most contaminated in terms of percent of samples having concentrations equal to or greater than dredged material disposal guidelines. The sediments in the St. Marys River upstream of the industrial complexes were uncontaminated.

Sediments containing chlorinated organic contaminants, coupled with external loadings, may result in excessive body burdens for aquatic life. Sediment core data indicates improvements but PAH concentrations remain a concern. As a result of the strong association of PAHs with silt and clay, higher concentrations were found in the embayments downstream from the Terminal Basins.

3. Biota

Benthic macroinvertebrate distribution in a system is often used as an indicator of ecological health and environmental impact. Normal benthic communities are characterized by diverse populations, presence of pollution intolerant taxa (e.g. caddisflies), and a relatively higher number of organisms per unit area. Adversely impacted benthic communities in the St. Marys River generally were restricted to a narrow band approximately 500 m wide, extending 3 km along the Canadian shore downstream of industrial discharges. Some recovery was apparent with increasing distance (e.g., 5 km) downstream from the Algoma Steel and St. Marys Paper discharges, however, complete recovery was not realized until the lower section of Lake George, some 24 km downstream from these discharges. Recovery was, in part, delayed by effluent from the East End WWTP. Clean water fauna characterized the nonindustrialized U.S. shore, the whole river upstream of pollution sources, and Lake Nicolet.

Despite reductions in certain pollutants from Algoma Steel, St.

Marys Paper, and the East End WWTP little improvement has been observed in the benthic community of the St. Marys River. Contaminants in the sediments, together with contaminants in the water column, are thought to severely restrict the survival of most macroinvertebrates in certain areas of the St. Marys River. It was generally observed that areas with visible oily residues were characterized by the absence of ephemeropteran Hexagenia.

Elimination or alteration of normal populations of aquatic insects and other invertebrates and their replacement by pollution tolerant species (which have limited value as fish food organisms) will also result in the alteration of the suitability of the river for supporting game fish populations. Further, contaminated sediments are a likely source of contaminants to benthic organisms and can exert toxic influences on them, either completely eliminating benthic populations or reducing the diversity to a few tolerant species. Uncontaminated clams exposed to river water near and downstream of the discharges accumulated significantly higher levels of certain PAH compounds, than clams introduced in the river upstream from the discharges.

The effects of contaminants on the food web in the St. Marys River and ecosystem is a concern that should be fully investigated. Toxic compounds that are deposited in the sediments may transfer to water, biota, and the atmosphere. Sediments may not be the final sink for persistent contaminants (e.g. PCBs) but may rather act as a source through redistribution of compounds to water and the atmosphere (45).

In general, it appears that past reductions in pollutant loadings to the St. Marys River have not been adequate to reduce sediment contamination and impacts to benthic organisms. The contaminants remaining in the sediment, particularly oil and grease but also metals and PAHs, are a major concern in this channel.

4. Uses Impaired

Fish Consumption

Fish from the St. Marys River (collected below the rapids) do not currently contain levels of organochlorines (PCBs; DDT; lindane; 2,3,7,8-TCDD) above available consumption guidelines. The consumption advice tables in the 1988 "Guide to Eating Ontario Sport Fish" indicate that mercury levels in large specimens of some game species (i.e. lake trout, northern pike, and walleye) are between 0.5 and 1.0 ppm and thus long-term consumption should be restricted to 0.226 kg/wk. It is recommended that children under 15 years of age and women of child bearing age should consume only those fish with a mercury content of less than 0.5 ppm. Mercury concentrations in fish are believed to be the result of natural sources.

Young-of-the-year yellow perch collected from Sault Ste. Marie, Ontario contained PCBs, but these concentrations (average 25 ppb) were well below the GLWQA Objective (100 ppb) for the protection of birds and animals which consume fish. No detectable levels of chlorophenols or chlorinated aromatics were found in these fish.

Preliminary analysis of whole fish showed that two bottom feeding species from the North Channel of Lake Huron contained detectable levels (low ppb range) of some PAHs. The only guideline for PAHs is the U.S.EPA AWQC Human Health Criteria of 31 ppb (ng/L) based on consumption of 6.5 gm of fish per day.

Aesthetics

In recent years, the occurrence of aesthetic problems has become less frequent than previously observed. Mats of oily fibrous material mixed with fine wood chips are noticed only occasionally on the Sault Ste. Marie waterfront extending as far as the Lake George Channel. These intermittent problems are, in part, due to the decomposition of fibers and fine wood particles found to be prevalent in the river sediments along the Canadian shore.

Occasional oil slicks resulting from spills have been sighted on the St. Marys River. However, the oil slicks have lately been confined to the Algoma Slip area and very occasionally downstream of the Terminal Basins. This suggests that the oil booms in the slip area are effective in containing the spills but that the oil separators at the Terminal Basins are not 100% effective.

Habitat

Commercial navigation, both the vessel traffic and engineering modifications of the river (i.e. building of locks, canals, and dredging), affect the aquatic biota and their habitats in the St. Marys River. Important fish spawning and rearing habitats have been destroyed by modification for locks and channels. Regulated flows for hydro power development have occasionally resulted in dewatering of the St. Marys Rapids with the resultant loss of benthic macroinvertebrate and fish productivity.

The shipping channel is essentially a portion of the soft bottom habitat which has been altered by dredging. The shipping channel is poor habitat for benthic macroinvertebrates as only two taxa are common, and both diversity and density are much lower in the shipping channel than in all other habitats. Turbulence created by passing ships and their propeller wash and oil spills are likely the reason for the lack of benthic organisms in the shipping channel. There are, however, no indications of pronounced sediment bound toxicity in the St. Marys River as a result of navigational activities (46).

The aquatic organisms in the emergent wetlands may be affected by ship passage which results in the temporary drawdown along the shore. A study of emergent wetland invertebrate populations of the St. Marys river showed that 18.9% of the mortality of *Lestes disjunctus* was attributable to ship passage (47). Drawdown induced by ship passage may also affect the survival of larval fish that inhabit the wetlands (48). Sediment is transported and deposited at increased rates during ship passage, and survival of aquatic organisms is threatened.

The present and proposed expansion of the dredging operation by A.B. McLean Ltd. at the headwaters of the St. Marys River (Whitefish Bay) is a concern to both Ontario and Michigan citizens. This proposed operation may allow up to 500,000 m^3 per year of sand and gravel to be dredged. Because Whitefish Bay is a major spawning habitat for Lake Superior whitefish, the Ontario government has requested A.B. McLean Ltd. to submit a detailed fisheries assessment of the current and proposed operation.

A.B. McLean Ltd. has also altered the southwest shoreline of the Algoma Slag Site to develop a dock facility. Development of the dock included the sinking of an old ore carrier and the dredging of the river bottom. Concern was expressed about the resulting downstream siltation.

C. SOURCES

Pollutants enter the St. Marys River system from both point and nonpoint sources. Point sources include effluents from municipal and industrial wastewater treatment facilities directly to the river and indirectly via tributaries. Nonpoint sources include atmospheric deposition, intermittent stormwater discharges, combined sewer overflows, rural land runoff, navigation, groundwater migration (including pollutants coming from waste disposal sites and landfills) and release from bottom sediments.

1. Point Source

An inventory of direct and indirect point source discharges to the St. Marys River is presented in Table VI-16. Direct point sources are defined as those facilities discharging directly into the St. Marys River, while indirect sources are those discharging to a tributary of the St. Marys River. There are no indirect municipal sources. The only major indirect industrial sources are the Algoma Steel Tube Mill and Cold Mill (cooling water only) which discharge to East Davignon Creek. The total 1986 annual average flow of municipal wastewater was 59 X 10^3 m^3/d. Industrial flows were 530 x 10^3 m^3/d.

All Ontario direct point source discharges were sampled by Environment Canada and OMOE in a 3 to 6 day survey conducted in August 1986 (49). Average daily gross loadings calculated from the survey results are presented in Table VI-17.

Loading estimates from the August 1986 UGLCCS survey were compared to estimates based on two long-term surveys; the OMOE MISA pilot site study (May to November 1986) and the effluent self-monitoring program (January to December 1986). This comparison revealed that loadings for phenols, total PAHs, ammonia, suspended solids and oil and grease from Algoma Steel are quite variable and that the UGLCCS data for some parameters are probably not representative of the operational conditions of treatment facilities. Therefore, average gross loadings calculated from the self monitoring or MISA pilot site data are introduced and included in Table VI-17. Table VI-18 illustrates the marked variability in concentrations of contaminants in effluents over a 1 year period (MISA data).

The total loading of oil and grease to the St. Marys River during the UGLCCS survey was approximately 10,000 kg/d. An average of 9,488 kg/d was discharged from Algoma's Terminal Basins, far exceeding the Control Order limit of 1,589 kg/d which was to be met by December 31, 1986. The oil and grease loading from Algoma during the UGLCCS survey was well above the average daily load as calculated from 1986 (annual) self monitoring data (1,950 kg/d), the August 1986 self-monitoring data (1,470 kg/d) and the MISA

TABLE VI-16

St. Marys River point source inventory.

Name and Location	Type of Facility	Population Served/ Production	Receiving Stream	Outfall Name(s)	1986 Average Annual Flow 103m3
Direct Dischargers					
Municipal					
1. Sault Ste. Marie, Ontario, East End WPCP	Primary (without phosphorus removal)	52,000	St. Marys River	Final effluent	41.7
2. Sault Ste. Marie, Ontario West End WPCP	Secondary, with continuous phosphorus removal	17,500	St. Marys River	Final effluent	9.1 (1986-first year Operation)
3. Sault Ste. Marie, Michigan, POTW	Secondary, with chlorination with phosphorus removal	15,000	St. Marys River	Final effluent	8.0
Industrial					
4. St. Marys Paper, Sault Ste. Marie, Ontario	Groundwood Pulp and Paper Mill	106,000 T/yr	St. Marys River	Final effluent	27.5
5. The Algoma Steel Corp., Ltd., Sault Ste. Marie Ontario	Integrated Steel Mill	3.5 x 106 T/yr	St. Marys River	Terminal Basin	354
				Bar and Strip Lagoon	59.5
				60" Blast Funace Sewer	45.9
				30" Blast Funace Sewer	29.5
			TOTAL FLOW		575.2
Indirect Discharges					
Municipal					
None					
Industrial					
6. The Algoma Steel Corp. Ltd., Sault Ste. Marie Ontario	Integrated Steel Mill		East Davignon Creek	Tube Mill Outfall	6.2
				24" Cold Mill Basin OTCW	7.8

TABLE VI-17

Loading summary of point source discharges to the St. Marys River (kg/d)[1].

Parameter	Algoma Steel	St. Marys Paper	East End WWTP	West End WWTP	Michigan WWTP	E. Davignon Creek	Fort Creek	Bennett Creek	Total Loadings to St. Marys R.
Flow (m3/d)	486,375	23,710	30,638	8,753	7,972	87,048	3,145	3,145	650,786
Oil and Grease	9,441	231	349.7	13.3	NA	NA	NA	NA	10,035
	(1950)+								
	(3547)**								(4141)
Ammonia	6,254	6.01	195.5	14.8	NA	17.6	0.172	2.8	6,481
	(3990)*								(4227)
Total Phosphorus	20.0	4.70	89.8	5.7	6.3@	2.7	0.41	0.066	129.6
Suspended Solids	4,234*	2,829	900.6	39.4	47.3@	1,713	353	158	10,274
	(8137)*								(15300)
Chloride	18,885	743	2011.1	598.5	NA	952.6	286	671	24,137
Cyanide	72.9	NA	NA	NA	NA	0.294	0.0031	0.022	73.2
Total Phenols	9.0	0.708	0.512	0.022	NA	0.61	0.0041	0.075	11
	(96.5)*								
	(114)**								(116)
Copper	-1.1	0.328	1.4	0.2	NA	NA	NA	NA	0.83
Iron	1,747	8.65	42.6	5.2	NA	71.8	12.2	1.22	1,889
	(2275)**								(2417)
Lead	4.81	0.168	1.01	0.187	NA	NA	NA	NA	6.18
Mercury	0.005	0	0.0005	0.0001	NA	NA	NA	NA	0.0056
Zinc	33.7	0.09	1.91	0.356	NA	0.761	0.127	0.054	37.3
Xylene	0.388	0.05	0.223	ND	NA	ND	ND	NA	0.66
Styrene	0.084	ND	NA	ND	NA	NA	NA	NA	0.084
Benzene	1.12	0	0.048	0.011	NA	ND	ND	NA	1.18
Chloroform	0.004	0.066	0.079	0.031	NA	ND	ND	NA	0.18
Methylene Chloride	0.124	0.0088	0.233	0.030	NA	NA	NA	NA	0.4
Toluene	0.231	0.168	0.158	0.005	NA	ND	ND	NA	0.56
2,4,6-Trichlorophenol	1.48	0	0.004	0.037	NA	NA	NA	NA	1.52
2,4-Dimethylphenol	1.21	-0.06	0.727	0.075	NA	NA	NA	NA	1.95
Total PAH's (16)	0.20	0.051	0.417	0.004	NA	0.04	0.006	.005	0.72
	(1.21)**								(1.73)
1,4-Dichlorobenzene	0.125	0.030	0.043	0.010	NA	ND	ND	NA	0.21
Mono & Dichloramine	NA	NA	2.64	0.600	NA	NA	NA	NA	3.24

NA = Not Analyzed, ND = Not Detected

[1] (based on data collected in 1986).

+ 1986 self monitoring data.

* Loadings for Terminal Basins from average for the self monitoring program for 1986 substituted into database as August loadings for those parameters considered atypical.

** Represents data of MOE Pilot Site investigation.

@ Loadings from November 1986 to October 1986 facility monthly operating report.

TABLE VI-18

Mean and range of contaminant concentrations observed in Algoma Steel and St. Marys Paper effluents.

Parameter	MDL	Algoma Steel 30" Blast Furnace	60" Blast Furnace	Bar & Strip Lagoon	Terminal Basins	St. Marys Paper
Oil and Grease	1.0 mg/L	3.7 (ND-40.0)	3.6 (ND-50.0)	8.3 (ND-581)	7.6 (ND-48)	18.4 (ND-720)
Ammonia	0.5 "	27.17 (ND-1,060)	0.100 (ND-1.060)	1.356 (ND-5.30)	7.481 (ND-16.50)	0.078 (ND-720)
Suspended Solids	0.1 "	52.19 (2.10-353)	30.48 (1.90-557)	12.85 (3.50-59.4)	26.04 (2.4-121)	190 (1.8-2150)
Cyanide	0.001 "	0.028 (ND-0.590)	0.025 (ND-2.00)	0.545 (ND-2.60)	0.106 (ND-0.90)	0.004 (ND-0.02)
Total Phenols	0.2 ug/L	473 (0.4-29,000)	3.06 (.20-28.4)	15.5 (0.40-144	395 (1.20-8750)	20.8 (0.6-374)
Iron	0.05 mg/L	8.53 (0.55-200)	5.20 (ND-140)	1.95 (ND-43.0)	6.01 (0.36-64.0)	1.36 (0.27-15.0)
Lead	0.01 "	0.038 (ND-0.59)	0.016 (ND-2.50)	0.076 (ND-0.82)	0.018 (ND-0.600)	0.030 (ND-0.830)
Mercury	0.01 ug/L	0.514 (ND-19.0)	- 0.016 (ND-.230)	0.009 (ND-.050)	0.045 (ND-.700)	0.018 (ND-.050)
Zinc	0.005 mg/L	0.168 (0.007-5.00)	0.039 (ND-1.00)	0.821 (.10-13.00)	0.021 (ND-.500)	0.063 (.005-.740)

ND = Not Detected at method detection limit (MDL).

Data from St. Marys River MISA Pilot Study, twice-weekly grab sampling, March 2 1987 to March 28 1987 (approximately 100 samples).

pilot site investigation data (3,547 kg/d). The reason for this variability is unknown. The East End WWTP had the second highest loading of oil and grease (350 kg/d) during the UGLCCS survey.

The Terminal Basins and the Bar and Strip Lagoon discharges of Algoma Steel were the principal sources of ammonia during the UGLCCS survey, contributing an average of 5,960 kg/d and 210 kg/d, respectively. The average ammonia loading from Algoma during this survey (5,254 kg/d) was higher than loadings based on the 1986 annual self monitoring data which indicated an annual average of 3,990 kg/d and the August 1986 average of 2,490 kg/d.

The average suspended solids (SS) loading to the St. Marys River during the UGLCCS survey was 10,274 kg/d. Approximately 8,000 kg/d was discharged by industrial and municipal facilities. Algoma Steel had the highest SS loading (4,234 kg/d), of which the Terminal Basins contributed 3,950 kg/d. This load was well below the average SS load from the Terminal Basins as estimated from the 1986 annual self monitoring data (7,790 kg/d), and the load based on August 1986 self monitoring data (6,640 kg/d). Based on the UGLCCS data, the Terminal Basins' effluent met the Amending Control Order limits required by March 31, 1990. However, self monitoring data indicate that the loads were above this limit as well as the current Control Order limit (7,355 kg/d).

St. Marys Paper contributed an average SS load of 2,830 kg/d, the second highest. Although effluent concentrations exceeded the Ontario Industrial Discharge Objective of 15 mg/L, St. Marys Paper was in compliance with their Certificate of Approval. Suspended solids loadings from the paper plant have declined steadily since 1968 (Table VI-19).

The average total phenols loading to the St. Marys River during the August 1986 UGLCCS survey was 11 kg/d. Algoma Steel contributed 9.0 kg/d, of which 8.2 kg/d was discharged from the Terminal Basins. The Point Source Workgroup Report (49) considered the measured loading from the Terminal Basins to be quite atypical and not representative of the true loadings when compared with Algoma's 1986 annual self monitoring data (95.7 kg/d). Loadings of total phenols to the St. Marys River from Algoma Steel, using Algoma's data and the MISA pilot site investigation data were 97 kg/d and 114 kg/d, respectively. St. Marys Paper had the second highest total phenols loading during the UGLCCS survey (0.7 kg/d). Average concentrations of total phenols measured in the Terminal Basins' effluent and St. Marys Paper final effluent exceeded the Ontario Industrial Discharge Objective of 20 ug/L.

During the UGLCCS survey, 17 PAHs were measured in the effluents. An average of 0.691 kg/d of total PAHs was discharged during the survey. The highest average loading of total PAHs was from the

TABLE VI-19

Historical summary of loadings to the St. Marys River (kg/d).

Parameter	1968	1973	1983
St. Marys Paper			
Total suspended solids	23,800	13,400	3,400
BOD$_5$	68,800	5,600	5,300
Sault Ste. Marie, Ontario East End WPCP[1]			
BOD$_5$[2]	2,146	2,150	3,500
Total dissolved solids	14,220	18,227	-
Total phosphorus	-	163	194
Total kjeldhal	-	1,000	-
Nitrate	-	10	-
Ammonia	-	700	-
Chlorine	-	2,500	-

1 Water Pollution Control Plant.
2 Five-day biochemical oxygen demand.

East End WWTP (0.417 kg/d). However, this average was skewed by high results on the first day of sampling, presumably due to an industrial spill to the sanitary sewer system. On the remaining 5 days of the survey those compounds were not found, indicating that, under normal conditions, PAHs would not be detected at 1.0 ug/L in the East End WWTP effluent. During the August 1986 survey, an average of 0.2 kg/d total PAHs was discharged by Algoma Steel. All PAH compounds analyzed for were detected in the Algoma Steel coke plant effluent which discharges to the Terminal Basins. However, only 3 compounds were detected in the Terminal Basins' effluent and only at trace concentrations, close to the analytical detection limits. As with other loading data presented thus far, there is substantial variability in calculated PAH loadings from Algoma Steel. Based on the MISA pilot site data, an average of 1.14 kg/d total PAHs was discharged from the Terminal Basins alone.

Total phosphorus loads during the UGLCCS survey were greatest from the Sault Ste. Marie, Ontario East End WWTP, averaging 90 kg/d. Effluent concentrations from this primary treatment facility exceeded the GLWQA objective of 1 mg/L. Historical data presented in Table VI-19, indicate that total phosphorus loadings from the East End WWTP increased from 1968 to 1983, probably due to overloading the system because of population growth. This problem may be alleviated by the new West End WWTP which came online in 1986.

Comparisons of the point source loadings during the UGLCCS survey (Table VI-17) indicates that Algoma Steel had the highest loading of oil and grease (9,441 kg/d), ammonia (6,254 kg/d), suspended solids (4,234 kg/d), chloride (18,885 kg/d), cyanide (72.9 kg/d), total phenols (90 kg/d), total metals (4,535 kg/d), total volatiles (1.95 kg/d) and chlorinated phenols (2.69 kg/d).

In the Algoma complex, the Terminal Basins' outfall is the major source of pollutants, followed by the Bar and Strip Lagoon for lead, zinc and cyanide (Table VI-20). The Terminal Basins effluent comprises about 80% of Algoma Steel's effluent flow. Yearly trends in the Terminal Basins effluent quality (Figure VI-25) indicate a steady decline in ammonia, cyanide and phenols during the last decade. These trends are based on data collected through Algoma's self-monitoring program.

During the August 1986 UGLCCS survey, the Sault Ste. Marie, Ontario, East End WWTP had the highest loadings of total phosphorus (89.9 kg/d), mono and dichloramine (2.64 kg/d), and chlorinated benzenes - chloroethers (0.341 kg/d). The East End WWTP was also the second highest contributor of oil and grease (350 kg/d), ammonia (196 kg/d), chloride (2,011 kg/d), total metals (47 kg/d), volatiles (1.06 kg/d), PAHs (0.42 kg/d) and chlorinated phenols (1.31 kg/d).

TABLE VI-20

Loading summary of Algoma Steel effluents to the St. Marys River (kg/d).

Parameter	MDL		30" Blast Furnace	60" Blast Furnace	Bar & Strip Lagoon	Terminal Basins
Flow m3/d			22,100	67,980	80,395	315,900
Oil and Grease	0.1	mg/l	N	N	9.9	9,488
Ammonia	0.1	"	N	8.3	290	5,956 (3090)@
Total Phosphorus	0.1	"	ND	4.5	ND	15.5
Suspended Solids	1.0	"	ND	N	347	3,946 (7790)@
Chloride	0.5	"	504	759	6,726	10,895
Cyanide	0.001	"	4.9	9.6	89.9	28.4
Total Phenols	1.0	ug/l	NA	NA	0.8	8.16 (95.7)@
Copper	0.005	mg/l	0.147	0.136	N	N
Iron	0.005	"	12.8	48.7	507	1,178 (1685)**
Lead	0.005	"	ND	0.68	2.93	2.6
Mercury	0.025	ug/l	N	0.002	0.007	0.003
Zinc	0.005	mg/l	0.33	2.1	28.8	3.2
Xylene	1.0	ug/l	N	N	ND	0.415
Styrene	1.0	"	ND	ND	ND	0.084
Benzene	1.0	"	ND	ND	ND	1.12
Chloroform	1.0	"	0.002	ND	0.0014	ND
Methylene Chloride	1.0	"	0.013	N	0.019	0.107
Toluene	1.0	"	N	N	ND	0.277
2,4,6-Trichlorophenol	2.0	"	ND	ND	ND	1.48
2,4-Dimethylphenol	2.0	"	N	N	0.367	0.892
Total PAHs	1-2.0	"	0.007 (0.038)**	0 (0.006)**	0.024 (0.022)**	0.157 (1.14)**
1,4 Dichlorobenzene	1.0	"	N	N	0.02	0.135

N = Negative Net Loading, ND = Not Detected, NA = Not Applicable, MDL = Method Detection Limit

** June 1986 OMOE MISA pilot site investigation (MDL=10 ng/L).
@ 1986 average self monitoring program of Algoma Steel.

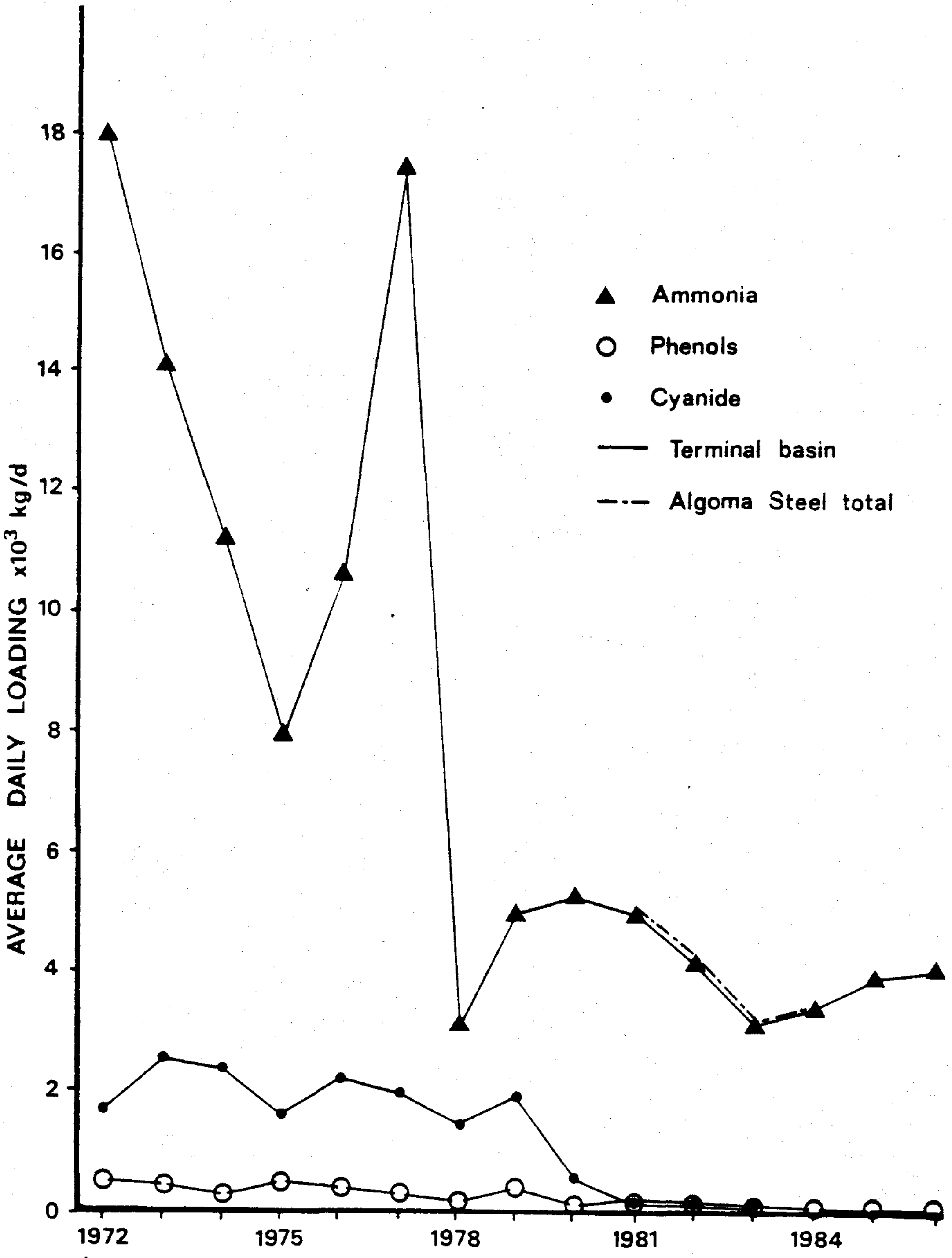

FIGURE VI-25. Annual average daily loading from Algoma Steel.

No loadings were obtained for the Sault Ste. Marie, Michigan Wastewater Treatment Plant (WWTP) for 1986 as the plant was being upgraded. Average suspended solids, total phosphorus and BOD loadings calculated from the facility's monthly operating reports (November 1986 to October 1987) were 47.3 kg/d, 6.3 kg/d and 53.6 kg/d, respectively. For the period of June 1987 to June 1988, inclusive, the reported average monthly loading (and ranges) for these three parameters were 79.9 (27.7 - 303), 13.6 (4.6 - 11.4) and 58.4 (11.5 - 102) kg/d, respectively with flows averaging 10,754 (6,232 - 15,390) m^3/d.

In general, the three Ontario tributaries (East Davignon, Fort and Bennett Creeks) do not appear to be significant sources of industrial contaminants to the St. Marys River when compared to the other sources. However, East Davignon Creek had the highest loadings for all parameters monitored. Total PAH loadings from East Davignon Creek (0.04 kg/d) during the 1986 MISA pilot study were comprised mainly of benzo(k)fluoranthene, dibenzo(a,h)-anthracene, fluoranthene, pyrene, indeno(1,2,3-c,d)pyrene and benzo(g,h,i)perylene. These compounds are related to the Algoma Steel operations. Although total PAH loadings from Bennett Creek in 1986 were an order of magnitude lower than from East Davignon Creek, the detection of coal tar in this creek during 1987 indicates the potential for additional inputs from this area.

2. Nonpoint Sources

Nonpoint pollutant loads are more difficult to assess than point sources. Nonpoint source pollutant loads are introduced into the environment from diffuse sources which enter the water system through a wide range of pathways. Furthermore, nonpoint pollutant loads are dependent on many uncontrollable natural phenomena such as rainfall, wind events, soil types and geological conditions. Due to the nature of nonpoint source pollutant loads, assessment of their magnitude and impacts is often difficult.

Urban Runoff

i) Michigan

The City of Sault Ste. Marie, Michigan has a combined storm and sanitary sewer system with ten Combined Sewer Overflows (CSOs) at the Edison Sault Electric Company Power Canal and along the river. A study completed in 1978 indicated that there were no adverse impacts from these CSOs on river water quality. The WWTP has since been upgraded and expanded (1986) and impacts are therefore expected to be minimal. However, the presence of CSOs indicates the occurrence of sporadic loadings to the river. Also, there are 8 storm drains discharging into the St. Marys

River, 15 to Edison Sault Electric Company Power Canal, and 11 to three minor tributaries (Seymour Creek - 2; Ashmun Creek - 7; and Mission Creek - 2). No loading estimates are available.

ii) Ontario

Surface drainage in the City of Sault Ste. Marie is provided by storm sewers which discharge either directly into the St. Marys River or into one of several creeks draining into the river. Stormwater also enters the sanitary sewer system and has caused hydraulic overloading of the Sault Ste. Marie East End WWTP. Three stormwater outfalls were sampled (50) in each of the subareas (residential, industrial and commercial) as shown in Figure VI-26. The mean concentrations of measured parameters are summarized in Table VI-21.

A methodology for estimating loadings of contaminants has been developed and applied to the City of Sault Ste. Marie, Ontario (50). Annual contaminant loading estimates (Table VI-22) were obtained by multiplying the annual flow volumes by the mean concentrations. The loading calculations were done separately for the land use types studied and the total loading was obtained as the sum of individual components. A summary of total stormwater loadings to the St. Marys River is given in Table VI-23, and where applicable, the low and high estimates are given.

In terms of loading magnitudes, there is a great deal of consistency among all three subareas. In general, the loadings can be ranked in a descending order as follows: chloride, iron, oil and grease, ammonia, phosphorus, lead, zinc, copper, nickel, phenols, PAHs, cyanide, cadmium, cobalt, Hg, PCBs (total), HCB.

Rural Runoff

i) Michigan

The St. Marys River geographic area encompasses 203,546 ha with the predominate land use being forest (73%). Wetlands cover 11% of the area, while cropland accounts for 11% of the land use. Due to the agricultural base of Chippewa County, the nonpoint source pollutants of concern are sediments, nutrients and pesticides.

Estimated annual soil erosion for the St. Marys River geographic area is 173,889 tonnes. The total estimated soil loss included wind, sheet and rill erosion categories. It does not include cropland ephemeral gully erosion which has been documented to be a significant source of erosion in some flat-lying areas in the State of Michigan. Nonirrigated cropland erosion accounts for 100% of the total estimated erosion.

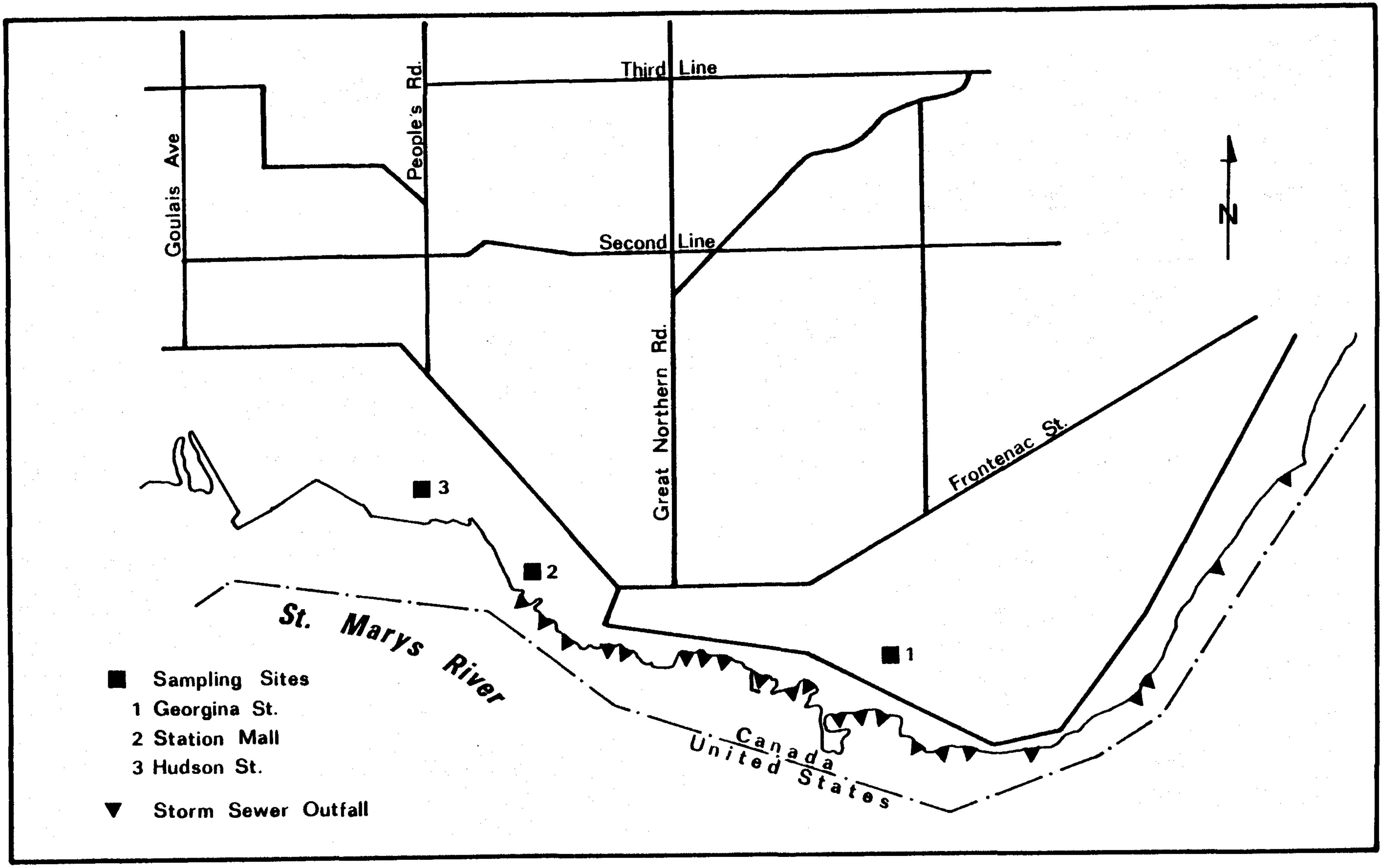

FIGURE VI-26. Storm sewer outfalls and sampling locations in Sault Ste. Marie, Ontario.

TABLE VI-21

Mean concentrations observed in urban runoff in Sault Ste. Marie, Ontario.

Parameter	Units	MDL	Stormwater Residential	 Commercial	 Industrial
Ammonia (N)	mg/L	0.001	0.87	0.42	0.49
Total Phosphorus	"	0.001	0.36	0.23	0.17
Chloride	"	0.050		1421	
				2851	
Cadmium	"	0.001	0.00	0.0011	0.00
			0.009	0.008	0.009
Cobalt	"	0.001	0.00	0.0062	0.00
			0.02	0.00	0.02
				0.02	
				0.00352	0.031
Copper	"	0.001	0.042	0.063	8.3
Iron	"	0.020	5.8	11.4	0.16
				0.21	0.000030
Lead	"	0.001	0.09	0.000013	0.000033
Mercury	"	0.00002	0.000032	0.000021	0.003
Nickel	"	0.001	0.012	0.014	0.021
			0.027	0.024	0.21
Zinc	"	0.001	0.29	0.29	2.6
Oil & grease	"	0.1	2.5	2.6	0.0100
Phenols	"	0.001	0.0165	0.0120	0.0030
Cyanide	"	0.010	0.0017	0.0027	0.00
HCB	ng/L	0.4	0.23	0.15	0.40
			0.43	0.42	-
OCS	"	1.0	-	-	13
Total PCBs	"	9.0	26	40	3,000
17 PAHs	"	50	11,500	4,700	3,500
			23,900	5,100	

---

1 Equivalent mean concentration.

2 Mean of concentrations detected in all three subareas.

Note:

At some sites large variations in concentrations of specific compounds were observed and/or a significant percentage of data was below the detection limits and for that reason two estimates, low and high, are given.

TABLE VI-22

Summary of loadings in urban runoff from the Sault Ste. Marie, Ontario area.

Parameter	Total Stormwater (kg/yr)	Total Stormwater (kg/d)
Ammonia (N)	9,800	26.8
Phosphorus	4,100	11.2
Chloride	1,850,000	5,068
	3,700,000	10,137
Cadmium	2.0	.0055
	78.0*	.0214
Cobalt	0	0
	263(46)*	0.721
Copper	572	1.57
Iron	92,100	252.3
Lead	1,550	4.25
Mercury	0.4	0.0011
Nickel	144	0.395
	338	0.926
Zinc	3,660	10.03
Oil & grease	33,300	91.2
Total Phenols	196	0.537
Cyanide	27	0.074
HCB	0.002	5.48×10^{-6}
	0.006	16.43×10^{-6}
Total PCBs	0.4	.0011
	3.2	.009
17 PAHs	122	.334
	238	.652

* Loadings calculated from data above the detection limit

Note:

At some sites large variations in concentration and/or a significant percentage of the data was below the detection limit and thus two loading estimates, low and high are given.

Daily loadings have been calculated assuming that annual loadings were uniformly distributed throughout the year.

TABLE VI-23

Loading summary of nonpoint source discharges to the St. Marys River (kg/d).

Parameter	Urban Runoff Ontario	Rural Runoff Michigan (livestock & soil erosion)	Atmospheric Deposition Ontario	Groundwater Michigan
Flow (m3/day)	35,077			184,150
Oil and grease	91.2			
Ammonia	26.8			
Total phosphorus	11.2	6.36		
Suspended solids				1,400
Chloride	5,068-10,137			
Cyanide	0.074			
Total phenols	0.537			
Copper	1.57			
Iron	252			
Lead	4.3			
Mercury	0.0011			
Zinc	10.03			
Xylene				
Stryene				
Benzene				
Chloroform				
Methylene chloride				
Toluene				
2,4,6-Trichlorophenol				
2,4-Dimethylphenol				
Total PAHs(16)	0.334-0.652		0.247	
Di-n-octylphthalate				
1,4-Dichlorobenzene				
Mono & Dichloramine				

Major sources of nutrients, in particular phosphorus, within the St. Marys River drainage area are fertilizer (commercial or manure spreading), livestock operations and soil erosion. It is estimated that a total of 5.18 tonnes of phosphorus are delivered per year to the water resources from livestock operations while soil erosion annually contributes approximately 1.18 tonnes of phosphorus to the water resources. A comparison of sources of phosphorus indicates that soil erosion contributes approximately 19% of the volume contributed by livestock operations and soil erosion. No estimates of pesticide loadings to the St. Marys River have been made.

ii) Ontario

No estimates of loadings from rural runoff are available for Ontario.

3. Atmospheric Deposition

Michigan

There are no estimates of atmospheric deposition available for the Michigan area for any of the UGLCCS parameters.

Ontario

Estimates of atmospheric loadings were attempted only for PAHs. Boom and Marsalek (51) collected 20 snowpack samples located in a grid centred around the City of Sault Ste. Marie, Ontario in order to establish the areal distribution of PAH depositions (Figure VI-27).

The areal distribution of PAH loadings in the snowpack tends to indicate that industrial emissions are the main source of PAHs to this area, with the highest loadings observed immediately downwind from the steel plant. Chemical finger printing indicated that the westerly stations were dominated by steel plant emissions, with the easterly stations being influenced by the other urban sources. The total quantity of PAHs stored in the snowpack in the study area was estimated to be about 18 kg for the 11 week accumulation period. PAHs stored in the snowpack are quickly released during the snowmelt period and thereby create a shock loading on the receiving waters (52). The average concentrations of total PAHs in fully mixed meltwater from the study area was estimated to be about 3 ug/L.

Although the data base refers to winter conditions, in industrial urban areas there are no seasonal variations in PAH depositions (53). Hence, the annual PAH loading extrapolated from the 2.5 month accumulation would be nearly 90 kg/yr. Based on this

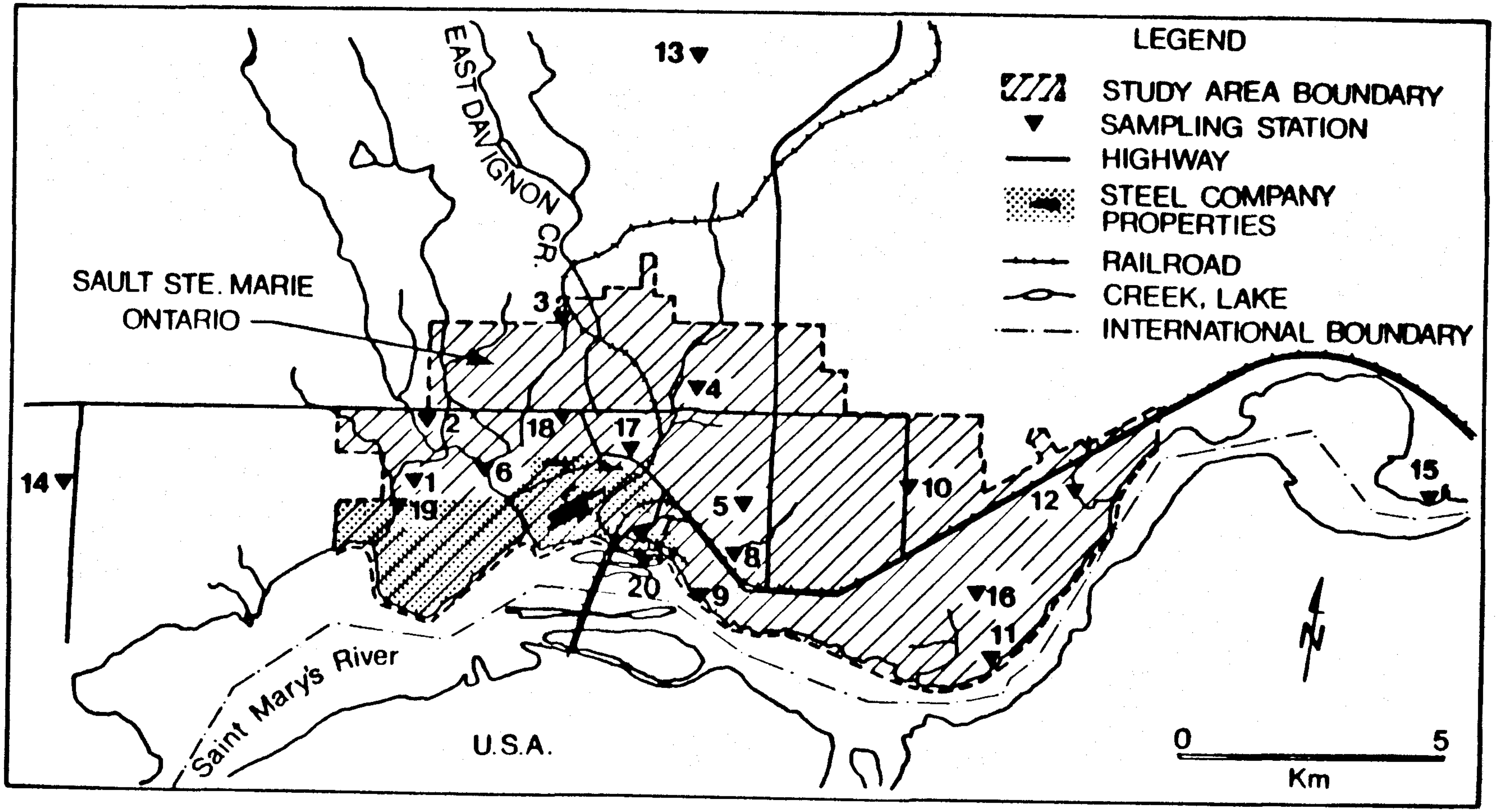

FIGURE VI-27. Snowpack PAHs sampling grid in Sault Ste. Marie, Ontario.

annual loading, estimates of annual atmospheric deposition rates for the most common PAHs found in the snowpack ranged from 13.6 - 21.8 kg/yr for phenanthrene; 17.2 -27.1 kg/yr for fluoranthene; 10.4 -16.9 kg/yr for pyrene; 1.5 - 5.2 kg/yr for both benzo(a)-pyrene and benzo(b)fluoranthene; and 2.2 - 5.7 kg/yr for benzo-(k)fluoranthene.

4. Contaminated Sediments

Studies have shown that polluted sediments have a direct impact on associated biota (29) and can be significant sources of contaminants to both the water column and aquatic organisms (31). Furthermore, such sediments can continue to be a source long after the external inputs (point and nonpoint) have been eliminated (31). However, the actual amounts of contaminants released from the sediment to the water column and organisms of the St. Marys River have not been quantified.

5. Groundwater Contamination/Waste Disposal

Michigan

Groundwater movement was investigated in an area extending 19 km inland along the St. Marys River from Whitefish Bay to Neebish Island. An inventory of active and inactive waste sites within 19 km of the St. Marys River was conducted as part of this investigation (19). Groundwater in the St. Marys River study area flows radially towards the St. Marys River. Total Michigan groundwater discharge directly to the St. Marys River is 2,156 L/s and contributes about 1,400 kg/d chloride (Table VI-23). Groundwater discharge from outside these areas contributes to the stream flow of the tributaries. Groundwater within the study area contributes about 47 percent of tributary flow.

Twelve sites of known, or potential groundwater contamination in the study area were identified and ranked. The majority of sites are solid waste landfills, storage sites and spills. Ranking of sites was based on their potential for contributing contaminants directly to the St. Marys River via groundwater by evaluating the hydrogeology, nature of waste material, and the distance to the St. Marys River.

One round of samples for analyses were collected from four wells installed by the United States Geological Survey (USGS) and three private wells. Some wells sampled by USGS were down-gradient from waste or spill sites including a well down-gradient from the Cannelton Industries Tannery waste site. Other locations were chosen to provide background information.

Organic compounds were generally less than their limits of analytical detection. Phthalate esters were detected at Cannelton Industries Tannery disposal site and downgradient from the Sault Ste. Marie disposal site (Union Carbide). It is possible, however, that the phthalates were related to shipping or laboratory contamination.

All samples exceeded GLWQA specific objectives and PWQO for zinc and total phenols and most exceeded the PWQO for phosphorus. Several other samples exceeded U.S.EPA AWQO for acute and chronic effects for mercury, lead and zinc. U.S.EPA Drinking Water Maximum Contaminant Levels were generally not exceeded except at the well at Cannelton Industries for chromium (primary standards) and iron and zinc (secondary standards).

Trace metal concentrations are based on nonfiltered well water and are probably not reflective of groundwater that discharges to the St. Marys River which is believed to be free of fine particulates. Thus, computation of loadings to the St. Marys River of chemical substances transported by groundwater is not currently feasible.

Local impacts on the water quality of the St. Marys River are posed by only one site in Michigan: Cannelton Industries Tannery disposal site. Impacts on the St. Marys River due to this site may occur through a combination of groundwater discharge, surface runoff, and erosion of contaminated soils and waste into the river.

State and federal regulatory file data indicate that high levels of chromium and other metals exist at the Cannelton Industries Tannery site. Down-gradient movement of contaminated groundwater from this site was detected by analyses of the well water. A remedial investigation/feasibility study has been initiated at this site under Superfund authorization.

Potential minor impacts on St. Marys River water quality are posed by the Sault Ste. Marie Disposal (Union Carbide) waste lime pile located near the river. This site is also known to contain cyanide contaminated wastes. The Superior Sanitation Landfill (3 Mile Road), containing municipal and light industrial refuse as well as sludges from the Sault Ste. Marie WWTP, is another potential source to the river.

Ontario

Two waste disposal sites were identified in Ontario. The Algoma Steel Slag Site was characterized as having a definite potential for impact on human health and safety. At this site, approximately 718,600 tonnes of solid waste and 66,800 tonnes of liquid waste are disposed each year. The predominant waste is slag from iron and steel operations. However, lime, industrial refuse, waste acid and oil, coke oven gas condensate, and sludge are also disposed on the site.

Detailed hydrogeological investigations at the Algoma Steel Slag Site have established that groundwater flows toward the St. Marys River, either directly, or indirectly by discharge to the Algoma Slip. High hydraulic conductivities in surficial slags and sands suggest rapid groundwater flow. Several investigations have documented groundwater and surface water contamination with metals, ammonia, cyanide, and PAHs which may be associated with this site. Work completed to date on the Algoma Slag Site has not conclusively proven the significance nor the magnitude of contaminants migrating off the site and impacting on adjacent groundwater, surface waters or biota. In early 1988, OMOE initiated a two year intensive study to quantify loadings and impacts associated with leachates from the site.

The other site in the area, the Sault Ste. Marie (Cherokee) Landfill is believed to have a negligible impact on surface waters of the St. Marys River. This landfill is licensed to handle municipal waste composed of 60% domestic waste (200 tonnes/d), 10% commercial waste (35 tonnes/d) and 30% sewage sludge (100 tonnes/d).

As summarized in Table VI-23, the majority of data on nonpoint source loadings is for urban runoff in Ontario. Therefore, few comparisons can be made between this source and other nonpoint sources of pollutants to the St. Marys River.

6. Navigation

The average number of vessels passing through the locks has decreased from 26,122 vessels in 1953 to 12,712 in 1970, and to 8,345 in 1986. The vessels carry mainly crude oil, grain, steel, coal, petroleum products, taconite and iron ore between Lake Superior and the industrial centres on the lower lakes.

Significant enhancement of the primary productivity takes place immediately after tanker passage (46). These observations suggest that there is an absence of pronounced sediment-bound toxicity in the St. Marys River.

7. Spills

Spills can be a significant source of contamination to a river system and constitute a major concern. The concern is that the river may, during a short period of time, be subjected to a shock contaminant loading that may be several orders of magnitude greater than the annual loading. A summary of spills from Algoma

TABLE VI-24

Summary of spills to the St. Marys River, Canadian sources (1983-1986).

Date of Occurrence	Material/Source	Action
Algoma Steel:		
March 7, 8, 9/83	High phenols/ Terminal Basins 2,200, 1,870 3,100 ppb, respect.	Cooler start-up No enforc. action
July 26/83	De-phenolized liquor/Tank Leak	Photos, samples tested
November 24/83	De-Phenol. liquor/pin-hole in tank/ min. quant. lost	Drained/welded/refilled
January 24/84	500-1,000 Igal HCl to Lub pit	Pumped to holding tank for re-use
December 13/84	Approx. 2,000 Imp.gal liquid tar @ #7 coke oven battery	Collected by Weldwood
January 22/85	700-1,000 ppb phenols/Terminal Basins	Operator error, operator log revised
April 17/85	75 m imp.gal/d Terminal basin discharge & stormwater drift across the river	Investigated & complaint verified
August 11/86	Process wastes (iron, SS)/Terminal Basins	Overflow due to rainfall, none recovered
August 15/86	3,200 imp.gal/d process wastewater (Fe, SS) Terminal Basins	None, no environmental impact expected
August 18/86	Ammonia, cyanide	Unknown
St. Marys Paper:		
July 12/86	20,000 lb H2SO4 to clear water sewer/tank leak	Repaired
September 13-16/85	45 imp.gal/d H2SO4/Tank leak	Leak plugged and tank emptied
East End WPCP:		
May 5/86	Raw sewage	None recovered
July 17/86	Chlorinated raw sewage	None recovered
Unknown Sources:		
May 28/86	Non-PCB oil	None recovered

HCl - Hydrochloric Acid
SS - Suspended Solids
H_2SO_4 - Sulphuric Acid

Steel and St. Marys Paper (Table VI-24) indicated that the spill on March 7,8 and 9, 1983 from the Terminal Basins may represent a short-term phenol loading of about 2.4 tonnes to the St. Marys River which is 1 to 2 orders of magnitude greater than the normal loading from this discharge (Table VI-20). This demonstrates a significant shock loading to the river over a short period.

Over the past 50 years there have been numerous coal tar and product spills on Algoma and Domtar properties in proximity to Bennett and Spring Creeks. The spills have been from tank overflow, pipeline breaks and process leaks. These spills have been up to 10,000 gallons or more into creeks and onto slag-filled shorelines.

In May of 1987, an oil slick was observed on Spring and Bennett Creeks. Upon further investigation, the creek beds were found to contain coal tar saturated sediments to depth in excess of .75 m and a dense oily free-phase liquid (suspected of being coal tar and/or creosote) was flowing along the surface of the sediments. Both companies were directed to remove any free-phase material from the creek bed and to install coffer dams and/or sandbags to prevent the flow of free-phase material to the St. Marys River. The companies were also directed to conduct studies to determine the extent of contamination of the creeks and adjacent soils, to determine the source(s), and to recommend remedial options to prevent further contamination of the St. Marys River.

8. Summary

Table VI-25 summarizes the relative contributions of point and nonpoint source loadings of selected organics and heavy metals to the St. Marys River. In general, the river is subject to a daily loading of 14 tonnes of suspended solids, 5 tonnes of free ammonia, 4.5 tonnes of oil and grease, and 3 tonnes of iron. Loadings of other contaminants such as PAHs, volatiles, phenol and cyanide ranged from 3 kg/d (PAH) to 117 kg/d (phenols).

The high loadings of suspended solids and oil and grease represent a major factor in the destruction of river habitat as reflected by an adversely impacted benthic community along the Ontario shoreline of the river.

Although loadings of contaminants from nonpoint sources were not sufficient to set a priority on these sources, available information indicated that up to 50% of PAHs, zinc and lead loadings to the river may be attributed to nonpoint sources.

TABLE VI-25

Loading summary of point source* and nonpoint summary to the St. Marys River (kg/d).

Source Parameter	PAHs	Volatiles	Suspended Solids	Oil & Grease	Ammonia	Lead	Zinc	Iron	Cyanide	Total Phosphorus	Total Phenols
<u>Point Sources</u>											
Industrial	1.25	3.1	11,090	3,810	4,395	7.4	38	2,290	74.0	25	115
Municipal	0.423	1.14	987	363	210	1.2	2.3	48	NA	102	0.53
Tributary	0.051	ND	2,224	NA	21	NA	0.94	85	0.32	3.2	0.69
<u>Nonpoint</u>											
Urban	0.334-0.652	NA	NA	91	27	4.3	10.0	252	0.074	11	0.54
Rural	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.4	NA
Atmospheric	0.247	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Groundwater	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TOTAL	2.621	4.24	14,301	4,264	4,653	12.9	51	2,675	74	148	118

NA - Not Available, ND - Not Detectable

* - Various data sources (Table VI-17)

D. DATA QUALITY ASSESSMENT

The OMOE data for PAHs in caged clams and surficial sediments was generated by an external contract laboratory that performed poorly in the UGLCCS round robins (Chapter IV). Consequently, this data was checked by OMOE GC/MS laboratory staff and only after their data quality concerns were addressed and the data declared qualitatively and quantitatively accurate was this information used in the report.

Some of the effluent and river water samples analyzed by the OMOE laboratory for total phenols in 1986 were flagged as possibly having been contaminated by phenolic substances due to an improper cap liner (i.e. concentrations may have been reported higher than actual). However, this data was used when subsequent sampling, during the 1987 MISA pilot site surveys, revealed similar concentrations in effluents and water.

In the Canadian point source study, the federal laboratory which analyzed PAHs had somewhat lower method detection limits (1-2 ug/L) than did the OMOE lab analyzing samples for the MISA pilot site study during 1986 (10 ng/L). Because this difference affected the quantification of PAH loadings from dischargers, the UGLCCS data set was supplemented by the MISA data.

E. PROCESS MODELING

1) Physical: Hydrodynamics, Wind, Waves and Currents

For the purpose of the modeling study, the St. Marys River has been divided into an upper reach - above the regulatory works, and a lower reach - below the regulatory works.

Upper St. Marys River

The primary factors involved in the flow distribution in the upper river are gravity, wind, bed friction and the associated pressure forces. One of the causes of water movement in the deep channels of the upper St. Marys River is the inertial forces exerted by the large inflows from Lake Superior through the narrow mouth at Pointe Aux Pins. In the localized shallows of Leigh Bay and Pointe Aux Pins Bay, an appreciable influence on the water circulation is exerted by wind stresses.

One objective of the modeling was to describe the hydrodynamics of this area using mathematical models. A three dimensional steady state finite element model was applied to this area. The mathematical formulations were based on the three dimensional equations for conservation of mass and momentum. The principal assumptions used were:

i) the pressure was assumed to vary hydrostatically;

ii) the rigid-lid approximation was made, i.e. the vertical velocity at the undisturbed water surface was assumed to be a constant value of zero;

iii) eddy coefficients were used to account for the turbulent diffusion effects (the vertical coefficient was assumed constant while the horizontal coefficients were assumed to be zero); and

iv) the dimensions of the study area were small compared to typical weather systems, so that the geostrophic wind is assumed uniform over the entire area.

The basic equations (55,56) contain three empirical constants, i.e., the vertical eddy diffusion coefficients, the wind drag coefficient and the bottom slip coefficient, which cannot be determined from theory alone but must be tuned by means of proper field data in such a way that agreement between the model and prototype is satisfactory. A sensitivity analysis involving a large number of computer runs was made for these coefficients in order to assist with the calibration process.

The model was calibrated and verified using current meter data from the following sources:

i) the U.S. Corps of Engineers;
ii) the Ontario Ministry of the Environment;
iii) Integrated Exploration Limited; and
iv) aerial photographs taken of the area.

The model indicates that the upper river is highly responsive to wind speed and direction. Its dynamic behaviour is important in the shallow bays where gyres readily form. Examples of gyres formed under no wind and north wind (19 km/hr) conditions are shown in Figures VI-28 & 29.

Some of the contaminants (e.g. PAHs) in the bays are associated with the movement of fine grained sediment particles; it is expected that the gyres will play a significant role in the transport of contaminants from the area of the slag site to Leigh and Point Aux Pins Bays. The model has indicated that up to two strong gyres can be formed simultaneously.

Combined with existing field data on current measurements in this area, the calibrated model provides a better understanding of the cause and effect relationship between the wind and the circulation patterns in the upper river. This will eventually lead to the construction of more detailed fate models for management purposes. In addition, the model may provide new insights to the complex hydrodynamics of the upper river for those who are involved in collecting field data for the area.

Lower St. Marys River

The lower river is a nonuniform natural channel with slightly over half of its width dredged to a minimum of 8.5 m for the passage of ships. The velocity field data on the lower river is available from the U.S. Corps of Engineers. The data indicate the presence of some dead zones and re-circulation zones in the river due to natural or man-made protuberances from the shoreline.

The lower river was simulated by KETOX (57). This is a model that has a steady-state depth averaged hydrodynamic submodel coupled to a convection-diffusion (mixing) submodel. KETOX model has the following features:

i) it provides a forward marching solution to the continuity and momentum equations for the river (58);

ii) it provides solution for the lateral dispersion coefficients across each cross-section of the river based on the turbulence transport equations (K and E); and

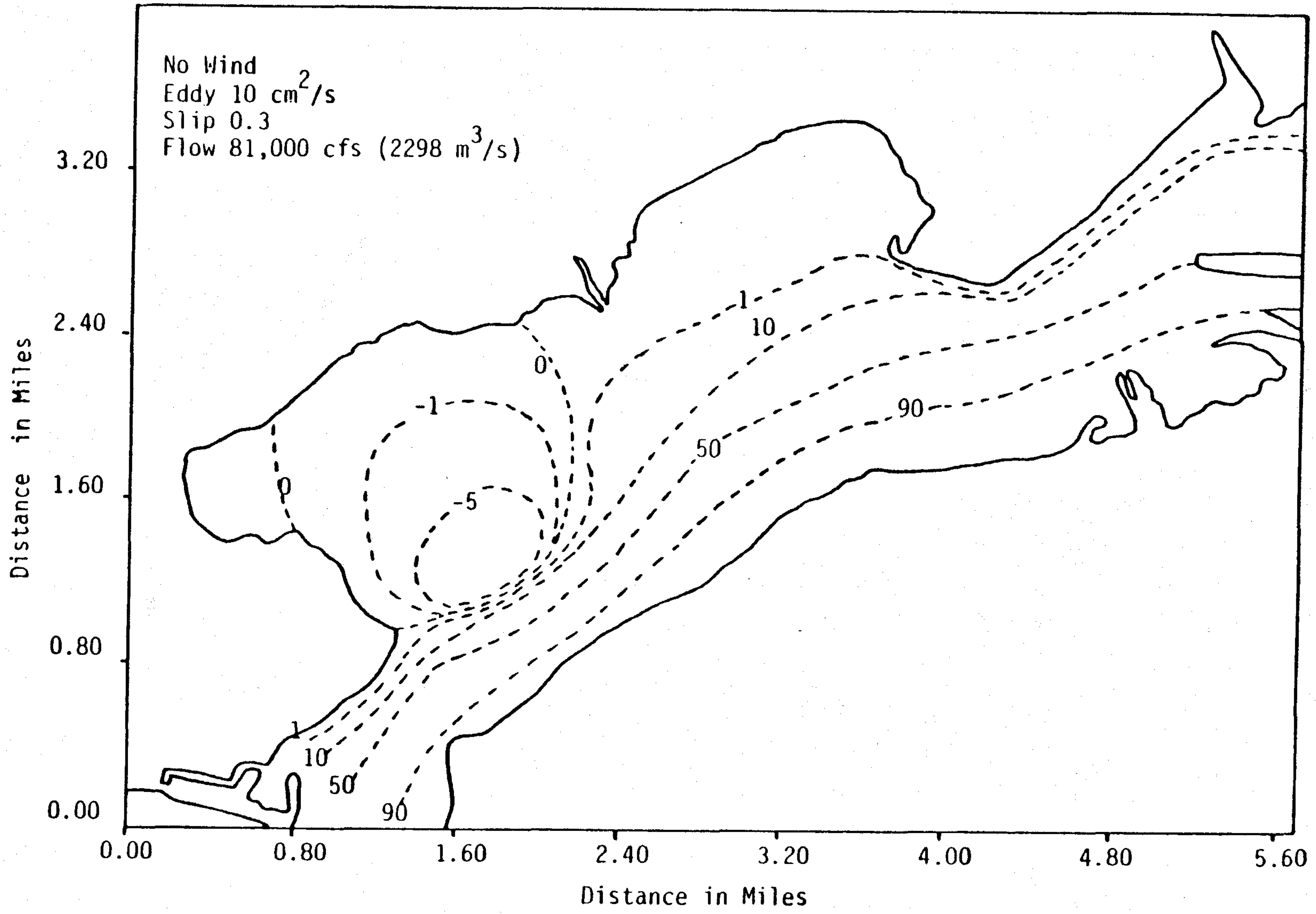

FIGURE VI-28. Dimensionless stream function circulation pattern (no wind).

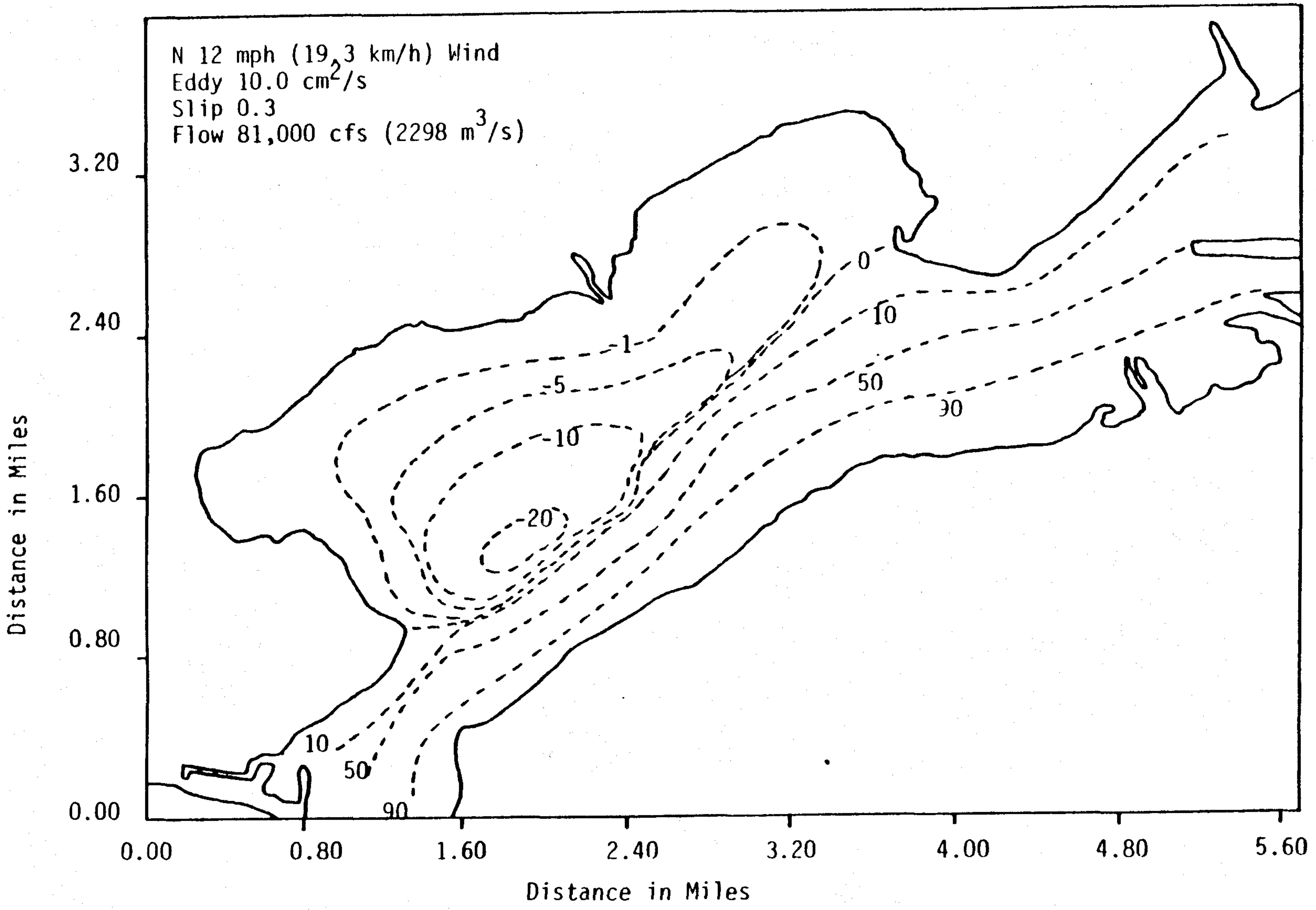

FIGURE VI-29. Dimensionless stream function circulation pattern (north wind).

iii) it can accept discharges from multiple outfalls.

The hydrodynamic component of KETOX was calibrated using U.S. Corps of Engineers (COE) 1984 field data based on current meter measurements and drogue surveys.

2. Physical-Chemical-Biological: Fate and Transport Models

The contaminant dispersion submodel of KETOX was calibrated using the 1974 OMOE phenol loadings and ambient measurements (10). The Model was subsequently verified with the 1983 OMOE phenol field data. The calibration and verification are illustrated in Figure VI-30 which is a dimensionless plot of the measured and predicted phenol concentrations along the Canadian shoreline starting from the Terminal Basins outfall location for the years 1974 and 1983.

The mixing model (K-E model) for the lower river (including the Algoma Slip and Control Structure) has been calibrated for hydrodynamics. For steady-state loading, isoconcentration maps can be developed with longitudinal resolution of the order of 15 m and lateral resolution as low as 1 % of the flow in the reach. This permits a reasonably accurate zone of effect or mixing zone to be defined so that various loading scenarios can be compared and evaluated.

Table VI-26 illustrates the longitudinal extent of the mixing zones associated with discharge from the Terminal Basins under the average summer river flow (2,450 m^3/s). The 1986 loadings for ammonia and cyanide (4,066 and 29 kg/d, respectively) will result in a mixing zone equal to or less than 100 m where the GLWQA and OMOE Water Quality Objectives are met. Also, there are no toxic effects within the mixing zone, although the effluent is toxic. The mixing zone associated with the phenol loadings from the Terminal Basins extends at least 7 km along the Ontario shore. Although the frequency of occurrence of low river flow (1.53×10^6 L/s) is about 0.1%, an estimate of the mixing zone associated with the 1986 loading is predicted to provide insight into the need for urgent reductions of phenol loadings. Figure VI-31 indicates that transboundary pollution may occur under the lowest flow possible.

Oil and grease within the bed sediment constitutes a major factor in the absence of <u>Hexagenia</u>. To model the impact of discharged oil and grease upon bed sediment, partitioning between water and sediment phases must be considered. For demonstration purposes, it is assumed that the concentration of oil and grease within the water column should not be more than 10% above the upstream background level (i.e., about 0.5 ppm). Using this guideline, the zone of effect is about 0.8 km. This same arbitrary guideline may be used for suspended solids, in order to minimize the amount of the organic portion of solids (which is responsible for most

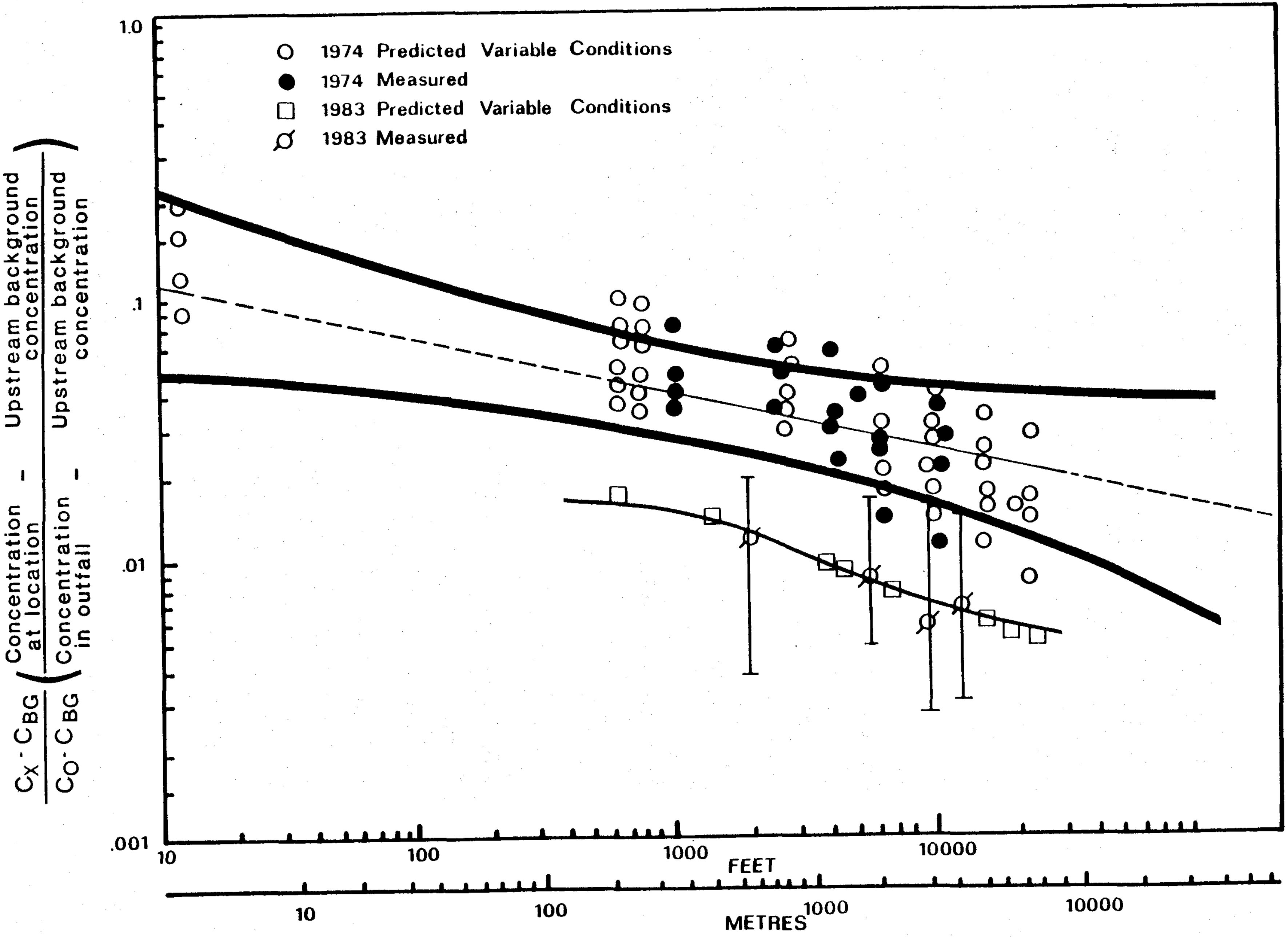

FIGURE VI-30. Predicted and measured phenol concentrations versus distance along the Canadian shoreline.

TABLE VI-26

Point source impact zone predictions from the Terminal Basins, under average summer river flow.

Parameter	1986 Loads (kg/d)	Length of Zone for 1986 Terminal Basin Loads (km)
Ammmonia	4,066*	<0.1
Cyanide	29**	<0.1
Phenol	114***	>7.0
Oil & Grease	1,413*	0.8
Suspended Solids	7,788*	7.0

Note: Loads from Table VI-19

* Average of self monitoring program of Algoma Steel
** UGLCCS data.
*** 1986 MISA Pilot Site data.

TABLE VI-27

Loadings (in kg/d) required to limit point source impact zones to 300 and 100 m from the Terminal Basins, under average summer flow (see text).

Parameter	300 m Impact Zone	100 m Impact Zone
Phenols	19	12
Oil & grease	950	590
Suspended solids	1,900	1,200

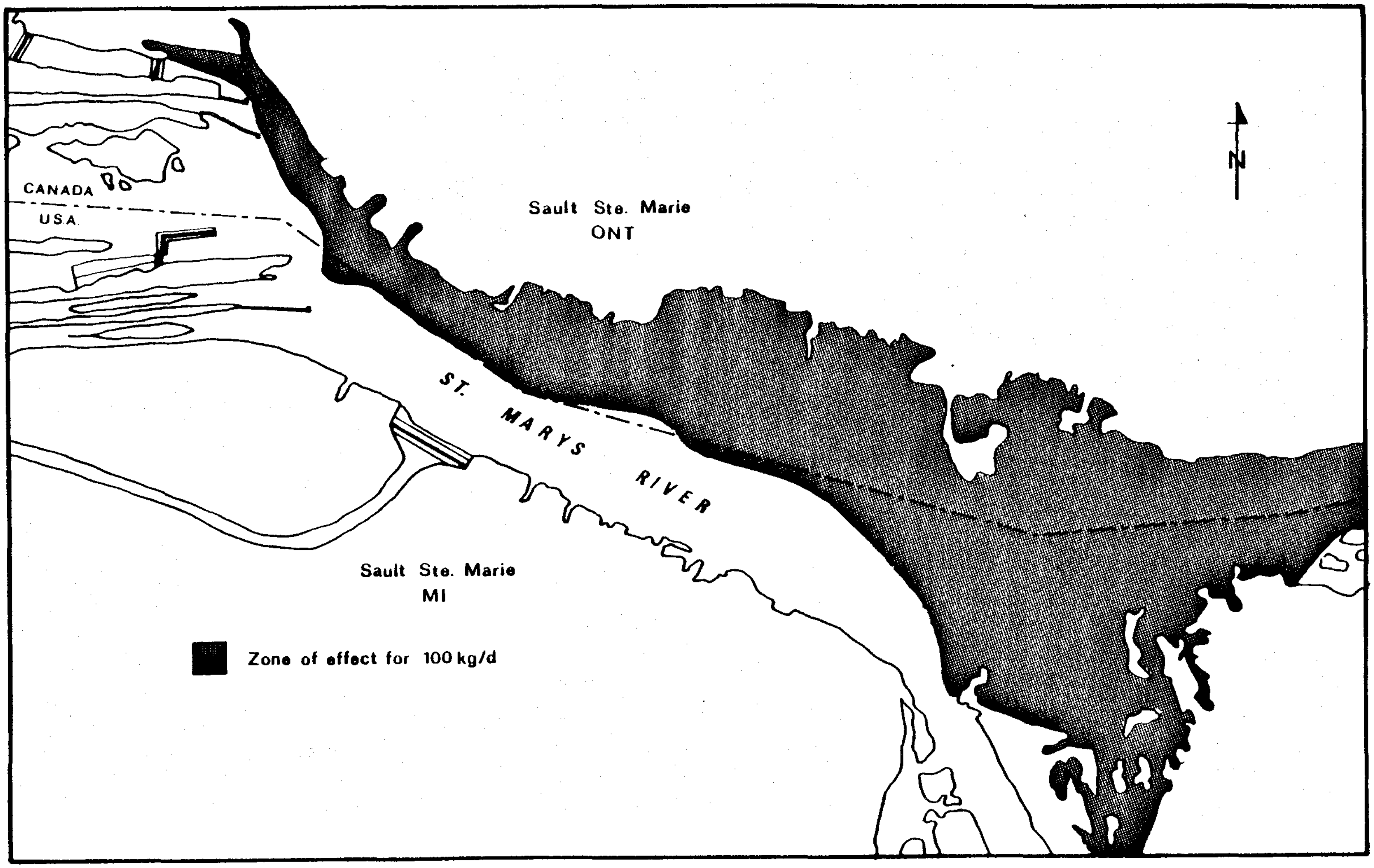

FIGURE VI-31. Zone of exceedence of phenol concentration of 0.002 mg/L for loads of 100 kg/d from the terminal basin under the St. Marys River's lowest flow conditions.

contaminants). Thus the concentration of suspended solids should not exceed about 1 ppm within the water column. This would result in a zone of effect of about 7 km.

These modeling tools may be used in a "regulatory mode" to derive the maximum effluent loads so as to meet the objectives and guidelines at selected distances downstream of any outfall. Table VI-27 summarizes these calculations for phenol, oil and grease, and suspended solids discharged from the Terminal Basins under the average summer flow in the river.

F. GOALS AND OBJECTIVES FOR REMEDIAL PROGRAMS

The goals of remedial measures in the St. Marys River should be the ultimate elimination of unacceptable adverse impacts on aquatic life and to ensure that the water is acceptable for drinking and recreation. Objectives will focus on the need to decrease the input, transport and biological availability of conventional and toxic pollutants in the St. Marys River.

Exceedences of water quality objectives are mainly restricted to a narrow band along the Ontario shore downstream of Algoma Steel and St. Marys Paper effluent discharges. Partial recovery from the effects of these inputs occurs downstream; however, discharges from the nonpoint sources (e.g. urban runoff) and the Sault Ste. Marie, Ontario East End WWTP delay complete restoration of satisfactory water quality with respect to several contaminants until Lake George.

Objective 1: **Reduce point source loadings of phenols, oil and grease, iron, phosphorus, and fecal coliform bacteria to meet water quality objectives throughout the river.**

Objective 2: **Eliminate point source impact zones downstream of each outfall through the reduction (to zero) of chronic and acute effluent toxicity.**

Although no water quality criteria exist for suspended solids, there is some indication that suspended solids and the associated contaminants may be a concern in the St. Marys River. Contaminants adsorbed onto the particulates can be deposited locally or transported long distances before settling out, thereby increasing the downstream extent of their impact.

Objective 3: **Reduce suspended solids loadings to the river.**

The full environmental significance of PAHs in the St. Marys River is presently difficult to evaluate due to insufficient data, and lack of compound specific toxicity information and standards. However, concentrations of total PAHs and selected PAHs, such as benzo(a)pyrene, were above available guidelines in river water and surficial sediments at one or more locations in the Sault Ste. Marie area. The presence of elevated levels of PAHs in caged clams introduced to the St. Marys River indicates that these compounds are potentially available to biota.

Objective 4: Reduce PAH Point and Nonpoint Source loadings to the river.

The benthic macroinvertebrate community in the St. Marys River is degraded along the Ontario shoreline downstream to Lake George. Generally, degraded communities exist in the vicinity of industrial discharges and in areas where sediments contain high concentrations of metals and organic contaminants. General reductions in conventional pollutant loadings from the major Ontario point sources do not appear to have resulted in proportional improvements in the health of the benthic community and may be related to occasional spills or persistent effects of contaminated sediments. The correlation of high oil and grease levels in sediments with low densities of Hexagenia nymphs indicates that reductions in the levels of oil and grease may be an important factor in the re-establishment of a healthy benthic community.

Depending on their geochemistry and organic content, polluted sediments may be a source of contaminants (e.g. heavy metals) to benthic organisms. This availability of contaminants may affect the benthic community as well as higher trophic levels.

Objective 5: **Improve the benthic macroinvertebrate community along the Ontario shoreline by reducing contaminant loadings and by the appropriate remediation of contaminated sediments.**

In addition to point and nonpoint discharges of contaminants, manmade modifications to the upper St. Marys River have resulted in changes and/or destruction of important benthic habitats and fish spawning areas (e.g. St. Marys Rapids). Currently, there is concern that human activities (e.g. aggregate reclamation) may result in further destruction of habitat due to physical removal and/or increased siltation.

Objective 6: **Prevent further benthic and fish spawning habitat degradation through the careful evaluation of proposed activities and modifications in the St. Marys River and upstream.**

G. ADEQUACY OF EXISTING PROGRAMS AND REMEDIAL OPTIONS

1. Existing Regulatory Programs (see Chapter III)

Ontario

i) Algoma Steel Operations

Table VI-28 shows Algoma's current discharge requirements. On June 13, 1983, Algoma Steel was served with an Amended Control Order aimed at controlling contaminants such as phenols, cyanide, ammonia, oil and grease and suspended solids which were found to be in contravention of Ontario's Environmental Protection Act. Since the issuance of the Control Order, Algoma's economic situation deteriorated to the point that the company could not fulfill all the Control Order requirements or dates of completion. As a result, on November 4, 1986, the Control Order was amended to extend the dates for compliance. In the spring of 1988 OMOE and Algoma negotiated ammendments to the 1986 Control Order to allow the operation of the #7 coke oven battery and to advance air emission requirements for the Algoma complex. The order was issued September 23, 1988 and included the following requirements:

Action	Deadline
- Reduce oil and grease loading to 1,023 kg/d	March 31, 1990
- Reduce total suspended solids loading to 5,108 kg/d	March 31, 1990
- Reduce phenol loading to 22.7 kg/d	June 30, 1989
- Reduce cyanide and ammonia to below level graphically illustrated by the diagonal line shown in Figure VI-32	Feb. 15, 1989

ii) St. Marys Paper

The St. Marys Mill is not subject to federal requirements because it existed prior to 1971 when the Federal Pulp and Paper Effluent Regulations were first promulgated. However, the federal limits may be used as a guideline and OMOE has incorporated the federal limit for total suspended solids (TSS) into the Certificate of Approval for the mill. This limit is based on the production rate for various unit processes, which varies from day to day.

TABLE VI-28

Comparison of point source effluent levels and permit requirements.

Current Requirements	Algoma Steel Terminal Basins	St. Marys Paper	East End WWTP	West End WWTP	Michigan WWTP
<u>Algoma Steel</u>					
(Control Order)					
Oil and grease - 1,589 kg/d	1,413*				
Suspended solids - 7,355 kg/d	6,717*				
Phenols - 22.7 kg/d	95.7				
(Compliance date 06.30.89)					
Cyanide + Ammonia See graph (Fig. VI-32) (Compliance date 02.15.89)	0/15 mg/L / 11.5 mg/L* toxic above limit				
<u>St. Marys Paper</u>					
(Certificate of Approval)					
Suspended solids - 10 T/d		3 T/d			
<u>East End WPCP</u>					
(Certificate of Approval)					
Suspended solids - 50% removal			65%		
BOD5 -30% removal			17%		
Phosphorus 1.0 mg/l#			2.9 mg/L		
<u>West End WPCP</u>					
(Certificate of Approval)					
Suspended Solids - 20 mg/L				4.8 mg/L@	
BOD5 - 20 mg/L				4.0 mg/L@	
Phosphorus - 1.0 mg/L				0.7 mg/L@	
Phenol - 0.01 mg/L				0.003 mg/L@	
Ammonia - 8 mg/L				1.9 mg/L@	
Chlorine - 0.5 mg/L				-	
<u>Michigan WWTP</u>					
(NPDES Permit)					
BOD5 - 30 mg/L					6.4**
pH - 6.5 to 9.0					7.2**
Suspended Solids - 30 mg/L					5.5**
Total Phosphorus - 1 mg/L					0.76**

* Based on average annual self monitoring data.
** Based on monthly operating report from November 1986 to October 1987.
@ Survey average concentration.
# The plant is not required to meet this limit until phosphorus removal facilities come on-line.

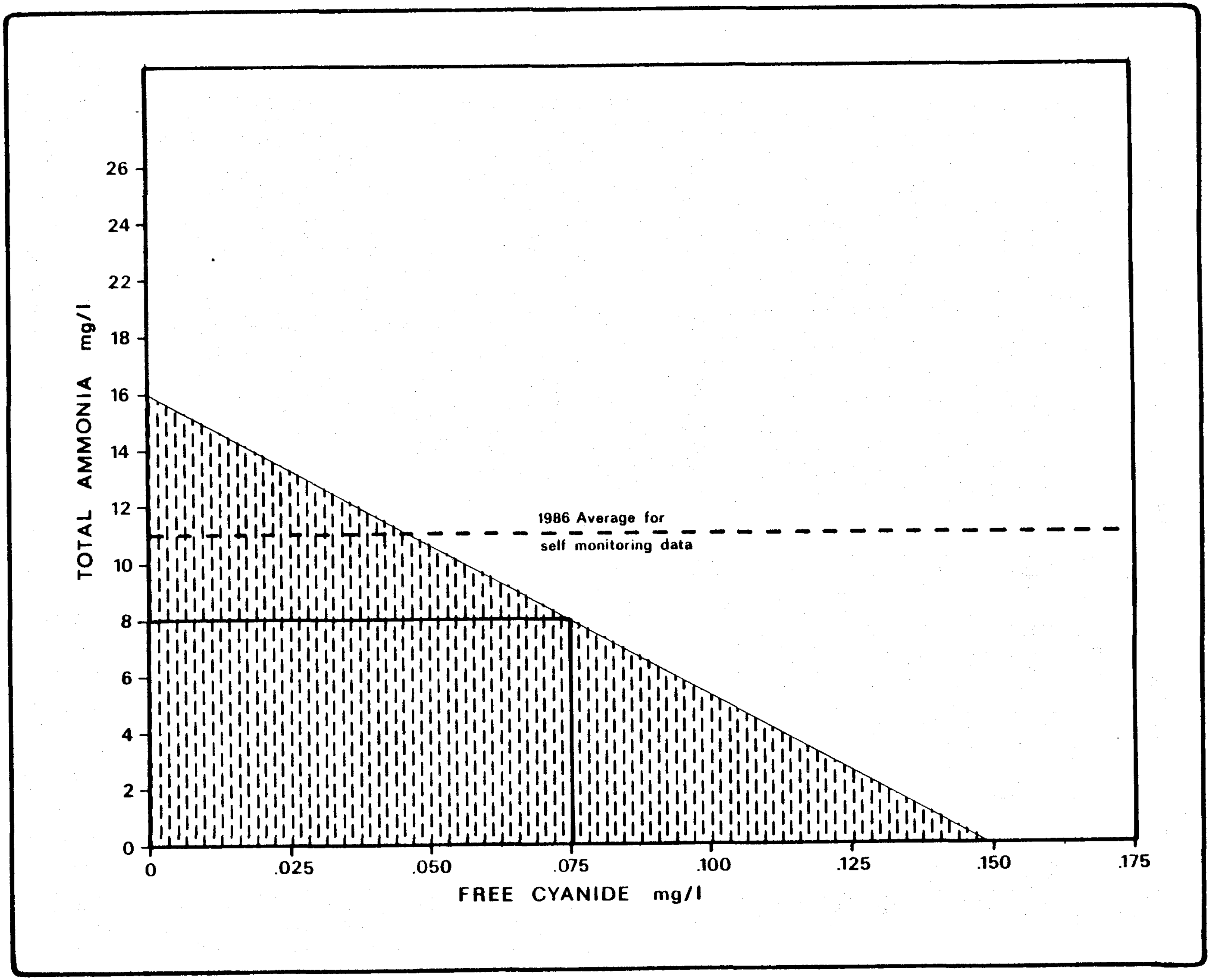

FIGURE VI-32. Algoma Steel allowable discharge concentrations of total ammonia and free cyanide from the terminal basin.

iii) Municipal Sewage Treatment Plants

Municipal WWTPs in Ontario are required to meet the general effluent limits specified by the Ministry of the Environment in OMOE Policy 08-01 "Levels of Treatment of Municipal and Private Sewage Treatment Works Discharging to Surface Waters" and OMOE Policy 08-04 "Provision and Operation of Phosphorus Removal Facilities at Municipal, Institutional and Private Sewage Works". This latter policy has not been applied to the Sault Ste. Marie East End WWTP. However, the GLWQA, Annex 3, does call for phosphorus controls of 1 mg/L on municipal waste water treatment facilities in the Great Lakes Basin with flows exceeding 3.7 x 10^3 m^3/d. A primary plant (e.g. East End WWTP) without phosphorus removal must achieve, on a annual average basis, a 30% removal of BOD_5 and a 50% removal of suspended solids (see Table III-7, Chapter III).

The West End WWTP, which is a secondary plant with phosphorus removal, is expected to meet the following Certificate of Approval requirements on the basis of arithmetic means of a minimum of 12 consecutive month analytical results from a minimum of one daily composite sample per month: BOD_5 and suspended solids, 20 mg/L; total phosphorus, 1.0 mg/L; total phenol, 0.01 mg/L; ammonia, 8 mg/L; and residual chlorine, 0.5 mg/L.

A model by-law ("By-Law to Control Industrial Waste Discharges to Municipal Sewers") was prepared by the OMOE and has been adopted by the City of Sault Ste. Marie. The by-law is intended to ensure the protection of WWTPs (including collection and disposal facilities) and to regulate the discharge of industrial wastes to municipal sewers.

The "Sault Ste. Marie Sewer By-Law" was passed in August 1968 and amended in April 1969. This by-law specifically regulates the discharge of conventional pollutants, metals and total phenols to sanitary and storm sewers. Other materials such as radioactive waste, benzene, gasoline and solvents are strictly prohibited. Cooling water or other unpolluted industrial water cannot be discharged to a sanitary sewer (City of Sault Ste. Marie, 1969).

Michigan

The effluent limitations contained in the NPDES Permit for the Sault Ste. Marie, Michigan WWTP are based upon application of regulations promulgated in accordance with the Federal Water Pollution Control Act Amendments of 1972 and the State of Michigan Water Quality Standards. The permit includes limits for BOD_5 - 30 mg/L monthly average, 45 mg/L 7-day average; pH - minimum 6.5, maximum 9.0; suspended solids - 30 mg/L monthly average, 45 mg/L 7-day average; and total phosphorus - 1.0 mg/L monthly average. From May 1 to October 15 of each year fecal coliform bacteria limits are 200/100 ml on a monthly average and 400/100 ml on a 7-day average. Effective January 1991 the 7-day average total residual chlorine in the effluent must not exceed 0.03 mg/L.

2. Actual Discharges vs. Control Requirements

Ontario

i) Algoma Steel

The levels of oil and grease and suspended solids associated with Algoma Steel's Terminal Basins discharges are periodically in excess of the Control Order's current requirements (Table VI-28). These exceedences have been referred to OMOE Investigations and Enforcement Branch for further action. The self-monitoring data indicated that discharges of cyanide and ammonia from the Terminal Basins were above the limits scheduled for February 15, 1989 (Figure VI-32). The combined effect of ammonia and cyanide discharging from the Terminal Basins constitutes toxic conditions. Bioassays on effluent samples collected from the Algoma Steel complex indicated that the Bar and Strip Lagoon effluent was the most toxic discharge to the river. The 96 hr LC_{50} for the Bar and Strip Lagoon effluent ranged from 2.2% to 100%. The Terminal Basins' effluent 96-hr LC_{50} ranged from 51% to 96% effluent in 1987. In the first quarter of 1988 the Terminal Basins' effluent 96-hr LC_{50} ranged from 7% to 52%.

There are no limits set in the Control Order for PAH compounds despite their presence at appreciable amounts in Algoma discharges. There are no zinc effluent limits set in the amended control order since measurement through self-monitoring or pilot site investigation programs indicated average concentrations less than the OMOE guideline of 1 mg/L. On occasion, however, daily levels of zinc from the Bar and Strip Lagoon exceeded the 1 mg/L level. The MISA pilot site investigation in 1986 revealed that 12% of samples exceeded 1 mg/L.

ii) St. Marys Paper

The St. Marys Paper Certificate of Approval (C of A) contains limits for only suspended solids. Currently, the suspended solids loading (3 tonnes/d) is well below the C of A requirement (Table VI-28).

iii) Municipal WWTPs

The East End WWTP must achieve, on an annual average basis, a 30% removal of BOD_5 and a 50% removal of suspended solids. In 1985 and 1986 the annual average removal for BOD_5 was 39% and 54%, respectively. The annual average total phosphorus concentration was 4.2 mg/L in 1985 and 3.4 mg/L in 1986. Thus, the BOD_5 and suspended solids requirements were both met in 1985 and 1986; however, the annual average total phosphorus concentration was above the GLWQA objective of 1.0 mg/L.

During the survey, the average BOD_5 removal was 17% and the total suspended solids removal 65% (Table VI-28). Effluent total phosphorus ranged from 2.8 to 3.1 mg/L. The implementation of phosphorus removal facilities, currently scheduled for January 1989, would be necessary to bring the total phosphorus concentration below 1 mg/L. Such facilities would also improve the reduction of BOD_5 and suspended solids. With phosphorus removal facilities in place, this plant would also be required to achieve 50% removal of BOD_5 and 70% removal of suspended solids on an annual basis.

The West End WWTP has only been on line since March 1986. During the first three months of operation the average effluent concentration of total phosphorus exceeded 1.0 mg/L. However, since then the plant has consistently met this requirement. The BOD_5 and suspended solids 20 mg/L limit was achieved on an annual basis and, except for BOD_5 in March 1986, the monthly averages have been consistently below 20 mg/L.

Michigan

The City of Sault Ste. Marie WWTP was not surveyed for the UGLCC Study. Because this plant was upgraded to secondary treatment in 1985 (on line 1986), historical effluent quality data collected prior to this period is no longer applicable. The compliance evaluation based on monthly average concentrations from November 1986 to October 1987 indicated the plant was in full compliance its NPDES permit for BOD_5, suspended solids, pH and phosphorus (Table VI-28).

3. Adequacy of Control Mechanisms

Control Orders

Models developed for the St. Marys River were used to assess the adequacy of effluent requirements stated in the Control Order for Algoma Steel Corp. Ltd. The regulatory mixing zone of 300 m is considered as the allowable zone beyond which no exceedence of water quality objectives is permitted under the expected range of natural conditions. This is based on an assessment of the significance of sites for aquatic, biological and/or human contact. The 300 m zone is recognized as a somewhat arbitrary limit and, after consideration by the RAP process, could be altered.

Table VI-26 indicates the existing discharges from Algoma Steel are exceeding a 300 m regulatory zone. Table VI-29 indicates the loading requirements which will result in levels complying with the OMOE and GLWQA at the boundary of the regulatory zone under average summer river flows. Ammonia and cyanide loadings of 7,000 and 95 kg/d will ensure no toxic effect at the end of the Terminal Basins' outfall. Levels at the boundary of the regulatory zone will be nontoxic during medium and low river flows. The phenol loading requirements (19 kg/d) in the Control Order will result in an exceedence during low river flow conditions but with a frequency of 0.1%.

Loadings of oil and grease and suspended solids stated in the Control Order may not be adequate to protect aquatic life in the river. An assumption that the concentrations of oil and grease and suspended sediment within the water column not exceed the background levels by more than 10% at the edge of the regulatory zone is used to provide adequate protection for aquatic organisms (e.g. Hexagenia). Based on this assumption, the Control Order requirements may have to be decreased to 950 kg/d for oil and grease and 1,900 kg/d for suspended solids. These loadings should be reduced further by about half to meet the requirements of the regulatory zone during low flow conditions. Limiting the oil and grease loadings to about 480 kg/d, should allow the recovery of aquatic organisms that were adversely affected by oil and grease discharges.

4. Ontario Regulatory Initiatives

Under Ontario's new MISA Program (Chapter III) effluent limit regulations will be developed on the basis of Best Available Technology Economically Achievable, for Algoma Steel Corp. Ltd., St. Marys Paper and the two Sault Ste. Marie WWTP's (to be promulgated by 1990/1991).

TABLE VI-29

Adequacy of effluent requirements for Algoma Steel.

Parameters	Control Order Loadings (kg/d)	Loading Requirements (kg/d) to Acheive the Regulatory Zone (300 m)
Ammonia	Reduce ammonia and cyanide to levels below the diagonal line (Fig.VI-32)	7,000
Cyanide		95
Phenol	22.7	19
Oil and grease	1,023	950
Suspended solids	5,100	1,900

H. RECOMMENDATIONS

Surveys of sediment quality, benthic community structure and water quality have revealed an impacted zone along the Ontario shore downstream of the industrial and municipal discharges. This zone was characterized by an impaired benthic community, contaminated sediments (zinc, cyanide, oil and grease, phenols, PAHs) and elevated concentrations of phenols, PAHs, iron, zinc, cyanide, phosphorus, ammonia, and fecal coliform bacteria in surface waters. Notwithstanding reductions in Algoma Steel effluents, impacts still exist in the benthic community in the river. Generally, the studies revealed that biota, sediments and water quality along the Michigan shore of the St. Marys River and in Lake Nicolet were good.

Based on these findings, the following recommendations are made in support of remedial programs already underway and to address the goals identified in Section F.

A. Industrial and Municipal Point Source Remedial Recommendations

1. Ontario and Michigan should incorporate the Great Lakes Water Quality Agreement's goal of the virtual elimination of all persistent toxic substances into their respective regulatory programs.

2. Algoma Steel which was the major contributor of ammonia, phenols, oil and grease, cyanide and suspended solids must continue to reduce loadings of these substances to meet the requirements of the Ontario Ministry of the Environment Control Order, the compliance dates of which should be strongly enforced. This recommendation is subject to recommendations 8 to 10, below.

3. The Sault Ste. Marie, Ontario East End WWTP should be equipped with phosphorus removal in order to bring the total phosphorus concentration in the final effluent down to the required 1 mg/L (this is expected to be on-line in 1989).

4. The treatment capacity of the East End WWTP is frequently exceeded. To reduce the frequency of plant overflows and bypasses this plant must be upgraded to provide secondary treatment and expanded, or a portion of the wastewater must be rerouted to the West End WWTP.

The Sault Ste. Marie, Ontario East End WWTP contributed the highest loadings of benzene-chloroethers and was the second highest contributor of oil and grease, ammonia, chloride, total metals, volatiles, PAHs, chlorinated phenols and phthalates. Elevated levels of PAHs and chlorinated phenols were observed only on the first day of sampling, presumably due to an industrial spill into the sanitary system.

5. The municipality, with the support of the OMOE, take steps to strictly enforce the Sault Ste. Marie Sewer By-Law and thus prevent the discharge of untreated industrial wastes to municipal sewers. The municipality and/or OMOE should also initiate an educational program to discourage home owners from disposing of hazardous or toxic waste in sewers.

6. Discharges of fecal coliform and fecal streptococci from Algoma Steel, WWTPs and combined sewer overflows must be reduced to meet Provincial Water Quality objectives.

7. The A.B. McLean aggregate extraction operations is potentially a significant source of suspended solids to the St. Marys River. The current, permitted extraction must be closely monitored and the requirements must be strictly enforced. Furthermore, the pending permit application must not be issued until a comprehensive environmental review indicates that the increased activity would not result in unacceptable adverse impacts.

In moving toward the virtual elimination of persistent toxic substances, future toxic controls will place increased emphasis on the ambient conditions of the St. Marys River ecosystem.

8. Discharge limits for point sources should be based on mixing zones with all water quality objectives met at the boundary of the mixing zone. This zone is expected to be reduced (ultimately to zero) as advances in treatment technology are implemented.

9. Depending on the parameter, Algoma Steel samples their effluent on a daily, weekly or monthly basis. Most of the controlled parameters are based on 12 month averages. Due to the variability in effluent characteristics, sampling should be more frequent. The frequency and type of sampling should be re-evaluated and audit sampling by OMOE should be increased.

10. Additional parameters, such as PAHs, should be regulated and incorporated into Algoma's monitoring program.

B. Nonpoint Source Remedial Recommendations

Concentrations and estimates of loadings from urban runoff are available only for the Ontario side. Estimates of atmospheric deposition on the Ontario side of the river indicated that significant amounts of PAHs might reach the river through the storm sewers. For rural runoff, loading estimates were available only for the Michigan side.

11. Ontario and Michigan should conduct additional studies for both urban and rural runoff to better identify and quantify loadings of trace inorganic and organic compounds.

Several active and inactive waste sites in Michigan and Ontario were identified as having the potential for contributing contaminants to the St. Marys River. These studies have been limited in scope and do not quantify the magnitude of the contaminant loadings entering the river.

12. Investigate the kinds of contaminants, the pathways of contamination (surface water and groundwater), and the magnitude of the contaminant flux; establish monitoring networks as required; and undertake necessary remedial clean-up activities at the following waste sites:

    i) the Algoma Slag Site;

    ii) Cannelton Industries Tannery disposal site (under CERCLA authority);

    iii) Union Carbide and Superior Sanitation landfills (under Michigan Act 307).

13. Spill containment must be improved at both industrial and municipal facilities to minimize the frequency of shock loadings to the aquatic ecosystem. This will entail spill prevention, development of contingency plans to deal with material reaching the river and following established procedures for the reporting of spills.

C. Surveys, Research and Development

14. Many PAHs have been shown to be bioaccumulative or to have toxic effects on aquatic organisms and some are proven carcinogens. The absence of specific, numerical water quality standards makes it difficult to regulate the discharge of PAHs. An accelerated effort to assess the ecological significance of PAHs and to develop compound specific criteria is required.

15. There are no regulatory guidelines to permit assessment of the biological significance of sediment associated contaminants. Development of such guidelines is required to aid in site-specific evaluations of contaminated sediments.

16. Impacts to benthic macroinvertebrate communities have been related to sediment quality. Further site specific work

must be completed to prioritize sediment "hot spots" based on biological impacts. In addition, physical and chemical characteristics of the sediment should be evaluated. This information will be used to determine appropriate remedial actions for sediments. Suggested studies include acute and chronic sediment bioassays as well as physical/chemical and bedload assessments.

17. The development of water quality based effluent limits for specific PAH compounds requires additional monitoring of point source discharges (water as well as air) and determination of PAH concentrations in resident aquatic indicator species.

18. There is a paucity of data on the near-field atmospheric deposition of metals and organics. This information should be obtained, and evaluated relative to other sources (e.g. effluents, urban runoff, Lake Superior) to the river.

19. Suspended solids are of concern due to their ability to deposit contaminants locally or to transport them long distances, before settling out. An investigation of the combined effects of suspended solids discharges from Algoma Steel, St. Marys Paper, and WWTPs should be completed. This may involve a sediment transport modeling effort that considers the sources, transport and ultimate deposition of sediment and contaminants. This study would also allow prioritization of sources for remedial action.

20. The NPDES Permit for the Sault Ste. Marie, Michigan WWTP includes effluent limits for BOD_5, pH, suspended solids, total phosphorus, fecal coliform, and residual chlorine. No loadings were measured for UGLCCS parameters during the 1986 survey period. Although no adverse impacts on the river ecosystem have been observed, trace contaminant loadings from this facility should be determined to verify the absence of environmentally significant loadings to the river.

21. The OMOE has issued fish consumption advisories for many large game fish due to mercury contamination. Although the main source of mercury is believed to be natural, there are potential sources in the Sault Ste. Marie urban area. Mercury has been detected, for example, in all point source effluents and in stormwater in Sault Ste. Marie, Ontario. Therefore, it is recommended that a study to determine the relative contributions of background and urban source(s) of mercury be completed.

22. Fecal coliform bacteria densities were detected in river water downstream of the Edison Sault Power Canal in Michigan. Further sampling must be conducted to determine

whether Michigan's fecal coliform standard is being exceeded and, if so, to identify the source(s) and appropriate remedial action.

23. For chemicals where ambient data and standards are available, the agencies must develop an ecosystem model. The model should provide insight into the fate of chemicals entering and leaving the river by various pathways as well as a systematic process for predicting the relative effectiveness of proposed corrective actions.

24. Although the current water quality objective for oil and grease is narrative (i.e. no visible sheen), a numerical objective should be developed that is based on no adverse impacts on sediment quality and associated benthos.

I. LONG TERM MONITORING

1. UGLCCS vs. Other Monitoring Programs

A presentation of the purposes for monitoring and surveillance activities is included under Annex 11 of the GLWQA and a discussion of considerations for the design of a long term monitoring program can be found in Chapter 7 of the Report of the Niagara River Toxics Committee (59). Because the focus of the UGLCC Study was toward remedial actions to alleviate impaired uses of the Connecting Channels System, long term monitoring recommendations will likewise focus on the evaluation of trends in environmental quality in order to assess the effectiveness of remedial actions. In general, post-UGLCCS monitoring should be sufficient to 1) detect trends in conditions noted by the UGLCCS, and 2) detect changes in ambient conditions which have resulted from remedial actions. Monitoring programs should be designed to specifically detect the changes intended by the remedial actions so as to ensure relevance in both temporal and spatial scales.

Two major programs sponsored by the IJC also contain plans for long term monitoring: the Great Lakes International Surveillance Plan (GLISP) and the Remedial Action Plans (RAPs) for Areas of Concern (AoC's) identified by the IJC. The GLISP for the Upper Great Lakes Connecting Channels is presently incomplete, pending results of the UGLCC Study, but it is expected to provide monitoring and surveillance guidance to U.S. and Canadian agencies responsible for implementing the provisions of the GLWQA that include general surveillance and research needs as well as monitoring for results of remedial actions.

The St. Marys River is one of the AoCs, and a RAP is being developed jointly by Michigan and Ontario. The RAP will identify uses impaired, sources of contaminants, desired use goals, target clean-up levels, specific remedial options, schedules for implementation, resource commitments by Michigan and Ontario as well as by the federal governments, municipalities and industries and monitoring requirements to assess the effectiveness of the remedial options implemented. Results and recommendations coming from the UGLCC Study will be incorporated extensively into the RAP, which will then be the document that influences federal, state and provincial programs for the St. Marys River. The recommendations for long term monitoring that are presented below are intended for consideration and incorporation into either or both the GLISP and RAP for the St. Marys River.

2. System Monitoring for Contaminants

Water

Knowledge of the concentrations of the principal contaminants in the water of the St. Marys River should be used to indicate general exposure levels for the biota, to identify changes and trends over time in the concentration levels, and to be used for general assessment of contaminant impacts. The parameters to be monitored include phenols, iron, cyanide, ammonia, total PAHs, oil and grease, benzo(a)pyrene, and ether solubles. Monitoring stations should provide information on contaminant concentrations throughout the river. For continuity, these should include the sampling transects identified in this study (i.e., SMU 1.0 and 0.5; SMD 0.2, 1.0, 1.2, 2.6, 4.2E, and 5.0E). Sampling frequency should be influenced by the variability in contaminant sources. Spring high flow conditions and late summer low flow conditions would be expected to bracket the normal seasonal variability in flow that could influence measured contaminant concentrations.

A mass balance approach to contaminant monitoring will help to identify any changes in the contaminant mass over time, and it will provide the basis for targeting future remedial actions by providing a comparison of the magnitude of the sources. A mass balance analysis should be conducted approximately once every five years, assuming that some effective remedial action has been implemented against one or more sources such that the total loadings of contaminants, or the relative contribution of the sources to the loading, has changed. The sources to be measured should include:

1) Head and mouth transects for upstream and downstream boundary movements. The number and locations of stations should relate to measured or predicted plume distributions. Suggested locations include Point Aux Pins, the head of Sugar Island, and the downstream end of Lake George and Lake Nicolet. Both dissolved and particulate fractions should be analyzed. The quantity of suspended sediment flux should also be measured.

2) Municipal and industrial point sources. During the survey, the sampling must be frequent enough to accurately reflect the likely loading fluctuations from the major point sources. The sources include the major outfalls of Algoma Steel, St. Marys Paper, and the East End WWTP, the West End WWTP and Sault Ste. Marie, Michigan WWTP.

3) Tributaries. Preliminary assessment has shown that contributions from tributaries to the St. Marys River are secondary to the industrial and municipal point sources. These findings should be confirmed periodically.

4) CSOs and Runoff. To provide an estimate of contaminant mass loadings expected during storm events, occasional studies on selected urban drainage areas should be conducted. Estimates should be made for all urban and agricultural runoff on both sides of the river.

5) Groundwater inflow. Groundwater monitoring systems designed to detect potential loadings to the St. Marys River need to be installed at the Algoma Slag Site and at Cannelton Industries Tannery disposal site following remediation. The existing monitoring system at the Cherokee Landfill should be utilized to detect potential loadings to the river.

6) Sediment transport. Preliminary studies indicate that bedload sediments moving into and out of the St. Marys River carry contaminant masses similar to, or exceeding the other sources. The mass flux should be quantified.

7) Atmospheric deposition. Direct atmospheric deposition of contaminants to the St. Marys River is expected to be minor. Deposition to the drainage basin and subsequent runoff into the river or its tributaries, however, could be an important source for some contaminants. Estimates of contaminant mass in both wet and dry deposition to the drainage basin should be made when unidentified nonpoint sources are found to be a major contributor of any of the contaminants of interest.

Sediments

Monitoring of sediments for concentrations of contaminants should be conducted periodically throughout the St. Marys River in order to assess both the trends in surficial contaminant concentrations and the movement of sediment-associated contaminants within the river. The grid used by the U.S.FWS during the 1985 survey would be appropriate for consistency in sampling sites and sediment composition. An analysis of sediment chemistry including both bulk chemistry, organic and inorganic contaminants, and particle size distribution should be conducted every 5 years, in conjunction with a biota survey (see "habitat monitoring" below). In the St. Marys River, particular attention should be given to sediment concentrations of oil and grease, phenols, cyanide, and PAHs.

Because the grid stations are distributed throughout the river reach and are associated with appropriate habitat for a sensitive benthic invertebrate (Hexagenia), the periodic survey will allow assessment of 1) contaminant distribution throughout the river sediments, 2) relative movement of the contaminants within the river sediments between surveys, and 3) correlation of contaminant concentrations with benthic biotic communities.

The sediment at any stations established at the mouths of tributaries to the St. Marys River should be monitored for organic and inorganic contaminants on an annual or biannual basis when significant remedial actions are implemented within the watershed for the tributary. The remedial actions should be expected to measurably reduce loadings of one or more particular contaminants via the tributary in order to trigger the more frequent sediment monitoring programs.

Biota

Long term monitoring of concentrations of contaminants in biota will provide a time series useful to track the bioavailability of contaminants to selected representative organisms. Three long-term monitoring programs are already in place and should be continued:

i) Annual or bi-annual monitoring of sport fish.

This program should focus especially on PAHs, mercury, and PCBs. The monitoring should be continued regardless of the differences that may be observed between acceptable concentrations or action levels that may be established by governmental agencies and the measured contaminant concentrations in the fish flesh. As a link between human health concerns and integrated results of remedial programs to reduce contaminants in the UGLCC System, this program is critically important.

ii) Spottail shiner monitoring program.

This program is designed to identify source areas for bioavailable contaminants. In locations where spottail shiners contain elevated levels of contaminants, additional studies should be conducted to identify the sources of the contaminants. Some upstream studies in tributaries may be required. Spottails should also be employed to confirm that remedial actions have been effective in removing or reducing the loading of one or more contaminants.

iii) Caged clams contaminants monitoring.

Caged clams should continue to be used at regular time intervals, perhaps in conjunction with spottail shiners, to monitor integrated results of remedial actions to reduce contaminant loadings to the water. Clams may be located at tributary mouths and downstream of suspected source areas. Repeated assays from the same locations should confirm results of remedial actions.

iv) Benthic survey

The macrozoobenthic community should be evaluated at least every 3 years. As a minimum, the abundance and distribution of the mayfly Hexagenia should be determined to serve as an indicator species of environmental quality. The grid used by the U.S.FWS during the 1985 survey (Figure VI-20) would be appropriate for consistency in sampling sites each survey. An analysis of sediment chemistry, including bulk chemistry, organic, inorganic and extractable (available) contaminants, and particle-size distribution, should be conducted for samples taken concurrently with the macrozoobenthic survey. These data will provide information on the quality of the benthic habitat.

v) Toxicity testing

Sediment toxicity tests, using whole sediment and sediment pore water or elutriate should be conducted at selected sites in conjunction with the benthic survey. Results will assist to differentiate between toxicity and substrate or dissolved oxygen effects.

3. Sources Monitoring

Remedial actions intended to reduce concentrations and/or loadings of contaminants from specific point sources generally require monitoring for compliance with the imposed criteria or standards for permitted contaminants. The monitoring may be conducted by the facility or by the regulating agency, whichever is applicable, but attention must be given to the sampling schedule and analytical methodology such that mass loadings of the contaminants can be estimated, as well as concentrations in the sampled medium. Monitoring of the "near-field" environment, i.e., close downstream in the effluent mixing zone, should be conducted regularly to document reductions in contaminant levels in the appropriate media and to document the recovery of impaired ecosystem processes and biotic communities. Such monitoring may be required for a "long time", but over a restricted aerial extent, depending on the severity of the impact and the degree of reduction of contaminant loading that is achieved.

For the St. Marys River, four actions were recommended that would affect specific sources of contaminants:

a) Reduction of toxic substances from Algoma Steel effluents, especially at the Terminal Basins. Reductions in loadings of phenol, cyanide, ammonia, oil and grease, and suspended solids are expected as a result of new effluent limitations imposed as part of the MISA program. Monitoring of sediments and biota for contaminant concentrations and effects downstream of the effluent should be conducted regularly to document any improvement in environmental conditions.

b) Enforcement of the regulatory mixing zone for the Sault Ste. Marie, Ontario East End WWTP. Ontario must design a monitoring plan adequate to determine that all water quality objectives are met at the boundary of the regulatory zone, and to determine if adverse environmental effects continue in the sediments and biota despite compliance with water quality objectives.

c) Enforcement of the Sault Ste. Marie, Ontario Sewer By-Law to prevent the discharge of untreated industrial wastes or contaminants disposed by homeowners into municipal sewers. Ontario will provide additional monitoring, inspection and enforcement tools for implementing controls of toxic discharges to sewer systems. The monitoring component must include assessment of continuing environmental effects in sediments and biota downstream of the sewer outfall, as well as monitoring for concentrations of selected contaminants in the sewer influent.

d) Equip the Sault St. Marie, Ontario, East End WWTP with phosphorus removal facilities. Frequent in-plant monitoring will be required to document that the target discharge limit of 1 mg/L is being met.

Other recommendations for specific contaminant sources involve an assessment of the present conditions or a study to quantify concentrations or loadings: review of PAHs for risk and hazard information; assess the need for further reduction of suspended solids from St. Marys Paper; quantify trace contaminants from the Sault St. Marie, Michigan WWTP, estimate loadings of trace organic and inorganic compounds from urban and rural runoff, and quantify potential releases of contaminants from waste disposal sites. Each of these items requires a specific program of data collection and analysis. Additional needs for longer term monitoring may be identified as a result of these studies.

4. Habitat monitoring

Habitat monitoring should be conducted to detect and describe changes in the ecological characteristics of the St. Marys River through periodic analysis of key ecosystem elements. In particular, quantification of the extent of wetlands along the St. Marys River should be conducted every three years. Aerial photography or other remote sensing means would be appropriate to discern both emergent and submergent macrophyte beds that are important as nursery areas for larval fish and other wildlife. Verification of aerial data should be conducted by inspection of selected transects for plant species identification and abundances. Changes in wetland areas should be correlated with fluctuating water levels and other natural documentable influences so that long term alterations in wetlands can be tracked and causes identified.

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CHAPTER VII

ST. CLAIR RIVER

A. STATUS OF THE ECOSYSTEM

1. Ecological Profile

Watershed Characteristics

The St. Clair River flows in a southerly direction forming the international boundary between the United States and Canada. This navigable waterway physically separates Lambton and Kent Counties in Ontario, and St. Clair County in Michigan. The St. Clair River is not a typical river system, occupying an alluvial valley, but must technically be regarded as a strait (1). This system is a true connecting channel or conduit which transports water, nutrients, sediments, and biota from Lake Huron to Lake St. Clair (Figure II-3).

The complex connecting channel between Lake Huron and Lake Erie that involves the St. Clair River, Lake St. Clair, and the Detroit River came into existence nearly 10,000 years ago with the retreat of the Pleistocene ice sheet. As the massive weight of ice was removed, an uplift in the form of glacial rebound occurred, leaving the St. Clair River/Lake St. Clair/Detroit River channel as the dominant outlet for the waters of the Upper Great Lakes. As time passed, the actions of the moving water enhanced the exit mechanism, until some 3,000 years ago, when the complex connecting channel became a permanent feature of the landscape.

The St. Clair system overlays 4,200 metres of sedimentary Paleozoic bedrock resulting from the hardening of ancient silts and muds to form extensive deposits of sandstones, limestones, dolomites, salts and shales. This thick depositional sequence rests upon a foundation of Precambrian igneous and metamorphic rocks. Fossil fuels have been extracted from the area for more than a century, beginning with the first oil field in North America developed at Oil Springs, Ontario, in 1858. Minerals of evaporative origin, such as halite (rock salt), have been extensively extracted by the Morton Salt Company for decades in St. Clair, Michigan.

The geologic origin of the St. Clair River resulted in a river system which forms the single outlet for Lake Huron, conducting its waters approximately 64 km southward to Lake St. Clair. Sediments in the river consist of gravel with sand in the interstices over glacial clay. Very little sediment deposition occurs along the river channel above the river delta. Prior to entering Lake St. Clair, the diminished velocities of the river with broadening provided an extensive depositional area. Thus, a large river delta system developed containing numerous distribution channels and an extensive region of wetlands. The shoreline of the St. Clair River, including the principal delta distribution channels, is 192 km in length.

Hydrology

As might be expected, water velocities within the St. Clair River are highest in the northern stretch of the river adjacent to the exit of Lake Huron, and lowest in the southern delta area. The total flow time from Lake Huron to Lake St. Clair is shown in Figure VII-1. It has been estimated to be 21.1 hr from Lake Huron to Lake St. Clair (2). The total average fall in this stretch is 1.5 m in vertical height (3). The mean water velocity is 3.5 km/hr, with a minimum of 1.1 km/hr in the delta area adjacent to Lake St. Clair (Figure VII-1)(2).

The river flow ranges between approximately 3,000 m^3/sec and 6,700 m^3/sec (2). The mean monthly discharge was 5,200 m^3/sec between 1900 and 1981 (6). Eight percent of this mean flow (410 m^3/sec) passes through the Ontario channels of the St. Clair Delta; the remainder (92 percent) passes through the more westerly main channels of the delta (7).

The river behaves like three separate panels of water: two nearshore sections strongly influenced by discharges; and a centre panel which passes through the river with minimal change.

On the Michigan side of the St. Clair River, four heavy industries are the principal users of river water for metal plating, paper manufacturing, and salt processing. By far, the heaviest municipal and industrial use occurs on the Canadian side of the river with ten major industrial plants in the Sarnia area producing refined petroleum, petrochemical and agricultural products. A large coal-fired power generating station is also located on the Ontario shore. A number of studies have shown that effluents

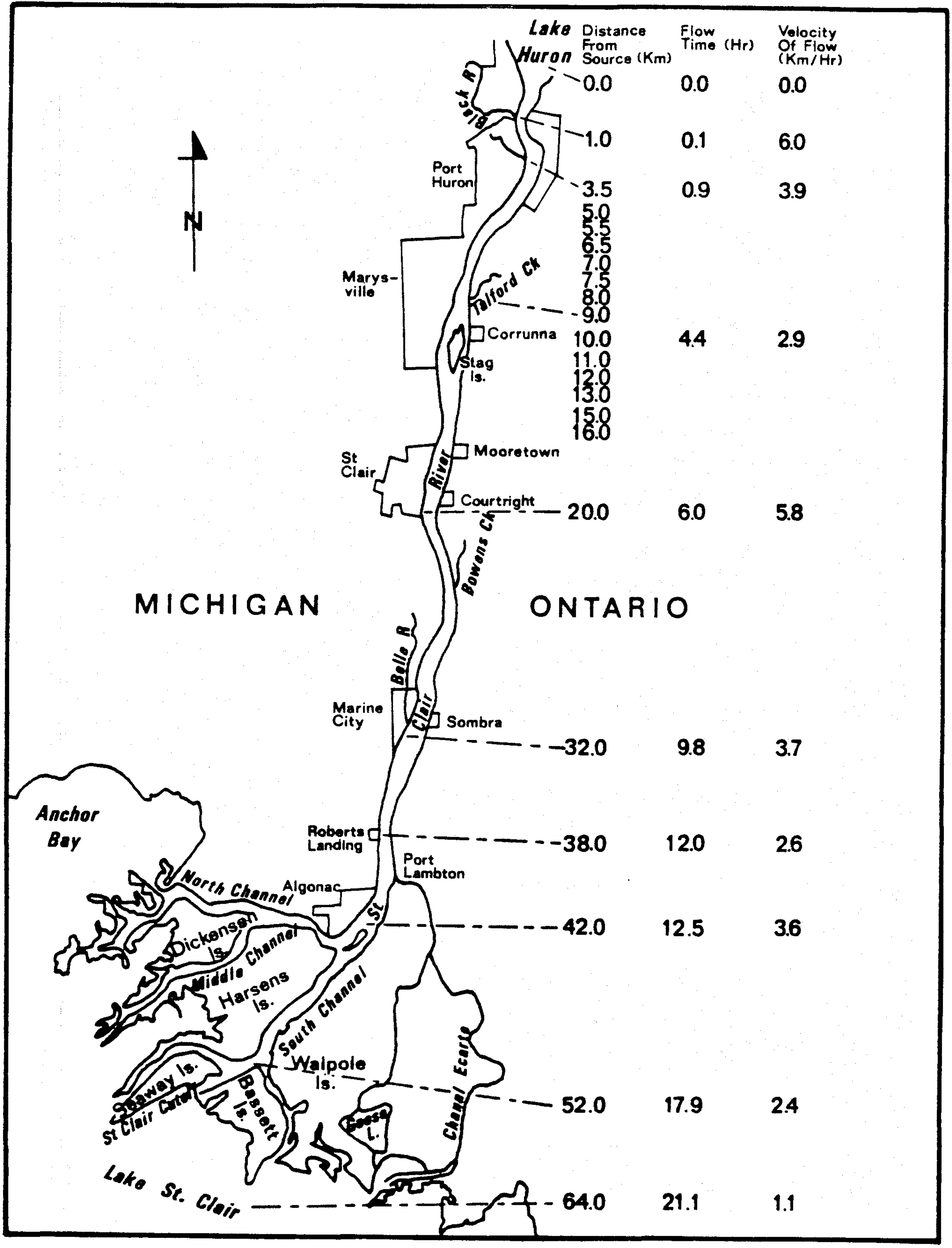


FIGURE VII-1. St. Clair River indicating approximate flow times and velocities of flow of various reaches of the river.

from a number of these plants have degraded the quality of the St. Clair River system (8-12).

Historically, waterborne commerce has been a very heavy user of the St. Clair River system. Traditionally, iron ore, limestone, and coal account for 90 percent of commercial shipping on the St. Clair River (13).

Habitats and Biological Communities

The St. Clair River ecosystem consists of five fundamentally distinct biologic zones: (i) open-water, (ii) submerged wetland, (iii) emergent wetlands, (iv) transition or ecotone, and (v) upland. Each of these zones may be subdivided by the community of organisms which occupy them, or by their physical characteristics.

The open-water zone may be subdivided into two major groups: (i) the channelized flow communities, and (ii) the open-water marsh communities. The channelized flow communities include such diverse groups as free-swimming nekton, e.g., fish, amphibians, and reptiles; drift communities, e.g., uprooted submerged and emergent plants, phytoplankton, and zooplankton; and sessile, burrowing, or attached communities, e.g., immature aquatic insects, invertebrates, and mollusks. The open-water marsh communities predominate in the St. Clair Delta area. They are typically either bullrush marshes, or cattail marshes. The open-water bullrush marsh is prevalent in the abandoned channels of the St. Clair Delta, or mixed with cattail marshes where water depth and sandy sediments favour the development of bullrush communities. Open-water cattail marshes are found in delta sections of the river where peaty or clayey hydrosoils predominate, and where water depth exceeds 15 cm (5).

The St. Clair River system contains approximately 550 ha of coastal wetlands. The primary type of wetlands in the St. Clair River belong to the river wetland group, and are composed largely of submerged species (5,14,15). These shoreward, submerged communities may be conveniently divided by location into the delta channel, and the river shoulder. The delta channel communities include both abandoned and active delta channels. The river shoulder communities border the channelized area of the river for a distance of 30-40 m, and rarely exceed 2 m in depth (2). Emergent wetland communities occasionally occupy the river shoulder area, but more often, these forms are to be found on point bars and within the river delta structure.

The transition zone, or ecotone, may be conveniently subdivided into three major categories of community types: (i) the island shoreline and transgressive beach, (ii) sedge marshes, and (iii) the transition wet-meadow. Long, narrow beaches of fine sand which support emergent vegetation are found on the Canadian side of the river delta. Transgressive or stranded beaches are also found on the islands of the delta area which support intermediate or transition communities, including tussock sedge (*Carex* sp.), reed (*Phragmites australis*), swamp thistle (*Cirsim muticum*), bluejoint grass (*Calamagrostis canadensis*), willows (*Salix* sp.), and the eastern cottonwood (*Populus deltoides*). The sedge marsh communities occupy a very narrow zone of transition between the wetter cattail marshes and the more terrestrialized upland zones. Typical residents of this community are nearly all members of the tussock sedge group (*Carex* sp.), with the exception of bluejoint grass (*Calamagrostis canadensis*). The transition wet-meadow communities represent a transition state between the sedge marshes and the upland communities. This community lies above the water table and is infrequently flooded. It consists of a mixture of grasses, herbs, shrubs, and water-tolerant trees, including quaking aspen (*Populus tremuloides*), red ash (*Fraxinus pennsylvanica*), red osier dogwood (*Cornus stolonifera*), swamp rose (*Rosa palustris*), bluejoint grass (*Calamagrostis canadensis*), rattlesnake grass (*Glyceria canadensis*), and panic grass (*Panicum* sp.).

The terrestrialized upland communities bordering the St. Clair River system include upland shrub, and deciduous hardwood. The upland shrub community consists of mixed shrubs and water tolerant trees, including eastern cottonwood and quaking aspen (*Populus* sp.), red ash (*Fraxinum pennsylvanica*), red osier dogwood and gray dogwood (*Cornus* sp.), wild grape (*Vitis palmata*), and hawthorn (*Crataegus* sp.). The deciduous hardwood community adjacent to the St. Clair River begins on an average of 1-3 m above the level of the river. Major species in this community include red ash (*Fraxinus pennsylvanica*) and members of the genus *Quercus*, including swamp white oak, pin oak, and burr oak. Other hardwoods include silver maple (*Acer saccharinum*), the American elm (*Ulmus americana*), eastern cottonwood (*Populus deltoides*), and shagbark hickory (*Carva ovata*). The terrestrialized upland communities are chiefly found in the less industrialized portions of the basin, particularly in southern reaches of the river, and notably in the island complex associated with the delta area.

i) Macrozoobenthos

The macrozoobenthos of the St. Clair River exhibits a higher taxonomic diversity than Lake St. Clair. The number of individual species observed in the river is in excess of 300 (2). Members of the Oligochaeta, Chironomidae, Gastropoda, Ephemeroptera, Trichoptera, and Amphipoda contribute most significantly to total macrozoobenthic biomass. Large numbers of *Hydra* sp. are present, but contribute little to biomass.

The genera *Cricotopus*, *Parachironomus*, *Parakiefferiella*, *Rheotanytarsus*, and *Stictochironomus* are the dominant chironomid forms. The most common amphipod is Hyalella, and the common trichopteran genera include Cheumatopsyche, Hydropsyche, and Oecetis. Species diversity is greatest in the Chironomidae, Trichoptera, and Oligochaeta. Numerous freshwater mussels are present in abundance in the St. Clair River, as are the common snail genera Amnicola and Elimia.

ii) Zooplankton, Phytoplankton and Macrophytes

The St. Clair River harbors relatively low densities of limnetic zooplankton (16). Several authors report that the St. Clair River zooplankton community is dominated by fugitive drift communities of zooplankton from Lake Huron (2,16,17). A total of 18 rotifer genera, 9 calanoid copepods, 4 cyclopoid copepods, and 6 cladocerans have been observed in the St. Clair River (18). While rotifers were most frequently seen (17), the dominant zooplankton species observed were Bosmina longirostris, Cyclops thomasi, and Diaptomus minutus.

The primary production system of the St. Clair River consists of phytoplankton, emergent macrophytes, submerged macrophytes, and the periphyton community associated with the submerged portions of the latter two groups. A single source of information is available regarding the phytoplankton composition of the St. Clair River. This study was completed more than a decade ago (17,19), and suggests that the phytoplankton community of the St. Clair River is dominated by diatoms occurring in patterns similar to the communities of Lake Huron. Dominant species reported in 1974 included Cyclotella sp., Fragillaria sp., Melosira sp., Stephanodiscus sp., Synedra sp., and Tabellaria sp. At the time of preparation of this manuscript, no published data were available related to native periphyton communities in the St. Clair River.

Submerged macrophytes are a prominent feature of the littoral waters of the St. Clair River. These extensive macrophyte beds provide food, shelter, and habitat requirements for fish and wildlife populations. Not only do they support a wide variety of migratory waterfowl, but young fish were observed to be more abundant from spring to fall among the submerged macrophytes than in the plant-free areas of the St. Clair River islands (20).

More than 20 submerged macrophyte taxa occur in the St. Clair River system (20,21). In order of frequency of occurrence, these include Chara sp., Vallisneria americana, Potamogeton sp., and Heteranthera dubia. Of this group, only Chara forms single species or monotypic stands of vegetation. Typically, submerged macrophyte stands are composed of 2-3 species; however, a stand with a maximum of 11 taxa has been reported (2). The greatest depth of water colonized by submerged macrophytes is not documented for the St. Clair River system, but most stands occur in water depths of 3.7 m or less. The 3.7 m depth contour accounts for 16 km^2 of the St. Clair River shoreline. It has been estimated that 88 percent of the St. Clair River bottom is covered by plant material within the 0-3.7 m range of depths (2).

A total of three submerged macrophyte taxa are found in the St. Clair River system. These species include Potamogeton crispus, Nitellopsis obtusa, and Myriophyllum spicatum. P. crispus is one of the first aquatic plants to appear in the spring. This plant serves as a host for aquatic invertebrates which are consumed by northward migrating waterfowl (1). Since it is also one of the most abundant macrophytes in the river during April to June, P. crispus provides an important spawning substrate for fish (22). N. obtusa was first reported in the St. Clair River in 1984 (23). M. spicatum was first observed in Lake St. Clair in 1974 (24), and became the fourth most common submerged macrophyte in the St. Clair River system by 1978 (21).

Emergent macrophyte distributions are less well understood. While Herdendorf et al. (5) provide some discussion of the emergent forms of the lower St. Clair River, no definitive study of species compositions, abundance, distribution, occurrence, or productivity has yet been made. Estimates, however, suggest that as much as 3,380 ha of the St. Clair River may be colonized by emergent vegetation (25,26). It is further estimated that 95 percent of the stands of emergent vegetation occur in the lower reaches of the river (1). Typical emergent vegetation within the river area proper includes cattails (Typha sp.) and reed (Phragmites australis). Within the delta, numerous canals, ponds, and abandoned channels support a wide diversity of emergent plant communities, including the yellow and white water lilies (Nuphar advena and Nymphaea tuberosa, respectively), buttonbrush (Cephalanthus occidentalis), arrowhead (Sagittaria latifolia), bullrush (Scirpus sp.), and water smartweed Polyhonum amphibium).

iii) Fish

With regard to fish populations, the St. Clair River is important in two respects: (a) it supports its own native fishery, and (b) it serves as a conduit, providing a means of access for movement of fish to both Lakes Huron and Erie. The latter aspect is particularly significant in association with fish spawning.

The St. Clair River is critical to the spawning and nursing of juvenile fish of between 23 and 41 taxa (4,27,28,29), with larval fish densities averaging 296 per 1000 m^3. Fish species observed within the river include walleye, muskellunge, rainbow trout, lake sturgeon, smelt, coho and chinook salmon, smallmouth bass, channel catfish, yellow perch, and freshwater drum (30).

Juvenile and adult fish were most often observed in the lower reaches of the river where macrophyte communities were abundant.

Forty-eight fish species are known or presumed to utilize the wetland areas associated with the St. Clair River. The management of this system is critical to protect both the habitat of these fish and the fish themselves from accumulating body burdens of chemical contaminants.

Haas et al. (31), conducted seven monthly surveys of fish in the St. Clair River which identified rock bass, yellow perch, and walleye as the most common forms. Fish populations vary seasonally, with smallmouth bass most numerous in the fall, and white suckers dominating the spring populations.

As was noted above, the river serves as a corridor for fish movement between Lakes St. Clair and Huron. Walleye are known to spawn in the delta area and tributaries of Lake St. Clair, and to move in late spring through the St. Clair River to southern Lake Huron. These fish typically return through the river in the fall of the year (30). This migration pattern is further complicated by walleye breeding migrations in which fish from Lake Erie move into the St. Clair River complex to spawn. Spawning areas in the St. Clair River area are also important for the rare lake sturgeon. The lake sturgeon enters the St. Clair River to spawn in the north channel of the St. Clair River Delta.

Regional Climate

The St. Clair River basin is characterized by typical inland climatic patterns modified by the water mass of the Great Lakes which surrounds it. Summer temperatures are regarded as warm and mild, and winter temperatures are moderately cold. Mean annual temperature regimes range from a high of 23.6°C in July, to a low of -4.4°C in January. Periodic cyclonic storms of varying intensity occur throughout the year, with the general exception of the high summer months (June, July, and August). During this period, thunderstorms are common as a function of atmospheric convectional uplift.

The modifying influence of the adjacent Great Lakes provides the St. Clair River region with the second longest frost-free season in the Great Lakes basin. On an average, the interval between the last vernal frost and the first autumnal frost is 160 days. The fall warming effect provided by the surrounding water masses retards the occurrence of autumn frost, thus extending the growing season. The spring cooling effects of the lakes also prevent premature vegetational growth, lessening the chances of crop and plant loss to late spring frosts (32). The length and intensity of the growing season may also be estimated from the accumulation of growing degree-days. This value is an index of the amount of heat available during a given growing season. The growing degree-day index is normally defined as the number of degrees of mean daily temperature above a threshold value of 5.6°C for the period in which that limit is exceeded. A normal year in the Port Huron/Sarnia area consists of 2,056°C (2).

Average annual water temperature values describe a classic sigmoidal curve, with winter minima occurring in mid-February (approximately 0.5°C), and the annual maxima being achieved in mid-August at values approaching 21°C (4). Mean water temperature recorded for the St. Clair River for the years 1967-1982 was 11.8°C (5).

Characteristically, the climate of the Great Lakes region is marked by a lack of major seasonal fluctuations in precipitation patterns. Extensive records for three adjacent weather stations - Mount Clemens, Michigan (1940-1969); Detroit City Airport, Detroit, Michigan (1940-1069); and Windsor, Ontario Airport (1941-1970) - indicate that the mean annual precipitation is 77.83 cm (33).

2. Environmental Conditions

Water Quality

Despite the highly industrialized character of the upper reaches of the St. Clair River, water clarity in the river is exceptionally high. This exceptional clarity is largely because Lake Huron is the primary source for the waters of the river. As a result, the suspended sediments are largely silicate in nature, derived from southern Lake Huron shoreline sands (1,2).

Urban centres are found along the length of the St. Clair River, and a major petrochemical complex is concentrated along the Ontario side in the Sarnia-Corunna area. Concerns relating to bacterial contamination, phenols, metals (particularly iron and mercury) and phosphorus were identified as early as the 1940s (34). Mercury (35) and lead (10) have been the metals of most concern. Phenols, oil and grease, and a variety of chlorinated organics including PCBs, hexachlorobenzene, octachlorostyrene, hexachlorobutadiene, and volatile organics were considered the major problem organics in the river (8,12,36).

Many of these inputs have been reduced significantly as a result of implemented control programs. Over the years, the focus of attention has shifted from nutrients and conventional pollutants to toxic substances that have been detected throughout the system, and concern for their effects on human health and the ecosystem.

The high flows in the St. Clair River are conducive to dilution of material inputs from sources along the river. But it should be kept in mind that, because of the flow pattern of the river, contaminant plumes tend to hug the shoreline, and thus, only a portion of the total flow (perhaps 5%) is available for dilution. Nonetheless, the concentrations of many of the contaminants of concern in the water column are extremely low, often from undetectable to the low ng/L range. This requires the use of state-of-the-art sampling and analytical methodologies to provide accurate results. Higher concentrations are often found in close proximity to sources. It should be recognized, however, that even low concentrations coupled with the high flow still produce loadings that are often significant. Table VII-1 illustrates approximate loadings for several UGLCCS parameters at typical concentrations and flows found in the river. While organisms respond in the short term to concentrations (e.g., acute toxicity), the system as a whole is ultimately responsive to loadings. This is particularly critical for persistent toxic organic pollutants and toxic metals, since these contaminants can have a severe impact on downstream lakes.

TABLE VII-1

Loading Ranges for UGLCCS Parameters in the St. Clair River.

Parameter Concentration Range		Associated Loading Range (kg/yr)	Chemical
1-10	ppm(mg/L)	$1.7x10^8-1.7x10^9$	Chloride
10-100	ppb(ug/L)	$1.7x10^6-1.7x10^7$	Phosphorus, Iron
0.1-1.0	ppb(ug/L)	$1.7x10^4-1.7x10^5$	Lead,Cobalt, Copper
10-100	ppt(ng/L)	$1.7x10^3-1.7x10^4$	Mercury
1-10	ppt(ng/L)	$1.7x10^2-1.7x10^3$	PCBs, PAHs, Cadmium
0.1-1.0	ppt(ng/L)	17-170	HCB, OCS

Even though considerable dilution does occur, the lack of lateral mixing leads to a considerable concentration gradient across the St. Clair River. For example, at Port Lambton (a distance of 34 km downstream of point sources in Sarnia), 95% of the contaminants still remain in Canadian waters. To illustrate, on September 23, 1985, HCB and OCS concentrations at Port Lambton were 1.6 and 0.05 ng/L, respectively, near the Canadian shore, and 0.02 ng/L and not detected near the U.S. shore. Similar gradients were found on three other occasions for samples collected at 100 m intervals across the river (37). These results show that contaminant inputs along each shoreline travel downstream in plumes which tend to hug the shoreline with limited lateral, cross-stream mixing. This fact has implications for locating water intakes for communities downstream of industrial sources using St. Clair River water for drinking purposes.

A comparison of typical ambient concentrations of UGLCC Study chemicals in the river and concentrations near point sources to water quality and drinking water guidelines for 1986 are shown in Table VII-2. Hexachlorobenzene (HCB) concentrations in the river near point sources below Sarnia are far in excess of both the Canadian water quality and WHO drinking water guidelines. Ambient water samples collected near the Canadian shoreline at Port Lambton are about one-tenth of the guideline values. No guidelines are available for octachlorostyrene (OCS), but an estimated water quality guideline can be calculated by multiplying the HCB guideline by the ratio of the bioconcentration factors of the two substances, BCF_{HCB}/BCF_{OCS}. This procedure assumes that HCB and OCS have similar toxicities. Comparing the OCS water concentrations to this estimated guideline suggests that OCS would exceed this calculated value in the river near point sources, but mean ambient values would be below this guideline. On the other hand, PCBs do not appear to present such an acute problem in the St. Clair River, even in the industrialized Sarnia area.

Benzo-a-pyrene (BaP) was assessed as a representative polynuclear aromatic hydrocarbon (PAH). No direct measurement of water concentrations was made for BaP. The BaP water concentration was estimated by using the Ontario Ministry of Environment's (OMOE) caged clam data (38) downstream of Imperial Oil (20 ng/g) and dividing by the bioaccumulation factor for invertebrates found by Frank et al., 680 (39). Near Sarnia and downstream at Port Lambton, the estimated BaP water concentration appears to exceed the guidelines by a factor of 3 or 4.

All metals, with the exception of lead near Sarnia and near Ethyl Corporation in Corunna, are well below the guidelines. The lead values near point sources slightly exceed the Canadian water quality objectives, but are well below drinking water standards.

Some other significant St. Clair River organic contaminants are compared to the guidelines in Table VII-3. All parameters exceed guideline values near point sources. Exceedences were particularly evident for perchloroethylene, carbon tetrachloride, hexachlorethane, hexachlorobutadiene, and pentachlorobenzene. Ambient mean concentrations are well below guidelines for all parameters. Maximum concentrations found well downstream of the sources are within an order of magnitude of the guidelines for benzene, perchloroethylene, and carbon tetrachloride.

Table VII-4 compares the concentrations of chemicals in suspended solids and unfiltered water at the head and mouth of the St. Clair River. The data clearly show that major sources of

TABLE VII-2

Comparison of UGLCC parameter concentrations in unfiltered[1] water to water quality and drinking water guidelines (all concentrations ug/L).

Chemical	GLWQA Specific Objectives[+]	Ontario++ Water Quality Objectives	WHO+++ Drinking Water Guidelines	Ambient Near Canadian Shore: Near Industrial Outfalls Mean	Near Industrial Outfalls Maximum	Downstream of Sources Mean	Downstream of Sources Maximum
Hexachlorobenzene	--	0.0065	0.01	0.4	2.4	0.0008	0.0016
Octachlorostyrene	--	(0.0006)*	--	0.027	0.14	0.00024	0.00012
PCB	--	0.001	3	< 0.02	< 0.02	0.0015	0.0022
Benzo-a-Pyrene	--	--	0.01	(0.03)**	--	(0.04)**	--
Lead	25	25	50	1.5	2.7	0.33	2.0
Cadmium	0.2	0.2	5	--	--	0.01	0.09
Mercury (Filtered)	0.2	0.2	1	0.011	--	0.007	0.04
Copper	5	5	1000	--	--	0.42	1.3
Iron	300	300	300	140	--	240	310
Cobalt	--	--	--	--	--	0.16	0.18

[1] From (36,37,41,51).

[+] International Joint Commission, Canada and the United States, Great Lakes Water Quality Agreement of 1978 (as amended 1987).

++ Ontario (Provincial) Water Quality Objectives (PWQO)(101).

+++ World Health Organization (WHO)(102).

* Estimated using the guideline 0.0065 ug/L for HCB and multiplying by BCF_{HCB}/BCF_{OCS}(22,000/240,000)(103).

** Estimated from Ontario Min. of the Env. caged clam studies (38).

\- Mercury - Filtered.

\- All other metals - Total.

TABLE VII-3

Comparison of other organic compounds found in the St. Clair River[1] to water quality and drinking water guidelines (all concentrations in ug/L).

Chemical	Ontario Water Quality Objective	WHO** Drinking Water Guideline	Near Industrial Outfalls Mean	Near Industrial Outfalls Maximum	Ambient Near Canadian Shore Downstream of Sources Mean	Ambient Near Canadian Shore Downstream of Sources Maximum
Benzene	25(interim)	10	5.3	23	0.56	4.3
Toluene	250(interim)	--	--	--	0.71	2.2
Perchloroethylene	-	10	81	1120	0.21	2.4
Carbon Tetrachloride	-	3	38	665	0.33	2.0
Hexachloroethane	-	--	0.2	0.83	0.004	0.007
Hexachlorobutadiene	-	--	0.40	1.3	0.002	0.006
Pentachlorobenzene	0.03	--	0.005	0.15	0.00007	0.00001

[1] From (36,37,73,74).

* Estimated using the guideline 0.1 ug/L for HCBD and multiplying by BCF_{HCBD}/BCF_{HCE} (17,000/1,200)(75).

** World Health Organization (WHO)(102).

TABLE VII-4

Comparison of chemical concentrations in unfiltered water (UW) and suspended sediments (SS) at the head and mouth of the St. Clair River.

Compound	UGLCCS Parameters Head		Mouth	
	SS(ng/g)	UW(ng/L)	SS(ng/g)	UW(ng/L)
Hexachlorobenzene	2.0	0.03	130	0.8
Octachlorostyrene	0.7	0.008	23	0.12
PCBs	--	2.3	--	1.5
	SS(ug/g)	UW(ug/L)	SS(ug/g)	UW(ug/L)
Lead	23	<3	42	<3
Cadmium	1.0	(0.01)*	0.8	(0.008)*
Mercury	0.04	0.002	0.28	0.011
Copper	24	(0.24)*	25	(0.25)*
Iron	16000	110	16000	140
Cobalt	17	(0.17)*	16	(0.17)*
Chloride	--	6200	--	8400

Compound	Other Parameters Head		Mouth	
	SS(ng/g)	UW(ng/L)	SS(ng/g)	UW(ng/L)
Benzene	--	ND	--	560
Toluene	--	ND	--	710
Perchloroethylene	--	ND	--	210
Carbon Tetrachloride	--	ND	--	330
Hexachloroethane	0.5	0.16	0.5	3.6
Hexachlorobutadiene	1.0	0.09	20	2.3
Pentachlorobenzene	2.2	0.012	4.5	0.072

* Estimated assuming an average suspended sediment concentration of 10 mg/L.

chemicals such as HCB, OCS and mercury occur along the river. There is no water or compound solids data for PAHs, but other media (caged clams and sediments) show that there are significant PAH sources in the Sarnia area. The chloride concentration also increases over the river's course. Marginal increases occur in lead and mercury concentrations; whereas, cadmium, copper, and cobalt do not exhibit significant concentration differences between the head and mouth. There is no apparent change in PCB concentrations along the river based on this very limited data set.

Some chemicals not on the UGLCCS contaminant test list that show significant sources along the river are the volatiles benzene, toluene, perchloroetheylene, and carbon tetrachloride. Hexachloroethane, hexachlorobutadiene, and pentachlorobenzene also display significant positive changes in concentration between the head and mouth of the river.

The partitioning of chemicals between the suspended solids and dissolved phase has a considerable impact on the ultimate fate of the contaminant. The more volatile organics such as benzene, toluene, perchloroethylene, carbon tetrachloride, and hexachloroethane exhibit little tendency to bind to suspended sediments. These compounds will be subjected to continual dilution as they move downstream, and will also be lost from the water by the process of volatilization. The other organics and the metals in Table VII-4 exhibit a much stronger tendency to become adsorbed to suspended particulates. This adsorption reduces the tendency of the chemicals to volatilize from the system. The ultimate fate of the particle-bound organics and metals will be temporary storage in Lake St. Clair followed by transport via the Detroit River to Lake Erie.

Once the particle-bound material reaches these lakes, it is partially available to benthic organisms. These organisms serve as a food source for fish, so the presence of these chemicals in the lake sediments causes an increase in the contaminant burden in consumable sport fish through the process of bioaccumulation. Details of the sediment/water partitioning of some of the persistent organics have been documented as part of the UGLCC Study (37,40).

In addition to concerns about the effect of effluent discharges on water quality, serious consideration must also be given to the effects of intermittent spills on aquatic life and drinking water quality in the river and in downstream areas, including Lake St. Clair and the Detroit River. Between 1974 and 1986, there were a total of 32 spills involving 10 metric tonnes or more of deleterious materials discharged directly to the St. Clair River (36). The most studied spill was that of 9,400 gallons of perchloroethylene (August 13 to 16, 1985) by Dow Chemical Company of Sarnia (36). Drinking water supplies in the downstream towns of

Wallaceburg, Walpole Island, Windsor, Amherstburg, and Marysville, Michigan, were analyzed twice weekly after the spill. As would be expected because of the lack of lateral mixing of the river no perchloroethylene was detected in the Marysville treatment plant on the U.S. side of the river. The highest concentration observed was 7 ppb in raw water at Wallaceburg and Walpole Island. Perchloroethylene concentrations of 2-3 ppb were found much further downstream at Windsor and Amherstburg on the Detroit River. The former values approach the World Health Organization (WHO) drinking water standard for lifetime exposure of 10 ppb.

Some water sampling conducted during the UGLCC Study indicated that higher concentrations of such chemicals as hexachlorobenzene and octachlorostyrene in unfiltered water and suspended sediments were associated with rainfall events (41,42). Further studies are required to assess the importance of such events to water quality.

Biota Impairments

A number of studies of various biologic components of the St. Clair River ecosystem, (phytoplankton, wetlands, submerged macrophytes, macrozoobenthos, and fish), suggest that the river is increasing in biological productivity in formerly impaired habitats (9,15,19,21,43,44). This increase in productivity is apparently a function of remedial actions to control the input of conventional pollutants and toxic substances and to improve the quality of the river water.

The distribution of macrozoobenthos in an aquatic ecosystem is often used as an index of the impacts of contamination on that system. Undisturbed benthic populations are normally characterized by very diverse populations with a relatively high number of organisms per unit area. Frequently, these populations include significant numbers of pollution intolerant organisms. Perturbed or impaired areas will demonstrate a characteristically reduced diversity of species, an absence of pollution intolerant forms, and typically a reduced number of organisms per unit area, except in the case of pollution with organic materials (e.g., sewage), where certain species tolerant of these conditions can thrive at incredible densities.

Distributions of macrozoobenthos in the St. Clair River have been well documented (1,2,9,45,46,47,48). In 1968, the Canadian shoreline exhibited macrozoobenthic populations characteristic of degraded conditions, compared with the U.S. shoreline. By 1977, however, it was clear that significant improvement had occurred, apparently in response to improved effluent treatment initiated some years prior.

Currently, benthic health along the U.S. shore is good (49,50), although there have been some historical problems downstream of the Black River (46). Figure VII-2 shows the water quality zones along the Canadian side of the river based on benthic invertebrate community structure. Term definitions in the figure are: toxic = no benthic organisms; degraded = large numbers of pollutant tolerant organisms; impaired = lower numbers of pollutant tolerant organisms plus facultative species; fair = atypical community structure; good = normal benthic community structure.

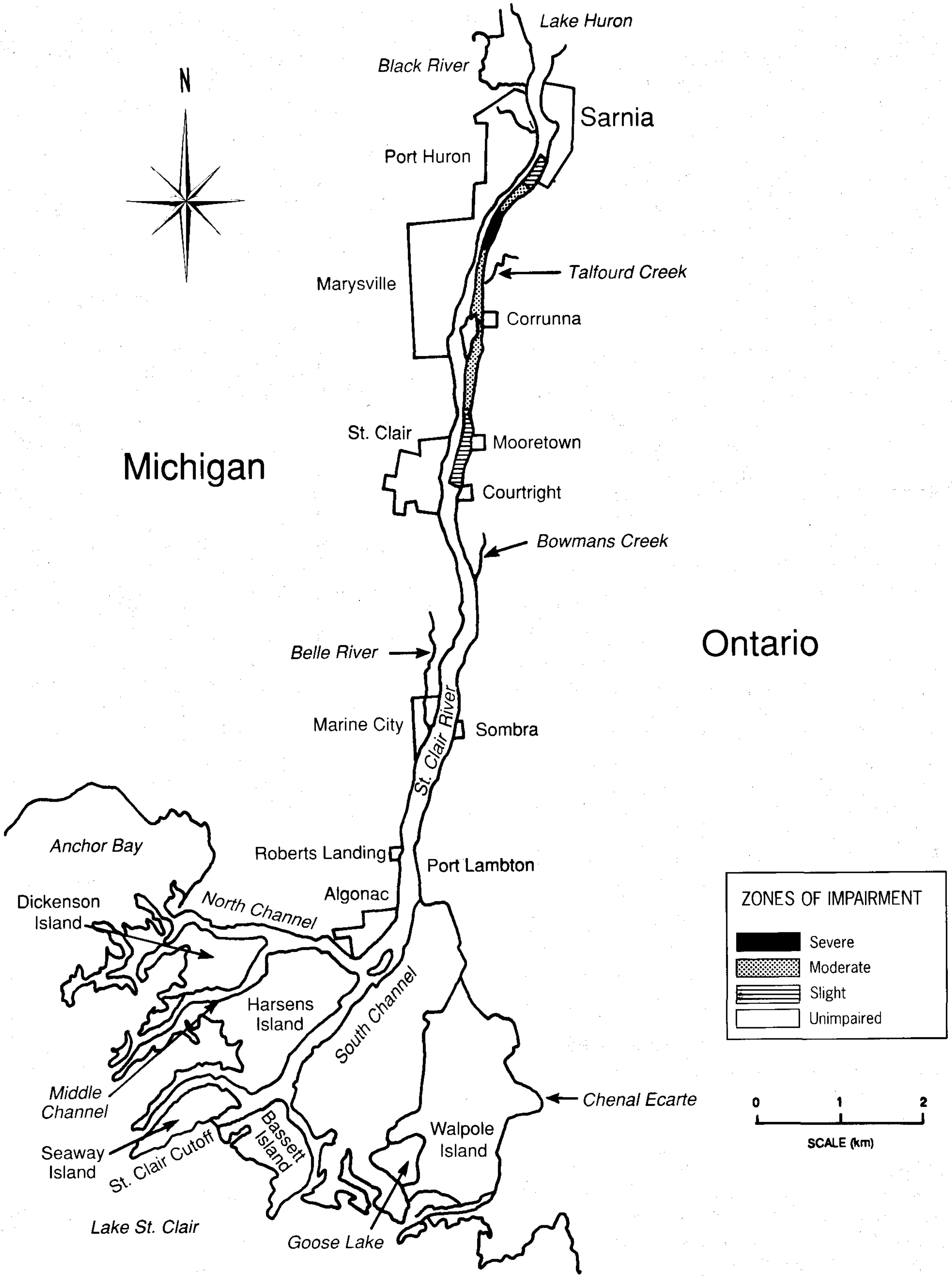
The benthic community begins to be impacted at km 5 near Sarnia's industrial complex. Conditions deteriorate to toxic downstream of Dow Chemical (km 6.5). The ecological status gradually improves until Talfourd Creek (km 10) where the water quality changes adversely to a degraded state. Following this 1 km zone, the benthic community along the Canadian shoreline gradually improves and reaches a "good" condition at km 20.

Historically, conditions along this river shore were much worse. In 1968, the toxic and seriously degraded zone extended over the entire portion of the river surveyed (at least 44 km). This major impact zone decreased to 21 km in 1977. A further improvement is evident from the above 1985 data which showed a major impact zone of 12 km (46).

Direct contaminant toxicity impacts to benthic fauna in the St. Clair River appear to be confined to the Sarnia industrial waterfront and a few km downstream. Recent studies (51) have shown that the sediments from the industrial area are lethal to Hexagenia, Hydallela, and fathead minnows. This confirms earlier work that showed only pollution-tolerant benthic organisms could survive in this region of the river (9).

A wider ranging problem is the bioconcentration and bioaccumulation of chemicals in biota at all trophic levels in the river and in downstream Lake St. Clair. Elevated concentrations of several contaminants with known sources in the St. Clair River have been found in plankton (51), macrophytes (51), benthic organisms [including native (36) and introduced clams (52)], young-of-the-year spottail shiners (36,53), and sportfish (36) in the river.

Of the UGLCCS contaminants, hexachlorobenzene, octachlorostyrene, and mercury are of greatest concern in the St. Clair River. Concentrations of between 50 and 100 ng/g of HCB and OCS have been found in various sportfish from the river (36), although some species contain little or no HCB or OCS. Elevated concentrations of chlordane, G-BHC and mercury were found in young-of-the-year spottail shiners at the mouth of Perch Creek on Lake Huron near the head of the St. Clair River (36). No fish consumption guidelines exist for these compounds, but the World Health Organization (WHO) has set a very low drinking water



NOTE:
Zones of impairment refer to the relative occurrence of pollution tolerant species and to the diversity of benthic species in general.

Figure VII - 2. Zones of benthic fauna impairment in the St. Clair River.

guideline of 10 parts per trillion for HCB. OCS is probably of comparable concern since it has a higher bioconcentration factor than HCB.

The University of Windsor (54) studied waterfowl and muskrats on Walpole Island in the St. Clair River. Their data show that the nonmigratory ducks contained consistently higher HCB and OCS residues than did their migratory counterparts. Muskrats on the island also contained measurable HCB and OCS residues. Weseloh and Struger (55) showed that flightless Peking ducks released on Bassett Island in the St. Clair River rapidly accumulated HCB. Residues of PCB, HCB, DDT and other chlorinated organics found in diving ducks in the Lower Detroit River also suggest that waterfowl in the St. Clair River may be a source of human toxicity (56).

Mercury levels in the edible portion of walleye from the Lake St. Clair/St. Clair River vicinity have shown a steady decline from a 1970 maximum value of nearly 2.5 mg/kg or ppm. Current mercury concentrations for walleye up to 45 cm in length are reported as less than 0.5 ppm and are suitable for unlimited consumption (57). Walleye in the 45-65 cm length class generally contain 0.5 to 1.0 ppm mercury, and above 65-75 cm are between 1.0 and 1.5 ppm (57).

In 1970, mercury in northern pike fillets was more than double that of walleye. Levels now, however, are less than 25 percent of the 1970 values. Northern pike up to 55 cm contain less than 0.5 ppm mercury while those larger than 55 cm contain between 0.5 and 1.0 ppm. Similar reductions in the mercury levels in white bass have been observed (57). Individuals up to 30 cm contain less than the 0.5 ppm consumption guideline. Larger fish of most species still contain mercury concentrations in excess of 0.5 ppm. This may be due, in part, to historical mercury contamination and to mercury recycling within the system. The PCB content of most fish in the St. Clair River and Lake St. Clair is below the 2 ppm consumption guideline set by the OMOE and the Michigan Department of Natural Resources (MDNR), as well as the U.S. Food and Drug Administration action level, but levels exceeding the Great Lakes Water Quality Agreement (GLWQA) Specific Objective of 0.1 ppm were found.

Alkyl lead compounds have been detected in game fish near Ethyl Corporation (11). Since the organolead compounds are much more toxic than inorganic lead, some attention may be required to control loadings from this source. There are no fish consumption guidelines for these compounds, although a tentative consumption guideline of 1.0 mg/kg was established by OMOE in 1984 for total alkyl lead.

Elevated concentrations of several PAHs have been found in caged clams downstream of Sarnia's industrial discharges. The data on these chemicals in the river are too limited at this stage to say whether or not these chemicals are a problem. Other trace metals on the UGLCCS parameter list, including cadmium, iron, copper, and cobalt do not appear to pose any problems in biota along the river.

Other contaminants that have been found at elevated concentrations in caged clams and fish from the river are: hexachloroethane, hexachlorobutadiene, pentachlorobenzene, perchloroethylene, carbon tetrachloride, and benzene (36). These contaminants may exert an individual toxicity effect. Further, the potential additive, antagonistic, or synergistic effects of multiple contaminant exposure to the river's biota and to fish and water consumers is completely unknown.

Bottom Sediments

The St. Clair River is essentially a conduit of water between Lake Huron and Lake St. Clair. Very little sediment accumulates because of the high current velocities in the river (0.6 - 1.8 m/s). Sediments are largely a pavement of well-rounded cobbles and boulders, with sand or till in the interstices over cohesive glacial clay, and sand ripples and dunes moving as bed load. There was no consistent trend along the shore in sediment thickness, but variations in an offshore direction indicate a wedge-shaped deposit that is thickest at the shoreline. The average thickness of the deposit is 9 cm, with a mean width of 100 m. The average texture of the samples was 63% sand, 32% gravel, and 5% silt-clay, with a mean grain size of 1.7 mm (58).

Based on very limited sampling, the inorganic elemental composition of the St. Clair River sediments was: SiO_2, 65%; Al_2O_3, 6.3%; Fe_2O_3, 6.9%; MgO, 3.5%; CaO, 12.7%; Na_2O, 1.3%; K_2O, 1.6%; TiO_2, 0.4%; MnO, 0.06%; and P_2O_5, 0.05% (59). On average, the organic carbon content of the sediments is fairly low (0.9%) as would be expected from the coarse nature of the river's sediments (60).

The most extensive recent sediment surveys of the river were conducted by the OMOE (60) in 1985 (78 stations), and by Oliver and Pugsley (61) in 1984 (45 stations). In addition, a more limited study of 33 stations (21 in the U.S.), in which the only organics analyzed were PCBs and oil and grease, was conducted in 1985 by the United States Fish and Wildlife Service (62). A more intensive survey covering 60 stations in the Sarnia industrial area was conducted by Environment Canada and Ontario Ministry of the Environment in 1985 (36).

These samples were collected using a variety of techniques including cores, Shipek dredge, and divers. The information derived from all these sampling methods is similar in this river because most of the surficial sediment is of recent origin (36). Only limited historical information is available from sediments in the river, since they are shallow and transitory in nature.

Despite the coarseness of the sediments, some heavily contaminated deposits were found in the river. Table VII-5 compares the sediment chemical concentrations to the criteria for open-water disposal of dredged spoils. The contaminant range indicates that a sediment guideline is exceeded at some location for every parameter except nitrogen and phosphorus. In the cases of PCBs, mercury, lead, copper and iron, the mean contaminant concentration in river sediments exceeds both the Ontario and several U.S.EPA guidelines. Most guideline exceedances occurred along Sarnia's industrial waterfront, but sediment samples collected at several other locations along both the Canadian and United States shores of the river also exceeded the guidelines for some parameters.

No sediment objectives are available for two of the important UGLCCS parameters, hexachlorobenzene (HCB) and octachlorostyrene (OCS). These chemicals are present at high concentrations in several locations along the river.

The UGLCC Study shows that the mean values for all parameters are highest along Sarnia's industrialized waterfront and gradually decrease downstream. The wide range of concentrations encountered in each river reach shows the extreme variability of sediment contamination along the river. This is likely due to the transitory nature of the sediment and their lack of homogeneity.

Areas of elevated concentration for HCB and OCS are found downstream of the Cole Drain (also known as the Township Ditch) and adjacent to Dow Chemical's First Street sewer discharge. Concentrations of HCB and OCS are in the high ppm range at the latter site. These extremely high sediment concentrations are caused by contamination of the area with nonaqueous waste material that has leaked from the Dow site in the past (63). The Dow First Street Sewer has been closed. It should be noted that some HCB/OCS-containing streams have been diverted to Fourth Street since the time of this survey. The HCB and OCS concentrations in bottom sediments diminished by one or two orders of magnitude downstream of Dow, but remained elevated, well above background levels, along the entire length of the Canadian Shoreline to Lake St. Clair (61).

Sarnia's industrial waterfront sediments also contain high concentrations of oil and grease. For oil and grease, other high concentration areas along the Canadian shoreline were found adjacent to downtown Sarnia upstream of major industries (2,200 and 1,300 ppm), adjacent to Imperial Oil (1,200 ppm), just above Talfourd Creek (4,700 and 1,200 ppm), just north of Corunna (2,300 and 1,100 ppm), and below Courtright (1,400 ppm).

TABLE VII-5

St. Clair River sediments compared to various criteria for open water disposal of dredged material (mg/kg).

	Criteria	Criteria	Criteria U.S.EPA 1977			St. Clair River Sediments*	
Chemical	(Canada)	(Ontario)	Non-Polluted	Moderately Polluted	Heavily Polluted	Range	Mean
PCBs	--	0.05	--	--	>10	ND-2.6	0.13
Oil and Grease	1500	1500	< 1000	1000-2000	>2000	43-5300	1000
Mercury	0.3	0.3	< 1.0	--	>1.0	ND-51	2.2
Lead	--	50	< 40	40-60	>60	ND-620	59
Cadmium	--	1	--	--	>6	ND-2.2	0.51
Copper	--	25	< 25	25-50	>50	3.3-190	30
Iron	--	10,000	< 17,000	17,000-25,000	>25,000	3,300-75,000	12,000
Phosphorus	1000	1000	< 420	420-650	>650	100-500	230
Kjeldahl Nitrogen	2000	2000	< 1000	1000-2000	>2000	ND-1400	420

* Data from (76).

Somewhat elevated concentrations of PCBs were found in the Sarnia area, but this may be due to an analytical interference problem from other chlorinated organics (64). The only additional PCB elevated concentration area was located just below Ontario Hydro, downstream of the industrial complex (1,900 ppb), and could indicate a PCB source to the river at this location.

In general, sediments on the U.S. side of the river do not contain significant quantities of HCB and OCS. PCB concentrations along this shoreline are also quite low, ranging from undetectable to 150 ppb (mean value, 36 ppb). A few minor areas of elevated concentrations for oil and grease were found above the Blue Water Bridge adjacent to Port Huron (2,300 ppm), above the Belle River adjacent to Marine City (2,000 ppm), and along the North Channel downstream of Algonac (1,200, 1,200 and 1,300 ppm).

The concentrations of metals along the Canadian shoreline from OMOE's complete river study (1985) show cadmium and cobalt concentrations are low and reasonably constant over the entire length of the river. A few minor exceedences of dredging guidelines are found for iron and copper, but in general, the concentrations of these metals in the sediments do not appear to be a problem. The highest value of copper (180 ppm) was found just downstream of Sarnia's sewage treatment plant outfall. The highest iron concentration (7.5%) was observed just south of Beckwith Street, Corunna, and the Corunna Waste Water Treatment Plant.

Total lead concentrations in the sediments were low over most of the river except just south of Ethyl Corporation. The highest value found was 330 ppm for the site closest to Ethyl, with downstream concentrations decreasing systematically (244 ppm, 180 ppm, and 79 ppm). Ethyl Corporation produces alkyl lead compounds which are used as anti-knocking agents in gasoline. It is likely that the sediments contain a mixture of inorganic and organic lead forms, all of which have been shown to bioconcentrate in fish (11). The high sediment lead concentrations at these sites indicate an active lead source in this location.

Historically the most serious heavy metal problem in the St. Clair River has been mercury. Mercury is present at significantly elevated values at and downstream from Sarnia's industrial complex. The highest mercury value (51 ppm) was recorded adjacent to Dow Chemical but all sites below the Cole Drain exhibit high concentrations. Although these concentrations are considerably lower than peak mercury values observed in the late 1960s and early 1970s (1,470 ppm)(35), they are still quite high. This suggests that continuing, albeit low level, sources of mercury in the area may be inhibiting reductions in sediment concentrations.

Prior to 1973, Dow Chemical operated mercury cell chlor-alkali plants on site. These plants were identified as the source of mercury. These facilities have since been decommissioned and replaced by new plants using the diaphragm process which does not use mercury. Point source data show that low concentrations (< 1 ug/L) of mercury are still discharged from the Dow site (65).

For the metals on the U.S. side of the river, the only major anomalous value was 620 ppm for lead for a site just downstream of the Canadian National Railway tunnel. The next site (approximately 1 km downstream) had a somewhat elevated concentration of 69 ppm. This site is also downstream of the Black River which had an elevated lead level in river mouth sediments. Most of the other metal concentrations on the U.S. side of the river are near Lake Huron background values. Sediment nutrient concentrations were low on both sides of the river and do not seem to be a problem (64).

Many other organic compounds not included in the UGLCCS parameter list are present in St. Clair River sediments. Hexachlorobutadiene, hexachloroethane, and pentachlorobenzene are other major components of waste byproducts from Dow's chlorinated solvent production. These compounds are present at high concentrations in the sediments adjacent and downstream of Dow, and are strongly correlated with HCB and OCS distributions. Similarly, the solvents perchloroethylene and carbon tetrachloride have been found at concentrations up to the percent range in sediments opposite Dow due to solvent spillage and leakage of non-aqueous wastes into the river at this site (61). Dow has taken action to reduce these problems since these analyses (66).

Polynuclear aromatic hydrocarbons (PAHs) have been found at concentrations up to 140 ppm near Sarnia's industrial complex. The alkylated PAHs were present in all samples at lower concentrations than the parent compounds. As high temperature combustion does not produce alkyl-PAHs, their presence indicates petroleum as a likely source. The presence of n-alkane concentrations that correlate well with oil and grease distributions in the area support the contention that refineries and petro-chemical plants are the probable sources.

A limited amount of data are available on dibenzo-p-dioxins and dibenzofurans in St. Clair River sediments (36). Maximum concentrations of total dioxins and furans found downstream of Dow's First Street sewers were 12 and 100 ppb, respectively. Most of these compounds consisted of the octa- and heptacongeners. The 2,3,7,8 tetrachlorodibenzo-p-dioxin was not found in any of the samples.

Four other chemicals were found at high concentrations in sediments collected near Sarnia: diphenylether, biphenyl, 4-ethylbiphenyl, and diethyl biphenyl (67). The concentrations of these chemicals ranged from undetectable (ND) to 490 ppm for diphenylether, from ND to 150 ppm for biphenyl, from ND to 5 ppm for

4-ethylbiphenyl, and from ND to 5.2 ppm for diethylbiphenyl. The ratio of these chemicals in the sediments is similar to that present in heat transfer fluids. Two such fluids, Dowtherm A (73.5% diphenylether/26.5% biphenyl) and Therminol VP-1, are produced only in the United States by Dow and Monsanto. These fluids also contain ethyl and diethylbiphenyls as lesser components. The sediment data indicated that heat exchange fluids entered the river from Sarnia's industrial complex.

Tributary Sediments

Sediment samples were collected from the mouths of tributaries entering the St. Clair River to identify other potential contaminant sources to the river. The analysis of the Canadian tributaries was conducted by the Ontario Ministry of the Environment in 1984 and 1985 (68). The Canadian tributary that contributes the greatest chemical burden to the river is the Cole Drain. While no bottom sediment samples were obtained at the Cole Drain during the Canadian tributary study, water quality and suspended sediment data reflect treated leachate and untreated runoff from several industrial landfill sites upstream. Levels of HCB (0-210 ng/L), HCBD (0-345 ng/L), HCE (0-550 ng/L) and OCS (0-160 ng/L) in whole water were generally 1-2 orders of magnitude higher than at other tributaries (68). Sediment samples from Talfourd Creek and Murphy Drain contained HCB levels of 55 and 103 ppb, respectively. Metal contamination in tributary sediments resulted in provincial dredging guidelines being exceeded at several Ontario tributaries for chromium, copper, iron and nickel. Mercury guidelines were exceeded in a single sample obtained from the Talfourd Creek mouth (0.76 ppm). Mean instantaneous loadings based on suspended sediment and water chemistry and instantaneous flow were calculated for four Ontario tributaries (Table VII-6).

The U.S. tributaries were analyzed in 1985 by the Great Lakes National Program Office (GLNPO) of the U.S.EPA (69). For the U.S. tributaries, a high value for lead (270 ppm) and somewhat elevated copper concentrations (160 ppm) were found in Black River sediments (Table VII-7). The Black River is potentially a source for anomalous lead concentrations observed south of the Black River confluence on the St. Clair River. Elevated concentrations for several parameters (PCBs 76 ppb, PAHs 33 ppm, oil and grease 11,600 ppm, lead 230 ppm, TKN 6,600 ppm and phosphorus 1,300 ppm) were found in an unnamed creek across the river from Lambton Generating Station. The only other anomalously high concentrations were found for PCBs, 490 and 95 ppb, in the Belle River. High levels of calcium, strontium and sodium were found in sediments near the Diamond Crystal Salt Company and suggest continuing inputs of total dissolved solids. Otherwise the

TABLE VII-6

Mean instantaneous loading values from Ontario tributaries[1] for suspended solids (SS) and water (WA)[2].

Parameter	Perch Creek		Cole Drain		Talfourd Creek (upstream)		Talfourd Creek (mouth)		Baby Creek	
	(ss)	(wa)	(ss)	(wa)	(ss)	(wa)	(ss)	(wa)	(ss)	(wa)
<u>Chlorinated Organics (ug/sec)</u>										
HCB	0.00	0.00	17.6	50.00	0.50	1.00	3.70	17.00	0.08	0.00
OCS	0.00	0.00	14.6	20.00	0.00	0.00	0.05	0.00	0.07	0.00
PCBs	41.5	0.00	4.00	0.00	9.80	0.00	1.70	0.00	0.30	0.00
HCBD	NA[3]	0.00	NA	59.0	NA	0.00	NA	3.00	NA	0.00
HCE	NA	0.00	NA	62.0	NA	0.00	NA	18.0	NA	0.00
<u>Pesticides (ug/sec)</u>										
Atrazine	0.0	186.0	1.0	89.0	0.0	512.0	0.0	557.0	0.0	271.0
alpha-BHC	0.00	0.0	0.04	2.5	0.00	0.9	0.00	6.8	0.00	0.0
gamma-BHC	0.00	5.0	0.01	0.4	0.00	0.2	0.00	0.9	0.00	0.02
Dieldrin	0.4	0.0	0.2	0.0	0.4	0.0	0.7	0.0	0.02	0.0
Endosulphan-I	0.00	0.0	0.1.	0.0	0.00	0.0	1.1.	0.0	0.01	0.0
pp-DDE	0.03	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.00
<u>Metals (mg/sec)</u>										
Cadmium	0.17	0.09	0.02	0.03	0.07	0.17	0.05	0.57	0.01	0.05
Chromium	14.3	20.7	1.5	0.2	3.4	5.7	7.2	5.9	0.7	1.4
Copper	4.4	32.6	4.4	0.1	2.9	7.3	6.1	1.9	1.0	2.1
Iron	6332	9163	434	372	2494	2648	1644	1124	512	550
Lead	5.02	13.644	1.02	2.43	1.93	3.573	2.9	7.442	0.42	0.364
Mercury	0.009	0.063	0.006	0.019	0.041	0.012	0.019	0.054	0.001	0.004
Zinc	26.44	62.64	6.1	12.33	11.62	19.32	13.22	25.24	2.67	5.53

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1 Data from reference (68).
2 The tributaries are arranged in a downstream order relative to the St. Clair River.
3 NA = Analyses Not Available.

TABLE VII-7

Summary of sediment quality in mouths of Michigan tributaries to the St. Clair River.

	NUMBER OF ANALYTICAL DETECTIONS	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
MAJOR METALS AND TRACE METALS (mg/kg)					
CALCIUM	10	350000	11000	65200	96051
MAGNESIUM	10	7500	4600	5150	812
SODIUM	10	3400	100	477	978
POTASSIUM	10	1100	200	570	337
ALUMINUM	10	8100	1100	4490	2259
IRON	10	17000	2100	10610	4203
ARSENIC	10	9.2	1.4	5.25	2.46
BARIUM	10	81	11	41.50	20.05
BERYLIUM	10	0.4	0.1	0.19	0.08
BISMUTH	10	17	8	9.99	3.17
CADMIUM	10	0.6	0.2	0.36	0.18
CHROMIUM	10	84	1.3	19.71	22.19
COBALT	10	9.7	1	5.51	2.60
COPPER	10	160	3.1	38.53	42.97
LEAD	10	270	7	86.50	87.76
MANGANESE	10	340	52	202.80	95.60
MOLYBDENUM	10	4.5	1	2.13	0.98
NICKEL	10	62	4	18.76	15.65
SILVER	10	0.3	0.3	0.30	0.00
STRONTIUM	10	2700	8.3	303.93	798.88
VANADIUM	10	22	2.8	13.62	6.12
ZINC	10	150	14	85.50	41.26
TIN	10	5.2	4	4.27	0.46
LITHIUM	10	22	3.7	13.81	5.42
SELENIUM	10	0.6	<0.1	0.24	0.20
YTTRIUM	10	8.6	1.1	5.10	2.27
MERCURY	7	0.5	0.1	0.21	0.14
NUTRIENTS AND OTHERS PARAMETERS IN ST. CLAIR RIVER TRIBUTARY SEDIMENTS (mg/kg)					
COD	10	91000	3000	29300	24742
OIL AND GREASE	10	11600	650	2146	3235
AMMONIA	10	250	8.3	83	61
TKN	10	6600	190	1627	1771
PHOSPHORUS	10	1300	93	576	321
CYANIDE	10	0.7	0.1	0.24	0.16
TOTAL SOLIDS (%)	10	74.7	13.5	58.05	17.19
TOTAL VOLATILE SOLIDS (%)	10	20	1.3	5.73	5.04
TOTAL PCBs, PAHs, PHTHALATE ESTERS, AND DDT & METABOLITES (ug/kg)					
TOTAL PCBs	7	490	39	150.86	151.53
TOTAL PAHs	6	32600	200	6866.67	11552.44
TOTAL DDTs	7	83	2	24.29	26.91
TOTAL PHTHALATES	8	1900	300	768.75	516.56
SELECTED OTHER ORGANICS (ug/kg)					
HCB		6	8	2	3.33
2.13					
DICHLOROMETHANE	10	65.6	1.2	26.41	20.23

Michigan tributaries do not appear to be significant sources of contaminants to the river.

Most sediments in the St. Clair River are transitory, having a lifetime in the river of less than one year (61). The moving bed sediments constitute only a very minor component (less than 1 percent) of total contaminant transport along the river (64). The ultimate sink of this fine sand that constitutes bed load appears to be the St. Clair River Delta. Sand cores taken from the delta area contain mercury and other contaminants to a considerable depth (64). Because of the contaminant storage in this area, contaminant body burdens in wildlife could remain elevated for a considerable period, even after control measures have been implemented. Most of the contaminants are transported via water and suspended solids which would be carried and dispersed further down the system into Lake St. Clair and Lake Erie.

B. SPECIFIC CONCERNS

A summary of specific concerns including contaminants and associated use impairments, media affected and location is provided in Table VII-8.

1. Conventional Pollutants

Nutrients

Phosphorous reduction programs have had a major impact on the discharge of phosphorus to the St. Clair River. Water column concentrations for total phosphorus (1984) were low, ranging from 0.009 to 0.03 mg/L (41). These values are much lower than reported for the river in the 1970s (45). Bottom sediments (64) and suspended sediments (41) for the river are both below the 1000 ppm guideline for open-water disposal of dredged sediments. The nitrate/nitrite concentration range found in the river (0.29-0.31 mg/L) is typical of that found in oligotrophic waters (70). Thus, the discharge of nutrients to the St. Clair River seems to be largely under control.

Chloride

Chloride loadings to the St. Clair River are very high. The chloride concentration changes from a mean of 6.2 mg/L at the head of the river, to 7.7 mg/L at the river's mouth (41). This change amounts to a daily river loading of about 585 metric tonnes of chloride. Chloride is a conservative parameter that will not be lost from the system. The increased salinity of the lower Great Lakes from these very large chloride inputs could potentially have a significant effect on the structure of biological communities in the system (71). A shift in the organism diversity to more saline-tolerant species (halophilic) could occur over long time scales.

Bacteria

Concentrations of bacteria increase along the course of the St. Clair River. Heterotroph counts in bottom waters along the Canadian shore increased from 2,200 organisms/ml at the head of the river, to 10,500 at the mouth (51). Sediment bacteria increased from 1,500 bacteria/ml at the head, to 450,000 at the mouth. Head to mouth changes along the U.S. shore were 110 to 13,000 organisms/ml for the water, and 700 to 27,000 heterotrophs/ml for the sediments. In some cases, swimming areas along the river have been closed due to bacterial contamination (72).

TABLE VII-8

Specific concerns in the St. Clair River, uses impaired, and geographic scope of the perceived problem.

CONCERN	USE IMPAIRMENT	MEDIA	GEOGRAPHIC SCOPE
Conventional Pollutants			
chloride	potential alteration of biological community structure	water	whole river lower Great Lakes
bacteria	potential human health hazard	water, sediments	some areas along river, increases downstream
UGLCC Parameters			
hexachlorobenzene	toxicity to biota human health	water, sediments, biota fish	below Sarnia whole river
octachlorostyrene	toxicity to biota human health	water, sediments, biota fish	below Sarnia whole river
PAHs	toxicity to biota	sediments, biota	below Sarnia below Lambton
oil and grease	toxicity to benthic community	sediment water (?)	whole river (esp. Ontario shore)
PCBs	human health hazard toxicity to fish	some fish sediments, biota	whole river below Lambton
mercury	human health toxicity to biota	fish, sediment	whole river (below Sarnia, esp. near Dow)
lead	human health toxicity to biota	fish sediment	below Ethyl Corp. below Ethyl Corp.
Other Contaminants			
hexachlorobutadiene	?	water, sediments, biota	below Sarnia (esp. near Dow)
hexachloroethane	?	water, sediments, biota	
pentachlorobenzene	?	water, sediments, biota	
benzene	toxicity to biota	water, biota	below Sarnia
perchloroethylene	toxicity to biota	water, biota	below Sarnia
carbon tetrachloride	toxicity to biota	water, biota	below Sarnia
diphenyl ether	?	sediments	Sarnia
biphenyl	?	sediments	Sarnia
phenols	?	*	Sarnia dischargers
pesticides	?	water	whole river

? - Further studies required to determine potential impact.

* - Historical problem, however, little data available on present concentrations in various media.

2. UGLCCS Toxic Organics and Heavy Metals

The priority contaminants in the St. Clair River found from the water, biota, and sediment reports are remarkably consistent. Hexachlorobenzene (HCB) and octachlorostyrene (OCS) are the two chlorinated UGLCCS chemicals of most concern. These chemicals are associated with Dow Chemical's Sarnia operations. Major sources include Dow Chemical's direct sewer discharges, and indirect leachate from Dow's Scott Road landfill via the Cole Drain. HCB in the St. Clair River water exceeds water quality guidelines near the discharges, and OCS exceeds an approximate guideline value calculated from bioconcentration considerations. The river sediments are contaminated with HCB and OCS all the way to Lake St. Clair (59,76). HCB and OCS are also bioaccumulated by all trophic levels of biota including plankton, benthic organisms, young-of-the-year fish, and sport fish.

PAHs, including benzo-a-pyrene, have been found in caged clams and sediments in the river. PAHs were not detected in water samples obtained from the mouth of Talfourd Creek, Baby Creek, Murphy Drain or the Cole Drain in 1984. Data on PAHs in the St. Clair system are limited at present, but sufficient information exists to demonstrate cause for concern.

The importance of PCB loadings to the St. Clair River is not a clear-cut issue. PCB concentrations in bottom sediments along Sarnia's industrial waterfront appear to be elevated. However, analytical difficulties in PCB determinations in this area have been cited (64). The presence of other halogenated organics may be leading to false high PCB readings (by a factor of 4) in sediments from this region (64,77). PCBs in fish from the river may also be misidentified and overestimated. Maximum PCB levels in sediments from Ontario tributaries were observed at the mouth of Talfourd Creek (65 ppb).

PCB levels appear to be somewhat elevated in sediments and young-of-the-year fish downstream of Lambton Generating Station. Because this site is about 15 km downstream of Sarnia's industrial discharges, PCB analytical interferences may be less significant at this site. Thus, a PCB discharge to the river may be occurring in this region. The PCB residues in fish from the river and Lake St. Clair have declined by 50% since 1976 (36). Except for a few of the larger fish of some species, most sport fish are less than the 2 ppm guideline.

Because of the considerable number of refineries and petrochemical plants along the Canadian side of the river, oil and grease discharges to the river are of concern. Oil and grease in sediments are highest along Sarnia's industrial waterfront, with many values exceeding open-water dredge disposal guidelines. Tar-saturated sediments were observed from just north of the Imperial/ Polysar boundary, to south of the Suncor property (36).

They occur at or just below the surface in cores collected up to 25 meters from the shore. The cohesion provided by the tar apparently stabilizes the contaminated sediments and hinders their incorporation into bed load transport.

Additional areas on the Canadian shoreline with high sediment oil and grease levels were adjacent to downtown Sarnia (upstream of the industrial complex), just above Talfourd Creek, just north of Corunna, and below Courtright. On the U.S. side of the river, oil and grease sediment levels were high above the Blue Water Bridge adjacent to Port Huron, above the Belle River adjacent to Marine City, and along the north channel downstream of Algonac. An unnamed creek across the river from Lambton Generating Station also contained anomalously high oil and grease sediment concentrations. However, the creek has no visible discharge to the St. Clair River and the high level here may be the result of a spill on Michigan Highway 29 (64). Oil and grease levels measured at the mouths of Baby Creek and the Murphy Drain were generally an order of magnitude higher than other Ontario tributaries with a maximum value of 7,380 ppm observed at the Murphy Drain.

Of the UGLCCS heavy metals, only mercury and lead appear to be of concern. Mercury concentrations of the larger fish of some species still exceed the consumption guideline of 0.5 ppm. Sediment mercury concentrations near Dow are still elevated, indicating a continuing mercury source in the area. The discharge of mercury to the river has been reduced dramatically since the 1970s, and fish mercury concentrations may be due, in part, to mercury recycling in the system.

Lead concentrations in sediments and biota are elevated downstream of Ethyl Corporation. Because a portion of the lead loading from this source is the more toxic alkyl lead compounds (11), the environmental implications of this discharge to the river are of concern.

3. Other Specific Contaminants

Three other contaminants associated with Dow's chlorinated solvent production that are consistently present in water, sediments, and biota in the river are hexachlorobutadiene, hexachloroethane, and pentachlorobenzene. The concentrations of these contaminants are highly correlated with HCB and OCS. The discharge of volatile organics to the river is also fairly high. Volatile substances of greatest concern in the area are benzene, perchloroethylene, and carbon tetrachloride. Near source inputs, these chemicals are found at higher concentrations than recommended water quality guidelines. They are also found in biota, including fish, in the river. Diphenylether and biphenyl are found at very high concentrations in sediments along Sarnia's industrial waterfront. The loss of heat exchange fluids to the river at this location is apparent.

Phenols have been a historical problem along the Canadian side of the river downstream from Sarnia. Since the implementation of improved waste water treatment by industrial waste dischargers in the area, the phenol loadings to the river have been drastically reduced (78). Very little data on phenols was produced for the water, biota, and sediment studies. The Point Source Workgroup (65) showed that discharges of phenols were still of concern in certain industrial and municipal discharges in Sarnia.

Pesticides are common organics that have been studied extensively throughout the Great Lakes Basin. Several common pesticides such as DDT and its breakdown products, alpha- and gamma-benzene hexachloride, and dieldrin are found in the St. Clair River (79). However, the concentration of these contaminants does not change significantly over the river's course, indicating that there are no significant sources along the river (37,79). Elevated concentrations of chlordane, gamma-BHC and mercury were found in young-of-the-year spottail shiners at the mouth of Perch Creek on Lake Huron near the head of the St. Clair River (36). Several pesticides were frequently detected in Ontario tributaries to the St. Clair River. These included alpha-BHC, a breakdown product of the insecticide lindane and atrazine, a triazine herbicide, found in whole water samples. The latter compound was estimated to account for a nearly 1 mg/s loss to the St. Clair River, from Talfourd and Baby Creeks and Murphy and Cole Drains. The predominant pesticide occurring on suspended solids was dieldrin; however, total loading from these creeks was in the order of 0.9 ug/s (68).

4. Habitat Alterations

Historically, humans made considerable changes in the St. Clair river for navigational purposes (80). Recent physical habitat alterations along the St. Clair River appear to be minimal; however, more information about shoreline development and its effects is needed before a definitive statement can be made. There has been periodic dredging in the lower channels of the river about every two years. Chemical alteration of the habitat is a problem for 12 km downstream of Sarnia's heavy industry, as indicated by benthic studies (49).

C. SOURCES

1. Municipal and Industrial Point Sources

A study by the UGLCCS Point Source Workgroup (65) indicates that a total of 52 known point sources were discharging to the St. Clair River in 1986. The total point source flow was estimated at 91,800 x 10^3 m^3/d. Apparently, 96 percent of this total was utilized by electrical generating facilities for once-through, noncontact cooling; of the remainder of the flow, 2,590 x 10^3 m^3/d, was contributed from industrial sources. Eighteen of these sources were sampled for a total of 26 study parameters. The calculated loadings from these analyses are presented in Table VII-9.

Industrial sources were found to be important contributors of most of the UGLCC Study parameters, compared with municipal facilities. The predominant sources were the petrochemical plants in the Sarnia, Ontario area, known as "Chemical Valley". The majority of the sources were located in the upper 10 km of the St. Clair River. These industrial sources were responsible for the majority of the loadings of HCB, OCS, PAHs, oil and grease, lead, mercury, copper, nickel, cobalt, iron, chromium, chlorides, total organic carbon (TOC), total suspended solids (TSS), and a spectrum of organic contaminants including volatile hydrocarbons, acid and other base neutral extractable hydrocarbons.

A comparison of municipal direct and indirect sources, and industrial direct and indirect sources by country of origin for each parameter of concern is shown in Table VII-10. Direct sources are those discharged to the river, indirect are discharged to tributaries or drains which flow into the St. Clair River.

The point source data are too limited (single day survey by the U.S., and three to six day surveys by Canada) to permit the calculation of precise annual loadings. For more common parameters, the data were compared to self-monitoring data collected by the industries and municipalities. This provides an indication as to how representative the sampling was. For most parameters, the point source samples were within normal ranges. Despite the limitations, the data are adequate to make conclusions and recommendations concerning relative point source contributions, and identify major point sources of concern.

The point source contributions of the following parameters were considered important by the Point Source Workgroup Report (65), based on concentration alone, for the reasons indicated:

TABLE VII-9

Loading summary of principal sources of UGLCCS paramerers to the St. Clair River (based on data collected in 1986).

PARAMETER	TOTAL LOADING (kg/d)	PRINCIPAL SOURCE(S)	% OF TOTAL	LOADING (kg/d)	CONCENTRATION RANGE (ug/L)	IMPORTANT PARAMETER (*)[1]
Total PCBs	0.006	Dow Chemical Port Huron WWTP	53.3 33.4	0.0032 0.002	ND-0.441[2] 0.025	-
Hexachlorobenzene	0.0247	Dow Chemical	>90	0.03	ND-0.829	*
Octachlorostyrene	0.0047	Dow Chemical	~100	0.0047	0.024-0.094	-
Total Phenols	12.2	Sarnia WPCP Dow Chemical Pt. Edward WPCP	35.5 14.6 13.9	4.32 1.78 1.69	52-165 3.5-4.5 11-1780	*
PAHs	0.331	Cole Drain Polysar Sarnia	32.6 30.8	0.172 0.163	1.2 (avg) 0.49 (avg)	-,* -
Total Cyanide	3.22	Marine City WWTP	55.9	1.8	270	*
Oil and Grease	3170	Cole Drain	41.0	1,300	1,700 (avg)	-
Total Cadmium	0.143	Sarnia WPCP	95.8	0.137	ND-7	-
Total Lead	29.0	Ethyl Canada	65.9	19.1	293-910	*
Total Zinc	44.9	Sarnia WPCP	47.9	19.7	110-710	-
Total Mercury	0.0445	Dow Chemical	64.5	0.0287	ND-0.88	-
Total Copper	11.8	Dow Chemical	52.9	6.24	ND-107	-
Total Nickel	4.37	Sarnia WPCP Polysar Sarnia Dow Chemical	22.3 15.0 14.7	0.973 0.657 0.644	5-15 26-44 0.82 (avg)	-
Total Cobalt	0.857	Polysar Sarnia	78.2	0.67	29-41	-
Total Iron	582	CIL Inc. Sarnia WPCP	35.9 23.6	209 137	530-670 1950-3150	-
Chloride	356,000	Dow Chemical	76.1	283,820	211,000 - 1,271,000	-
Phosphorus-P	89.9	Sarnia WPCP Port Huron WWTP	27.4 15.5	43.6 24.6	550-1300 480	-
Ammonia-N	1670	Sarnia WPCP Polysar Sarnia CIL Inc. St. Clair County - Algonac WWTP	37.9 21.0 15.3 10.8	633 350 256 181	5800-20000 17300-20000 600 (avg) 21,000	*
Total Organic Carbon	6700	Polysar Sarnia Sarnia WPCP	34 28	2,200 1,850	45000-60000 33000-51000	-
Total Suspended Solids	9400	CIL Inc.	53	4,980	17000-24000	-
Biochemical Oxygen Demand	7740	Sarnia WPCP	26	2,000	41000 (avg)	-
Total Chromium	16.1	CIL Inc. Polysar Corunna	56 16	8.96 2.5	20-22 258-567	*
Total Volatiles	254	Polysar Sarnia Dow Chemical Ethyl Canada	51 20 17	124.0 51.0 43.2	ND-37,400 ND-1,500 ND-1,500	*
Total Acid Extractables	1.09	Polysar Sarnia	66.4	0.74	ND-77	-
Total Other Base/Neutrals	1.03	Dow Chemical	76	0.78	ND-5	-

[1] Facilities and parameters are designated as "important" under the condition described in the text and in the UGLCCS Point Source Workgroup Report (65).

[2] Detected once only in 5 samples of First Street 54" sewer (MDL 0.06 ug/L).

TABLE VII-10

Loadings of contaminant parameters for sources surveyed on the St. Clair River[a] (kg/d).

PARAMETER		MDL(s) (ug/L)	MUNICIPAL DIRECT	MUNICIPAL INDIRECT	INDUSTRIAL DIRECT	INDUSTRIAL INDIRECT	TOTAL DIRECT	TOTAL INDIRECT	PT. SOURCE TOTAL	% OF PT. SOURCE TOTAL
FLOW[a] $10^3 m^3/d$ (SOURCES SURVEYED)	U.S.	-*	86.8	NS**	20.1	30.6	107	30.6	138	6.5
	CDN.	-	53.2	0.49	1,760	161	1,810	161	1,974	93.5
	TOTAL	-	140	0.49	1,760	192	1,920	192	2,110	100
TOTAL PCBs[b]	U.S.	.0001	0.0025	NS	0.00029	NA	0.00577	-	0.00577	64.3
	CDN.	.1	0.0	NA***	0.0032	0.0	0.0032	0.0	0.0032	35.7
	TOTAL	-	0.0025	-	0.0035	0.0	0.00897	0.0	0.00897	100
HCB[b]	U.S.	.00001	0.00012	NS	0.0000148	NA	0.000076	-	0.000076	0.3
	CDN.	0.02	0.0003	NA	0.0238	0.0005	0.0241	0.0005	0.0246	99.7
	TOTAL	-	0.00042	-	0.0238	0.0005	0.0242	0.0005	0.0247	100
OCS[b]	U.S.	-	0.000005	NS	NA	NA	-	-	-	-
	CDN.	0.02	0.0	NA	0.0046	0.0001	0.0046	0.0001	0.0047	-
	TOTAL	-	0.000005	-	-	-	-	-	-	-
TOTAL PHENOLS	U.S.	10	0.500	NS	0.0	0.158	0.500	0.158	0.657	5.4
	CDN.	1	6.01	NA	4.52	0.983	10.5	0.983	11.5	94.6
	TOTAL	-	6.51	-	4.52	1.14	11.0	1.14	12.2	100
PAHs	U.S.	1-15	0.0	NS	0.0	0.0	0.0	0.0	0.0	0
	CDN.	1-2	0.119	NA	0.0396	0.172	0.159	0.172	0.331	100
	TOTAL	-	0.119	-	0.0396	0.172	0.159	0.172	0.331	100
TOTAL CYANIDE	U.S.	5	2.37	NS	0.0	0.0	237	0.0	2.37	-
	CDN.	1	NA	NA	0.171/NA	0.683	0.171/NA	0.683	0.854+	-
	TOTAL	-	-	-	-	0.683	2.53+	0.683	3.22+	-
OIL & GREASE	U.S.	2,000	357	NS	32.8	294	390	294	684	21.6
	CDN.	100	268	NA	899	1,320	1,170	1,320	2,490	78.4
	TOTAL	-	625	-	932	1,610	1,560	1,610	3,170	100
TOTAL CADMIUM	U.S.	0.2	0.00497	NS	0.0	0.0	0.00497	0.0	0.00497	0.3
	CDN.	5	0.137	NA	0.0014	0.0	0.138	0.0	0.138	99.7
	TOTAL	-	0.142	-	0.0014	0.0	0.143	0.0	0.143	100
TOTAL LEAD	U.S.	1	0.158	NS	0.020	0.0306	0.178	0.0306	0.208	0.7
	CDN.	5	2.20	NA	25.7	0.889	27.9	0.889	28.8	99.3
	TOTAL	-	2.36	-	25.7	0.919	28.1	0.919	29.0	100
TOTAL ZINC	U.S.	2	3.42	NS	0.305	0.0613	3.72	0.0613	3.79	8.4
	CDN.	5	19.9	NA	18.5	2.69	38.4	2.69	41.1	91.6
	TOTAL	-	23.1	-	18.8	2.75	42.1	2.75	44.9	100

TABLE VII-10. (cont'd)

PARAMETER		MDL(s) (ug/L)	MUNICIPAL DIRECT	MUNICIPAL INDIRECT	INDUSTRIAL DIRECT	INDUSTRIAL INDIRECT	TOTAL DIRECT	TOTAL INDIRECT	PT. SOURCE TOTAL	% OF PT. SOURCE TOTAL
TOTAL MERCURY	U.S.	0.0001	0.00144	NS	0.000046	NA	0.00148	-	0.00148	3.7
	CDN.	0.025	0.0021	NA	0.0354	0.0053	0.0375	0.0053	0.0428	96.3
	TOTAL	-	0.00354	-	0.0354	0.0053	0.0389	0.0053	0.0443	100
TOTAL COPPER	U.S.	1	0.864	NS	0.107	0.104	0.971	0.104	1.08	9.0
	CDN.	5	1.66	NA	7.64	1.46	9.30	1.46	10.8	91.0
	TOTAL	-	2.52	-	7.75	1.56	10.3	1.56	11.8	100
TOTAL NICKEL	U.S.	4	0.425	NS	0.0410	NA	0.466	-	0.466	10.8
	CDN.	5	1.03	NA	2.11	0.761	3.14	0.761	3.90	89.2
	TOTAL	-	1.46	-	2.15	0.761	3.61	0.761	4.37	100
TOTAL COBALT	U.S.	0.001	0.024	NS	0.003	NA	0.027	-	0.027	0.5
	CDN.	5	0.170	NA	0.670	0.0	0.830	0.0	0.830	99.5
	TOTAL	-	0.194	-	0.673	0.0	0.857	0.0	0.857	100
TOTAL IRON	U.S.	14	56.0	NS	1.63	6.95	57.6	6.95	64.6	11.1
	CDN.	5	151	NA	338	28.3	489	28.3	517	88.9
	TOTAL	-	207	-	338	35.3	546	35.3	582	100
CHLORIDE	U.S.	1000	8,830	NS	4,720	398	13,500	398	14,000	3.9
	CDN.	500	6,720	NA	336,000	16,300	342,000	16,300	342,000	96.1
	TOTAL	-	15,500	-	341,000	16,700	355,000	16,700	356,000	100
PHOSPHORUS AS P	U.S.	10	51.8	NS	0.60	5.79	52.4	5.79	58.2	64.7
	CDN.	100	48.2	0.412	-26.8[c]	9.94	21.4	10.3	31.7	35.3
	TOTAL	-	100	0.412	-26.2[c]	15.7	73.8	16.1	89.9	100
AMMONIA AS N	U.S.	10	282	NS	1.45	0.89	283	0.89	284	17.0
	CDN.	100	658	NA	721	4.62	1,380	4.62	1,380	83.0
	TOTAL	-	940	-	722	5.51	1,560	5.51	1,670	100
TOTAL ORGANIC CARBON (TOC)	U.S.	10	874	NS	105	551	979	551	1,530	22.8
	CDN.	100	1,980	NA	2,760[e]	434	4,740[e]	434	5,170[e]	77.2
	TOTAL	-	2,850	-	2,870	985	5,720	985	6,700	100
TOTAL SUSPENDED SOLIDS (SS)	U.S.	4,000	969	NS	287	306	1,250	306	1,560	16.6
	CDN.	1,000	525	23.3	6,340	943	6,870	966	7,840	83.4
	TOTAL	-	1,490	23.3	6,630	1,250	8,120	1,270	9,400	100
BIOCHEMICAL OXYGEN DEMAND (BOD5)	U.S.	2,000	1,220	NS	78.8	735	1,300	735	2,040	-
	CDN.[d]	2,000	5,700	6.88	NA	NA	-	-	-	-
	TOTAL	-	6,920	6.88	-	-	-	-	-	-

MDL = Method Detection Limit
* "-" = Not Applicable
** NS = No Sources
*** NA = Not Analyzed
a - Data from (65).
b - Note significant differences for MDLS.
c - Negative net loadings at CIL, Dow Chemical 4th Street Sewer, Polysar 54" Sewer.
d - Selected Canadian Industrial sources only.
e - Not including CIL (negative 4130 kg/d TOC).

UGLCCS Parameters:		Non-UGLCCS Parameters:	
i.	Hexachlorobenzene (HCB)	vii.	Chromium
ii.	Total Phenols	viii.	Total Volatiles
iii.	Chrysene, Pyrene and Fluoranthene		
iv.	Cyanide		
v.	Lead		
vi.	Ammonia Nitrogen		

i) Hexachlorobenzene (HCB): the major source of HCB, the Dow Chemical 1st Street 42" and 54" sewers, had variable concentrations (ND-0.829 mg/L). Although effluent quality cannot be directly compared to ambient water quality standards or guidance, effluent concentrations exceeded the Provincial Water Quality Objective of 0.0065 ug/L. Since the survey, the process streams containing HCB have been diverted to a spill containment pond. The pond discharges to the Dow 4th Street Sewer. The effect of this change on the loadings is unknown. The total loading was 25 grams/day.

ii) Total Phenols: the Ontario Industrial Discharge Objective of 20 ug/L was exceeded at Polysar Sarnia and Suncor. Effluent concentrations at the Sarnia WWTP and the Pt. Edward WWTP also exceeded the Ontario Municipal Effluent Objective of 20 ug/L. The total loading was 12.2 kg/d of which about 70% was contributed by these four facilities.

iii) Chrysene, Pyrene, Fluoranthene: these PAHs were found in one source and only at low concentrations. However, these concentrations were in excess of the U.S.EPA AWQC Human Health Criteria for total PAHs for fish ingestion of 31.1 ng/L; the only ambient water quality guidance available for PAHs. This criterion is below the method detection limit of the analytical methods used. This suggests that other point sources may too be discharging at levels of concern. The total loading of these three compounds was 190 g/d.

iv) Total Cyanide: an exceptionally high concentration of total cyanide (270 ug/L) was found at the Marine City WWTP. The City has an industry that discharges potential cyanide containing waste water to the WWTP and cyanide has been detected in the WWTP in the past. Other point sources discharged total cyanide at levels below industrial discharge objectives and often below ambient water criteria. The total loading was 3.22 kg/d.

v) Total Lead: this parameter is of concern only in the Ethyl Canada effluent. This is due to its presence in concentrations in excess of the GLWQA specific objective and the OMOE Provincial Water Quality Objective (PWQO) of 25 ug/L. The total loading of lead was 29 kg/d, 66% of which was attributed to Ethyl Canada.

vi) Ammonia-Nitrogen: concentration in excess of the 10 mg/L Ontario Industrial Discharge Objective were present in the Sarnia WWTP and the Polysar Sarnia Biox effluents. The total loading was 1.67 tonnes/d.

vii) Total Chromium: high concentrations (258 to 567 ug/L) were detected at Polysar Corunna. The effluent would require substantial dilution to meet the GLWQA Specific Objective of 50 ug/L and the Michigan Rule 57 allowable level of 1.5 ug/L at the edge of the mixing zone. The total loading from all sources was 16.1 kg/d.

viii) Total Volatiles: the total loadings of this group of compounds was 254 kg/d. Benzene, chloroethane and toluene accounted for 72% of the total. Polysar Sarnia (51%), Dow Chemical (20%), and Ethyl Canada (17%) were the main contributors of these compounds. Each facility had concentrations of one or more volatiles well in excess (> 10x) of ambient guidelines.

Principal Effluent Contributors:

In terms of effluent loadings, the following facilities were considered to be the principal contributors of one or more of the parameters studied.

<u>Canada</u>:

a. Sarnia WWTP - phenols, nickel, phosphorus, and ammonia.

b. The Cole Drain, Sarnia - PAHs, oil and grease, and cyanide.

c. Polysar, Sarnia - benzene, phenols, cobalt, and ammonia.

d. Dow Chemical, Sarnia - HCB, OCS, PCBs, copper, mercury, and volatiles.

e. Suncor, Sarnia - volatile aromatics (associated with a process upset at the time of the survey).

f. Ethyl Canada, Corunna - lead, mercury, volatiles (chloroethane).

g. CIL, Courtright - iron, TSS, and chromium.

<u>U.S.</u>:

a. Port Huron WWTP - PCBs, phosphorus.

b. Marine City WWTP - cyanide.

c. St. Clair County - Algonac WWTP - ammonia.

2. Urban Nonpoint Sources

Michigan

There is a remarkable lack of data regarding the impacts of urban nonpoint sources on the water quality of the St. Clair River system from Michigan. In 1986, the Michigan Department of Natural Resources (81) completed a stormwater discharge inventory of the areas adjacent to the St. Clair River. The data within this inventory consisted only of location and size of discharge pipes within the St. Clair River study area. No data relative to flows, water quality, contaminant concentration, annual discharge, or loading values were provided.

The inventory reports that, on the Michigan shoreline, three urban areas have storm sewers which drain directly or indirectly into the St. Clair River. These urban areas include: Port Huron, which identified 10 storm sewers discharging directly into the St. Clair River, and 14 which discharge into the Black River; Marine City, which describes three storm sewer outlets discharging into the Belle River; and Algonac, which reports two storm sewers discharging directly into the St. Clair River. The cities of Marysville and St. Clair, Michigan, have no stormwater discharges.

Ontario

No data were available for contaminants in U.S. sources of urban stormwater and combined sewer overflow. But a comparison of Canadian discharges due to urban nonpoint sources, with industrial/municipal point sources is shown in Table VII-11. In most cases, the point source to nonpoint source ratio is much greater than one, suggesting that most materials are derived from industrial and municipal point sources.

While the total number of stormwater discharges on the Ontario side of the St. Clair River were not identified, considerably more information is available from the study of Marsalek and Ng (82) for the urban runoff for the city of Sarnia. The 50,200 residents of the City of Sarnia are served by combined and separate sewers, and in some of the less developed areas, by open channels. Combined sewers serve the older areas of the city (540 ha) and discharge into an interceptor which runs along the St. Clair River. The interceptor has four overflow structures which allow direct dumping of untreated combined sewage into the St. Clair River when interceptor capacities are exceeded. In nonoverflow periods, the sewage is conducted to the sewage treatment plant.

Available resources prevented Marsalek and Ng (82) from directly measuring combined sewer flow rates. Instead, they used the U.S. Army Corps of Engineers STORM model (83) to estimate urban runoff

TABLE VII-11

Comparison of industrial/municipal point source discharges with urban stormwater and combined sewer overflow^{s}a (kg/yr, Canadian sources only).

PARAMETER	ST. CLAIR RIVER		
	POINT	URBAN NON-POINT SARNIA	PS/NPS RATIO
Ammonia-Nitrogen	505,000	7,300 18,600	69 27
Phosphorus	27,000[b]	2,200 5,100	12 5.3
Chloride	131,000,000	1,180,000 2,360,000	111 56
Cadmium	50.4	8.6 48.2	5.9 1.05
Cobalt	0.84	150	0.0054
Copper	3,930	460	11
Iron	189,000	43,100 48,800	4.4 3.9
Lead	10,500	2,030	5.2
Mercury	15.6	0.8 1.5	19 10
Nickel	1,420	149 242	9.5 5.9
Zinc	15,000	2,430	6.2
Oil and Grease	907,000	47,200 73,400	19 12
Total Phenols	4,200	121 136	35 31
Cyanide	311[b]	23	13
HCB	8.9	0.8	11
OCS	1.7	0.015	113
Total PCBs	1.2	1.4 1.5	0.86 0.80
17 PAHs	120	52 74	2.3 1.6

[a] Based on Canadian Industrial/Municipal Point Source Survey Data (daily average multiplied by 365), and results reported by Marsalek and Ng (82). Some urban runoff values have upper/lower estimates.

[b] Industrial point sources only.

and combined sewer overflow. Using this model, they calculate annual surface runoff in Sarnia to be 6.7 x 10^6 m^3/yr, and a combined sewer overflow value of 1.0 x 10^6 m^3/yr, for a total annual average of 7.7 x 10^6 m^3/yr.

Contaminant concentrations in Sarnia stormwater and combined sewer overflows were measured in samples collected during storm events. Mean values for these parameters are presented in Table VII-12. For parameters with a significant percentage of data below detection limits, a low estimate where undetected values are considered zero, and a high estimate, where they are set equal to the detection limit, are reported.

The concentrations for the various contaminant parameters measured in field studies were multiplied by annual flow volumes to yield annual contaminant loading estimates. The results of these calculations are presented in Table VII-13. Where applicable, both low and high loading estimates are given.

When loadings derived from stormwater and sewer overflows are compared, overflow incidents are a major source of ammonia and phosphorus. Both sources are apparently equal in their contributions of loadings of oil and grease, zinc, and mercury; but for all remaining parameters, stormwater is the dominant source. Marsalek and Ng (82) estimate that stormwater contributes approximately 80 percent of total loadings of industrial chemicals derived from urban runoff.

3. Agricultural Nonpoint Source

The watershed of the St. Clair River region includes a geographic area of approximately 340,000 ha, of which approximately 6 percent, 20,976 ha, are located within Lambton County, Ontario. Within this drainage area, major tributary watersheds include Talfourd Creek in Canada, and the Belle, Pine, and Black Rivers in Michigan (84).

A total of nearly 70 percent of the St. Clair River geographic area is agricultural land. More than 60 percent of the total cropland in both Canada and the U.S. is under intensive cultivation. The chief cash crops grown are corn and soybeans. Livestock operations are dominated by beef and dairy farming, followed by swine and poultry husbandry.

Nonpoint sources of aquatic pollution associated with agricultural operations have traditionally included the additions of nutrient compounds, increases in particulate burdens from land erosion, and the inputs of fugitive pesticides and herbicides (84).

TABLE VII-12

Mean concentrations observed in stormwater and combined sewer overflows in Sarnia (82).

Parameter	Unit	Stormwater			Combined Sewer Overflows
		Residential	Commercial	Industrial	
Ammonia (N)	mg/L	0.4	0.27	0.70	3.9
					15.7[*]
Phosphorus (total)	mg/L	0.37	0.16	0.22	0.4
					3.4
Chloride	mg/L	--	172[a]	--	32.9
		--	343[a]	--	65.3
Cadmium	mg/L	0.00	0.0023	0.0007	0.005
		0.006	0.008	0.009	0.008
Cobalt	mg/L	0.00	0.00	0.00	0.00
		0.02	0.02	0.02	0.02
Copper	mg/L	0.009	0.051	0.087	0.14
Iron	mg/L	3.1	5.0	9.4	2.5
		--	--	--	8.4
Lead	mg/L	0.066	0.28	0.45	0.29
Mercury	mg/L	0.00006	0.00004	0.00018	0.00005
		0.000063	--	--	0.00075
Nickel	mg/L	0.018	0.005	0.030	0.005
		0.026	0.025	0.039	0.023
Zinc	mg/L	0.18	0.33	0.48	0.24
		--	--	--	1.64
Oil & Grease	mg/L	2.1	4.1	10.3	7.5
		--	--	--	34.8
Phenols	mg/L	0.0170	0.0107	0.0188	0.0099
		--	--	--	0.0255
Cyanide	mg/L	0.0035	0.0017	0.0030	0.0030
HCB	ng/L	1.55	4.4	257	12
		--	--	--	43
OCS	ng/L	--	2	--	2
PCBs (total)	ng/L	75	146	324	150
17 PAHs	ng/L	8,500	2,800	6,700	5,000
		12,000	3,300	7,000	15,400

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[*] For parameters with a significant percentage of data below detection limits, a low estimate where non-detected values are considered zero, and a high estimate, where they are set equal to the detection limit, are reported.

[a] Equivalent mean concentration.

TABLE VII-13

Summary of annual loadings in urban runoff from the Sarnia area (kg/yr) (82).

Parameter	Stormwater	Overflows	Total
Ammonia (N)	3,600	3,700	7,300
	--	15,000*	18,600
Phosphorus	1,800	400	2,200
	--	3,300	5,100
Chloride	1,150,000	31,600	1,180,000
	2,300,000	62,700	2,363,000
Cadmium	3.8	4.8	8.6
	40.2[a]	8.0[a]	48.2[a]
Cobalt	0	0	0
	131(23)[a]	19(3)[a]	150(26)[a]
Copper	326	134	460
Iron	40,700	2,400	43,100
	--	8,100	48,800
Lead	1,750	280	2,030
Mercury	0.7	0.1	0.8
	0.8	0.7	1.5
Nickel	144	5	149
	220	22	242
Zinc	2,200	230	2,430
Oil & Grease	40,000	7,200	47,200
	--	33,400	73,400
Phenols	112	9	121
(total)	--	24	136
Cyanide	20	3	23
HCB	0.8	0.0	0.8
OCS	0.013	0.002	0.015
PCBs (total)	1.3	0.1	1.4
	--	0.2	1.5
17 PAHs	47	5	52
	59	15	74

* Where applicable, both low and high loading estimates are given.

[a] Loadings calculated from data above the detection limit.

Nutrient Additions

The use of commercial fertilizers and livestock manure as soil builders potentially contributes to the pollution of adjacent aquatic resources by adding excessive burdens of bacteria, nitrogen, and phosphorus. On the U.S. side of the St. Clair River, commercial fertilizers are applied to approximately 78 percent of tillable land, while livestock wastes are added to 8 percent. The total quantity of phosphorus generated from manure has been estimated at 3,800 tonnes/yr (85). In Canada, croplands receive an estimated 3,800 tonnes of commercial fertilizer per year. This value translates to 376 kg/ha. Analysis of soil fertility and crop requirements indicate that as much as two times more phosphorus fertilizer is being used than is required in both the U.S. and Canada. Livestock operations on the Canadian side of the river generate a further 6.3 tonnes/yr of phosphorus, ultimately disposed of on farm land.

Studies of the Black River (84,85), a U.S. tributary to the St. Clair River, noted that phosphorus concentrations ranged from 0.03 to 0.73 mg/L, and averaged 0.14 mg/L. The PWQO for phosphorus in rivers is 0.03 mg/L. In Ontario, several creeks were monitored with similar results. Phosphorus concentrations ranged from 0.033 to 0.665 mg/L in Talfourd Creek, Baby Creek, Murphy Drain and the Cole Drain (68,84,86). All samples from the Ontario tributaries exceeded provincial water quality standards for phosphorus.

Pesticide Additions

Agricultural pesticides are used extensively in the St. Clair River basin for the control of weeds, plant diseases, and insects. Wall et al. (84,85) estimate that some 500,000 kg were used annually on the U.S. side. The majority (75 percent) of the compounds used were herbicides, with atrazine, alachlor (now banned in Canada), cyanazine, and metolachlor being the most frequently used. Additionally, nearly 9,000 kg of restricted-use pesticides were sold in four counties of the St. Clair River area (84). In this category, parathion and other organophosphorus insecticides were highest in sales. In Canada, approximately 30,000 kg of pesticides were applied annually (2.3 kg/ha). At the time of the study, the most common herbicides used were identical to those used on the U.S. side.

The Belle and Black rivers on the U.S. side were monitored for pesticides between April and August of 1985 (84). The loads to the Black River for atrazine, alachlor, cyanazine, and metolachlor were reported as 0.3, 0.22, 0.99, and 0.07 g/ha, respectively. Loadings for the same compounds to the Belle River were reported as 0.12, 0.03, 0.03, and 0.07 g/ha, respectively.

Analysis of sedimentary materials from the St. Clair River tributaries yielded the observation that restricted-use pesticides were present in 70 percent of the samples. Chlordane and metabolites of DDT were most frequently observed.

Ontario tributaries were monitored for pesticides including organochlorine, organophosphorus and carbamate insecticides as well as phenoxy acid and triazine herbicides.

Atrazine was detected in 47% of all water samples from Ontario tributaries of the St. Clair River at concentrations up to 8,450 ug/L. Additional pesticides which were detected less frequently, included gamma-BHC, pp-DDE and endrin. Alpha-BHC was detected in 62% of water samples but typically at levels below 5 ng/L.

The frequency of sampling was insufficient to estimate annual loadings; however, mean instantaneous loadings for atrazine indicate that Talfourd Creek is discharging approximately 0.5 mg/sec to the St. Clair River.

Industrial organic compounds were detected primarily on suspended solids and were consequently observed in bottom sediments at the tributary mouths. Concentrations of HCB, OCS and PCBs were observed in whole water, suspended solids and bottom sediments from Ontario. Several elevated levels were measured on suspended solids at the Cole Drain (HCB - 5,800 ng/g; OCS - 5,400 ng/g) and at Talfourd Creek (PCBs - 77,840 ng/g)(68,84,85). The significance of these intermittent peaks cannot be determined based on the limited data available.

4. Atmospheric Deposition

Direct atmospheric deposition of contaminants to the St. Clair River is likely to be negligible because of the relatively small surface area of the river. However, atmospheric deposition may be defined as the sum of the contaminants deposited from the atmosphere on a stream or lake surface (direct input), plus that material which has fallen on upstream areas and is transported through the connecting channels to downstream bodies of water. This phenomenon is likely the mechanism responsible for the regular observation of common pesticides observed in the St. Clair River (87). Such compounds as the metabolites of DDT, alpha- and gamma-benzene hexachloride, and dieldrin are routinely reported in water samples from the St. Clair River, but the concentration of these contaminants does not change significantly over the length of the connecting channel. This fact suggests that there are no active sources along the St. Clair River (37,79).

5. Groundwater Contamination/Waste Sites

Three different groundwater flow systems contribute to the overall groundwater discharge, or flux, including discharge from surficial aquifers, from intermediate flow systems and from deep bedrock systems. Groundwater in the unconsolidated surficial deposits generally flows to the St. Clair River. Locally, however, the direction of groundwater flow is influenced by surface water drainage and glacial landforms. Groundwater flow directions in the deeper units are as yet not well defined.

Total groundwater seepage directly to the St. Clair River was estimated by three independent teams of investigators to range between 645 L/s and 741 L/s and to average about 700 L/s. The U.S. Geological Survey estimated total groundwater discharge to the river from groundwater discharge areas, based upon tributary baseflow information. The University of Wisconsin - Milwaukee used a combined geophysical and hydrological method to compile continuous measurements of groundwater flow passing through the St. Clair River bed. The University of Windsor Great Lakes Institute deployed seepage meters and mini-piezometers to measure seepage in the Sarnia area (88).

Shallow groundwater in the study area, which does not discharge directly to the St. Clair River, contributes about 10% of stream flow to the tributaries of the St. Clair River. Rates of groundwater seepage to the St. Clair River generally decreased downstream, with higher fluxes noted in the Sarnia and Port Huron area, and between Stag Island and Courtright coinciding with areas having the largest number of sources of groundwater contamination.

Although the total amount of discharge to the St. Clair River is small relative to the St. Clair River's water budget, the heterogeneities that are apparent in the nature and the distribution of groundwater flux suggest that inputs of contaminated groundwater may be locally significant.

Surface Runoff from Landfills

Groundwater is not a principal route of contaminant transport from many waste sites in the St. Clair study area. Low hydraulic conductivities of surficial materials here restrict infiltration and groundwater movement. Surface runoff from waste sites to storm drains, and small tributaries which flow to major surface water bodies appears to be of greater importance as a contaminant transport pathway.

Michigan's Potential Groundwater Contamination Sources

Groundwater movement was investigated in an area extending 19 km inland along the St. Clair River. An inventory of active and inactive waste sites within this area was conducted as part of this investigation. Twenty-six sites of known, or potential groundwater contamination were identified and ranked. The majority of sites are solid waste landfills, regulated and unregulated hazardous waste disposal sites, storage sites and spills. Other potential sources that were reviewed included leaking underground storage tanks, contaminated well water, and underground injection wells. Underground injection wells were not ranked for potential contributions to contaminant burdens and are treated separately below.

Those sites in areas which discharge directly to the river were ranked and assigned priorities for potential impacts upon the St. Clair River. Ranking of sites, using a modification of U.S.EPA's DRASTIC ranking system, was based on their potential for contributing contaminants directly to the St. Clair River via groundwater by evaluating the hydrogeology, the nature of waste material as described in state and federal files, and the distance to the river (89). The 7 highest ranked sites had the greatest potential for impact upon the St. Clair River (Table VII-14). The water table in this region was generally less than 4.6 m below the land surface and the individual sites had priority pollutants and/or inorganic contaminants.

Evaluation of Potential Impacts

One round of samples were collected from 8 observation wells that were installed by the U.S. Geological Survey (USGS) in each groundwater discharge area. Actual locations of wells depended upon the number of up gradient waste sites, the size of the groundwater discharge area, and on permission for drilling from landowners. It was possible to locate two wells near waste sites, including a well installed down gradient of both A and B Waste Disposal and the Hoover Chemical Reeves Company, and a well installed down gradient from the Wills Street Dump Site. Other locations were chosen to provide background information. Analyses were made for 72 volatile, base neutral, acid extractable, and chlorinated extractable hydrocarbons, and 24 trace metals and other chemical parameters. These analyses were compared to both surface water quality criteria and objectives, and drinking water standards.

i) Organic

The pesticide endosulfan was detected in one sample. Phthalate esters were found in four of eight samples. N-nitrosodiphenylamine, was detected in a well at a level in excess of U.S.EPA

TABLE VII-14

Confirmed or possible Michigan contamination sites within the St. Clair River groundwater discharge areas*.

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1. Grand Trunk Railroad (CERCLIS/RCRA/Act 307)
The Grand Trunk Railroad site is an oil pipeline leak. There is a perched water table about 2 feet below the surface that is underlain by about 100 feet of lake clays and a gravel aquifer. Oil may have discharged to a sewer and ditch (MDNR). Groundwater contamination is not indicated in the Act 307 listing. There are no monitoring wells. The upper, perched aquifer is contaminated with diesel fuel. Sandy soils on site are saturated with oil and may contribute oils to the shallow aquifer (observed, 1979, from PA). Oils and #2 diesel fuel flowed to WWTP via storm drain on site (observed 1978 - 1979, from PA). Note: CERCLA authorities were not applied because the observed release was limited to petroleum products which are covered under the Clean Water Act.

2. A and B Waste Disposal (CERCLIS/RCRA/Act 307)
The A and B Waste Disposal site is a transfer facility where wastes are sorted for resale/cycling and disposal. Soil and groundwater samples contain toluene, xylene, trichloroethylene and tetrachloroethylene. There are alleged incidents of dumping paint thinner on the ground. Groundwater contamination is not indicated in the Act 307 listing. There are no monitoring wells.

3. Hoover Chemical Reeves Company (CERCLIS/RCRA/Act 307)
The Reeves Company buys and distributes paint products locally. In the past, the facility built fiberglass buildings for Port-a-john. Hoover Chemical manufactures adhesives. Drums containing paint and adhesive wastes are stained on site. Groundwater contamination is not indicated in the Act 307 listing. There are 5 monitoring wells.

4. Eltra Corp. Prestolite Wiring (CERCLIS/RCRA/Act 307)
This company is a RCRA generator and treatment/storage/disposal facility. Various halogenated and non-halogenated solvents, electroplating wastes, lead and ketones are stored in containers on site. There are no monitoring wells.

5. Wills Street Dump Site (CERCLIS/Act 307)
The Wills Street Dump Site is located within one-half mile of the St. Clair River. Drums from the St. Clair Rubber-Michigan Avenue plant were dumped into open pits each year for 8 years. These liquid wastes included toluene, acids, and polyurethane. Over the eight year period, as many as 1,500 drums were dumped. A ditch just east of the site empties into the St. Clair River (MDNR). Groundwater contaminations is not indicated in the Act 307 listing. There are no monitoring wells.

The site was not submitted to NPL for the following reasons: Marysville's drinking water surface water intake is located 1.5 mi. upstream of the Wills St. Dump and 90' of clay overlies the aquifer used for drinking water. Nonetheless, the site is near a wetland. On-site soil samples contained low levels of 1,1-dichloroethane, 1,1,1-trichloroethane and toluene. Also found were elevated levels of phenol and Arochlor - 1260.

6. General Technical Coatings (Act 307)
Paint and solvents are stored in barrels at the General Technical Coatings site. The site is within one-quarter mile of the St. Clair River. Ground-water contamination is not indicated in the Act 307 listing. The site was removed from the Act 307 list after cleanup.

7. Winchester Disposal Area (CERCLIS/Act 307)
The Winchester Disposal Area site is an unlicensed refuse dump. It is located in a low marshy area near Port Huron. The site is unfenced and continued dumping is possible. No records of the types or amounts of wastes present exist. Drums have been seen on the site and more may be buried (MDNR). Ground-water contamination is not indicated in the Act 307 listing. There are no monitoring wells.

The fill on-site is at least ten feet thick in some areas. No cover was ever applied. Drums, concrete and household appliances are exposed. Tens of thousands of tires are stacked on site up to ten feet high in areas. In 1981 three monitoring wells in this area were sampled. Down-gradient wells in the vicinity of Winchester Disposal Area, showed higher concentrations of phenolics, cadmium, copper, lead, zinc and iron than were found in an up gradient well in the vicinity of the Winchester Disposal Area.

CERCLIS:	Site is listed within the information system for Superfund and is considered for clean-up under the Comprehensive Environmental Compensation and Recovery Act of 1980.
RCRA:	Facility has a Resource Conservation and Recovery Act identification number.
Act 307:	Site is listed on Michigan's compilation of sites of known and possible environmental degradation.

* Information from (88).

Human Health Criteria for carcinogens at a 10^{-6} risk level. It is possible that phthalate esters were introduced during sampling or shipment.

ii) Inorganic

U.S.EPA Drinking Water Primary Maximum Contaminant Levels (MCL) were exceeded for chromium at one well, for lead at six of eight wells and for barium at two wells.

Table VII-15 contains a summary of groundwater quality in these wells based on unfiltered samples (88). The metals are generally associated with finely-divided particulates. Groundwater that discharges to the St. Clair River is thought to be free of fine particulates, and thus of lower trace metals concentration than determined for these samples. Thus, a computation of the loading of the St. Clair River by chemical substances transported by groundwater does not seem feasible at the current time.

Several sites that were selected as priorities for investigation by the USGS may have potential for local impacts upon the St. Clair River.

Elevated levels of barium, cobalt, copper, lead, zinc, and nickel contamination, as well as the n-Nitrosodiphenylamine contamination in well G3 appear to be related to discharges from A and B Waste disposal, or Hoover Chemical Reeves Company, or a combination of the two. The proximity of well G3 and of the two sites to the St. Clair River suggests that seepage of contaminated groundwater originating from the sites may result in local impacts upon St. Clair River biota or water quality.

Elevated lead, mercury, and zinc in well G4 might be attributable to the Wills Street Dump Site.

Elevated chromium, lead, iron, zinc and phosphorus concentrations in well G1, and elevated barium, copper, iron, lead, nickel, total organic carbon, and oil and grease concentrations in well G8 had no identifiable source.

Generally, it seems that environmental problems of waste, storage, treatment and disposal facilities are associated with overland flow or runoff, rather than through groundwater discharge. Low hydraulic conductivities, and hydraulic gradients suggest that groundwater is not a major route of contaminant transport to the St. Clair River from these sites. Nonetheless, the possible presence of unidentified discontinuous stringers of sand and gravel may serve to enhance contaminant transport locally.

TABLE VII-15

Summary of St. Clair River area groundwater quality[1] in Michigan U.S.GS wells[2].

	NUMBER OF ANALYTICAL DETECTIONS	MAXIMUM	MINIMUM	MEAN	STANDARD DEVIATION
Antimony, total (ug/L)	8	13	<1	3.25	4.60
Arsenic, total (ug/L)	8	15	<1	7.38	5.24
Barium, dissolved (ug/L)	8	2100	51	568.38	710.51
Beryllium, dissolved (ug/L)	8	21	<1	3.13	6.88
Cadmium, total (ug/L)	8	<1	<1	<1	0.00
Chromium, total (ug/L)	8	59	<1	20.63	16.19
Cobalt, total (ug/L)	8	200	<1	36.38	62.75
Copper, total (ug/L)	8	730	2	170.63	243.14
Iron, total (mg/L)	8	500	1.2	110.93	158.86
Lead, total (ug/L)	8	6300	23	1457.38	1954.81
Mercury, total (ug/L)	8	0.5	<0.1	0.23	0.21
Nickel, total (ug/L)	8	1300	<1	253.13	415.85
Selenium, total (ug/L)	8	<1	<1	<1	0.00
Zinc, total (mg/L)	8	390	2.5	83.59	119.87
Carbon, total organic (mg/L)	8	190	3.6	41.58	56.72
Chloride (mg/L)	8	250	11	91.50	82.63
Cyanide, total (mg/L)	8	<0.01	<0.01	<0.01	0.00
Dissolved solids (mg/L)	8	1560	145	541.13	439.20
Oil-grease, total (mg/L)	8	18	3	7.00	4.42
Nitrogen, total (mg/L)	7	2.5	0.2	1.69	0.72
pH (units)	8	11.2	8.1	10.11	1.13
Phenols, total (ug/L)	8	6	2	4.13	1.05
Phosphorus, total (mg/L)	8	0.57	0.021	0.19	0.19
Specific conductance (us/cm)	8	2380	322	928.88	622.58
Endosulfan (ug/L)	1	0.08	0.08	0.08	0.00
Bis (2-ethylhexyl)phthalate (ug/L)	3	1500	6	528.67	687.50
Butyl benzyl phthalate (ug/L)	2	6	6	6.00	0.00
n-Nitrosodiphenylamine (ug/L)	1	10	10	10.00	0.00

[1] Data from (88).
[2] All wells were installed by U.S. Geological Survey.

Ontario's Potential Groundwater Contamination Sources

On the Ontario side of the St. Clair River, a total of 16 designated waste disposal sites were identified in Lambton County. The Ontario sites were prioritized to determine those sites that require monitoring or remedial investigations. In designing criteria for this evaluation, emphasis was placed on identifying sites which lack specific information that is important in assessing environmental impacts. Thus, sites lacking particular information could rank higher than sites having evidence of impact. Seven main groups of criteria were selected:

1. Geologic Information
2. Hydrologic Information
3. Hydrogeologic Information
4. Geochemical Information
5. On Site Monitoring
6. Waste Characterization and Containment
7. Health and Safety

Specific questions within these groups, that are significant in assessing the site environmental impact were used to derive a quantitative score. Three categories of priorities were developed, including:

Priority 1 Sites: those sites with a definite potential for impact on human health and safety;

Priority 2 Sites: those sites which require immediate investigation in order to determine the potential for impact either on the environment or human health and safety; and

Priority 3 Sites: those sites requiring additional monitoring, but with lesser potential to impact their surrounding environment.

The Nonpoint Source Workgroup (88) reported that three sites in Lambton County were categorized as Priority 1 Sites. Included in this category were:

1) Dow Chemical, Scott Road
2) Polysar Limited, Scott Road
3) P and E Oil Recyclers, Petrolia.

Ten sites in Lambton County were identified as Priority 2 Sites. These locations included:

1) K and E Solid Waste, Sarnia Township
2) Unitec, Inc., Moore Township
3) C.I.L., Inc., Lambton Works, Sombra Township
4) City of Sarnia Landfill, Sarnia Township
5) Canflow Services, Petrolia

6) Dow Chemical, La Salle Road, Moore Township
7) Ladney, Moore Township
8) Sun Oil Company, City of Sarnia
9) Fiberglass Canada, Ltd., City of Sarnia
10) DuPont of Canada, Ltd., Moore Township.

Priority 3 sites in Lambton County included three listings. These were:

1) Walpole Island, Walpole Island Indian Reserve
2) Esso Petroleum, Scott Road, City of Sarnia
3) Johnson Construction, Sarnia Township.

It is important to note that the ranking schemes for U.S. and Canadian sites are not strictly comparable. Site characteristics of the four highest priority sites are provided in Table VII-16.

Most contamination problems associated with waste sites are centered in the Scott Road area of Sarnia. Shallow groundwater and surface water drainage here is to the Cole Drain. In addition to Dow and Polysar landfills, other waste disposal sites may be contributing contaminants to the Cole Drain and are situated adjacent to the Dow and Polysar landfills. These include the City of Sarnia sludge lagoons, Fibreglas Canada's landfill site, and further south the Esso Petroleum Landfill site. Due to the uncertainty of the origin of contaminants in the Cole Drain, the Ontario Ministry of the Environment has undertaken a study of surface runoff within the Scott Road watershed. Preliminary findings to date indicated the presence of slightly elevated levels of hexachlorobenzene and octachlorostyrene in surface water draining from the landfill area.

Underground Injection Wells

i) Michigan

In the United States, the U.S.EPA has the primary responsibility to establish and enforce protection of underground sources of drinking waters through its Underground Injection Control (UIC) program. This program regulates five classes of injection wells:

Class 1: Industrial and municipal disposal wells which inject below the lower most formation containing underground sources of drinking water.

Class 2: Injection wells associated with oil and gas production and liquid hydrocarbon storage.

Class 3: Special process wells used in conjunction with solution mining of materials.

TABLE VII-16

Site characteristics of Ontario high priority waste sites in the St. Clair River area*.

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1. Dow Chemical, Scott Road - The site has been in operation since 1948. Disposal operations consisted of controlled land filling and clay capping hazardous and non-hazardous solid and liquid waste that originated from the production of vinyl chloride. Included were various oily sludges and solvents containing chlorinated hydrocarbons, specifically hexachlorobutadiene. Also, contaminated soils and equipment from around the production facilities have been transported to the waste disposal site. Approximately 1000 tonnes of waste (28% non-hazardous, 26% liquid and 46% hazardous waste, MOE 1984) were disposed annually. Surface and groundwater monitoring systems have been in place since 1980, as well as a leachate control and treatment system. The leachate control system consists of a collecting/holding ditch along the north boundary of the site. The contents of the ditch are treated with activated carbon beds and released to the Scott Road ditch, which drains to the Cole Drain. The effectiveness of a steel sheet pile wall to contain off site groundwater flow has not been demonstrated. Surface runoff is the most likely pathway for movement off site. Surface runoff is not properly contained and may be migrating towards the adjacent Fibreglas Canada site. Ground water mounding within the landfill is likely to create a large hydraulic gradient across the sheet pile wall resulting in short circuiting of the wall, and increased off site ground water flow. The present monitoring program is inadequate and needs to be improved. Dow has also found and removed contaminants from the Cole Drain.

2. Polysar Limited (Scott Road) - The Polysar Limited disposal site off Scott Road in Sarnia serves the nearby Polysar manufacturing facilities. The site has been in operation since 1942 and consists of industrial wastes and fly ash areas. Disposal operations consist of controlled land filling of various inert sludges, plastic resins and alkali, inorganic and rubber-accompanied waste over an area of approximately 11 hectares. At present, approximately 25,000 m^3 of liquid wastes are received per year. Land filling is waste with fly ash or imported clay and silted clay material. Surface runoff and waste leachate are directed into surface storage lagoons where monitoring and treatment is required. Monitored parameters include pH, total organic carbon, phenols, copper and ammonia. Off site releases of surface waters has ceased, and all surface waters are now treated at the company's biological oxidation treatment plant. In general, groundwater monitoring in this site is inadequate to determine whether or not contamination is leaving the site. The company is in the process of retaining a consultant who will be charged with the task of initiating a more detailed hydrogeological investigation of the site, including more frequent sampling of existing piezometers.

3. P & E Oil Recyclers - The P & E Oil Recyclers site stores used oil in underground tanks and disposes of oil field brines in two deep disposal wells. In 1982, 50 m^3 (10,000 gal) of waste were accepted at the site. The major industries served are: Dome Petroleum, Imperial Oil, Polysar Limited, and Uniroyal. No surface water of groundwater monitoring programs are in effect. The site was developed in the latter part of the 19th century by the Canadian Oil Company for the subsurface storage of crude oil in underground cedar-lined tanks. The tanks were excavated in heavy clay soil to depths ranging from 4 m (13 ft) to 18 m (60 ft) below grade. In 1965 and 1969 two deep disposal wells were drilled into the Detroit River Group and were used for the disposal of liquid industrial wastes until 1974, when the Ontario Ministry of the Environment regulated against the disposal of industrial wastes, except for oil field brine, in this fashion. This regulation led to the storage of industrial waste in the subsurface storage tanks. The underground storage tanks have capacity to hold over 13,650 m^3 (3,000,000 gal), and the last documented reports indicate that all tanks are full. The liquid contents of the tanks were determined to contain oil, brine, water, caustic and/or acidic compounds, phenolic compounds, mineral salts and heavy metals, including lead and chromium. The potential for off-site migration exists and has been documented. At present, there is virtually no on-site containment for the off-site migration. In addition, many of the tanks are uncovered, or those that are covered have weakened, rotting wooden roofs, therefore allowing infiltration of precipitation which will cause overflows of the contents. A Control Order has been proposed by the Ministry of the Environment

4. CIL, Lambton Works - The Canadian Industries Limited Plant near Courtright, produces chemical fertilizers. There is little topographic relief, but surface drainage is either directed to the St. Clair River, or eastward to Clay Creek. Prior to the decommissioning of the phosphate plant, the facility used phosphate rock which naturally contains minor amounts of radioactive radium and uranium. These elements appear in waste gypsum slurry which was discharged into two 50 hectare holding ponds. The ponds also contain phosphate, ammonia, and fluoride, with a water pH of 1.0. Due to the use of sulphuric acid originating from one of the company's other facilities in Quebec, the pond waters have become contaminated with dinitrotoluene (DNT). From 1975 to 1981, separation filters containing radium concentrations as high as 12,000 pCi/g from the CIL manufacturing process were disposed at the Sombra Township (Wilkesport Landfill Site). This disposal resulted in areas of elevated radiation exposure rate and localized hot spots. Under the direction of the Ontario Ministry of the Environment and the Ministry of Labour, CIL removed several truck loads of contaminated soil from the landfill for storage in the berm of one of CIL's gypsum ponds. The waste soil and debris are presently contained inside the walls of the gypsum pond, all radioactive materials are now stored in a concrete bunker on site.

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* Information from (88).

Class 4: Hazardous waste wells which inject into or above underground sources of drinking water (wells in this category were banned in 1985).

Class 5: Wells not falling into one or more of the above categories; including heat exchange wells, domestic waste wells, and cesspools.

A total of 72 injection wells are presently rule authorized or permitted on the U.S. side of the St. Clair River. Of this total, 63 are in current operation, two are temporarily abandoned, and seven are permanently plugged and abandoned.

Class 1 Wells:

Consumers Power Company Facility in Marysville, Michigan currently has two temporarily abandoned Class I Non-Hazardous Industrial Waste wells. These wells will be reclassified as salt water disposal wells (2D) per clarification of 1986 Safe Drinking Water Act Amendments. The wells are designed to inject brine associated with the hydrocarbon storage operations at their facility. The injection zone for these fluids are the Eau Claire and Mt. Simon Formations at a depth greater than 1,380 m at a pressure of 12,757 kPa (1,850 psi).

Class 2-D Salt Water Disposal Wells:

Eleven Class 2-D salt water disposal wells are currently operating in the St. Clair area. One additional salt water disposal well is temporarily abandoned, and two others have been permanently plugged and abandoned. Disposal intervals for Class 2-D wells in this area range from the Detroit River Group of formations at a depth of 267 m to the Eau Claire Formation at a depth of 1,350 m. Permitted injection pressures range up to 8,960 kPa (1,300 psi). All Class 2-D wells in the area with one exception have passed mechanical integrity tests: one of the ANR Pipeline Co. wells had failed its mechanical integrity test on April 9, 1986 and was shut down, but has since been reworked and retested for mechanical integrity, and is functioning properly as of June 6, 1986.

Class 2-H Hydrocarbon Storage Wells:

Class 2-H, Hydrocarbon Storage Wells service natural gas storage reservoirs, or are used for storage of refined petroleum products, or liquified petroleum gas (LPG). Gas storage reservoirs for natural gas are depleted gas fields into which gas produced in other areas is stored for future marketing. Injection and withdrawal of gas is typically through former gas production wells which have been converted to storage. Injection and withdrawal may be through the same well, or through separate wells. Observation wells are used to monitor reservoir pressures, reservoir capacity and other parameters.

Currently there are 11 hydrocarbon storage fields or facilities located in the St. Clair River area with an average surface area of 406 acres. These fields have all been converted to hydrocarbon storage since 1970. Most gas storage reservoirs in St. Clair County are in the Middle Silurian Niagaran Reefs, and Salina Carbonates and Evaporites. Depths to the gas storage reservoirs range from 659 to 884 m and the thickness of the reservoirs ranges from 1 to 92 m. The Middle Silurian Reefs are used principally for the storage of natural gas that is produced elsewhere and stored for future marketing. This activity is carried out principally by the Consumers Gas Company. The Salina Evaporites are primarily used for the storage of LPG and other refined petroleum products.

Amoco Productions company operates a LPG storage facility having seven wells in the Salina-A Evaporite. The depth to these caverns ranges from 690 to 750 m and the estimated capacity of all the caverns is 2,265,000 L. Consumers Power Company operates 9 wells completed in the Salina-B Salt for the storage of refined petroleum products.

Class 2-R Enhanced Oil Recovery Well:

Five Class 2-R, enchanced oil recovery wells, operate in the St. Clair River area in the Detroit River Group of Formations and the Niagaran Dolomite. One well, formerly operated by Vans Tank Truck Service, failed its mechanical integrity test in April of 1986 and is no longer in operation.

Class 3-G Solution Mining Wells:

Solution mining wells operate through production of artificial brines by wells completed a hundred m or more apart in the same salt bed. Salt is dissolved by pumping water through one well into the bedded salt, and out through the second well. The brine that is produced is processed to recover bromine, iodine, and sodium, calcium and magnesium chlorides. The Salina Group evaporites presently produce brines, but the Devonian Detroit River Group has also been used in the past for production.

Eight Class 3-G solution mining wells are operated by Diamond Crystal Salt Co. Four additional solution mining wells have been operated in the past by Morton Salt Co. but have since been plugged and abandoned.

Other Wells:

No Class 4 wells operate in the St. Clair River area. Seventeen Class 5 wells operate in the St. Clair River area.

The impacts of Michigan Underground Injection wells in the area upon the St. Clair River are uncertain. However, it appears that, with the exception of short-term mechanical integrity problems for a salt water disposal well and an enhanced oil recovery well, all wells are operating in an environmentally sound manner.

ii) Ontario

In Lambton County, Ontario, deep injection wells were used to dispose of industrial wastes during the period 1958-1972 and are still used for the disposal of cavern brines and oil field brines (88). There are about 35 deep wells in Lambton County (Figure VII-3). The Lucas formation of the Detroit River Group was heavily utilized prior to 1976 for the injection of industrial waste. The freshwater aquifer lies above this bedrock, therefore the potential exists for wastes to flow upwards into the aquifer and thus migrate to the St. Clair River.

The industrial waste wells were located in three areas. The most heavily utilized area was the industrialized section south of Sarnia, adjacent to the St. Clair River. In this location wells were used by Imperial Oil Ltd. (5 wells), Shell Canada Ltd. (2 wells), Sun Oil Company (1 well), Polymer Corp. (1 well), and Dow Chemical Ltd. (2 wells to the Salina formation) (Figure VII-3).

The second area is located inland from the river and included the well of Marcus Disposal (1 well), Thompson Wright Co. (2 wells), and Tricil-Goodfellow (2 wells). A third area is found in Courtright adjacent to the St. Clair River, and consists of 2 wells belonging to Canadian Industries Ltd. (CIL) (Figure VII-3).

The Primary waste types disposed into the wells were spent caustics, acids, phenols, minor hydrocarbons, and brine. The volumes of industrial wastes disposed of into the Detroit River Group total 7,513,722 m^3. In the industrial area of Sarnia, it was usually necessary to inject waste under pressure to achieve the required injection rate. The wells close to the St. Clair River often required pressures up to 3,103 kPA (450 psi) at surface to inject the waste. The average injection pressure was 2,758 kPa (400 psi).

Cambrian Disposal Ltd., owned and operated 7 wells in Lambton County, for the disposal of cavern-washing brine waters. Between 1971 and 1985 the total volume of waste injected under gravity into these wells, was 10,194,889 m^3. All wells used for the disposal of brine materials have established monitoring well networks on adjacent properties to determine water quality in the freshwater aquifer. The company is also required to pay a levy for each cubic metre of waste injected for the perpetual care of the well once it is abandoned.

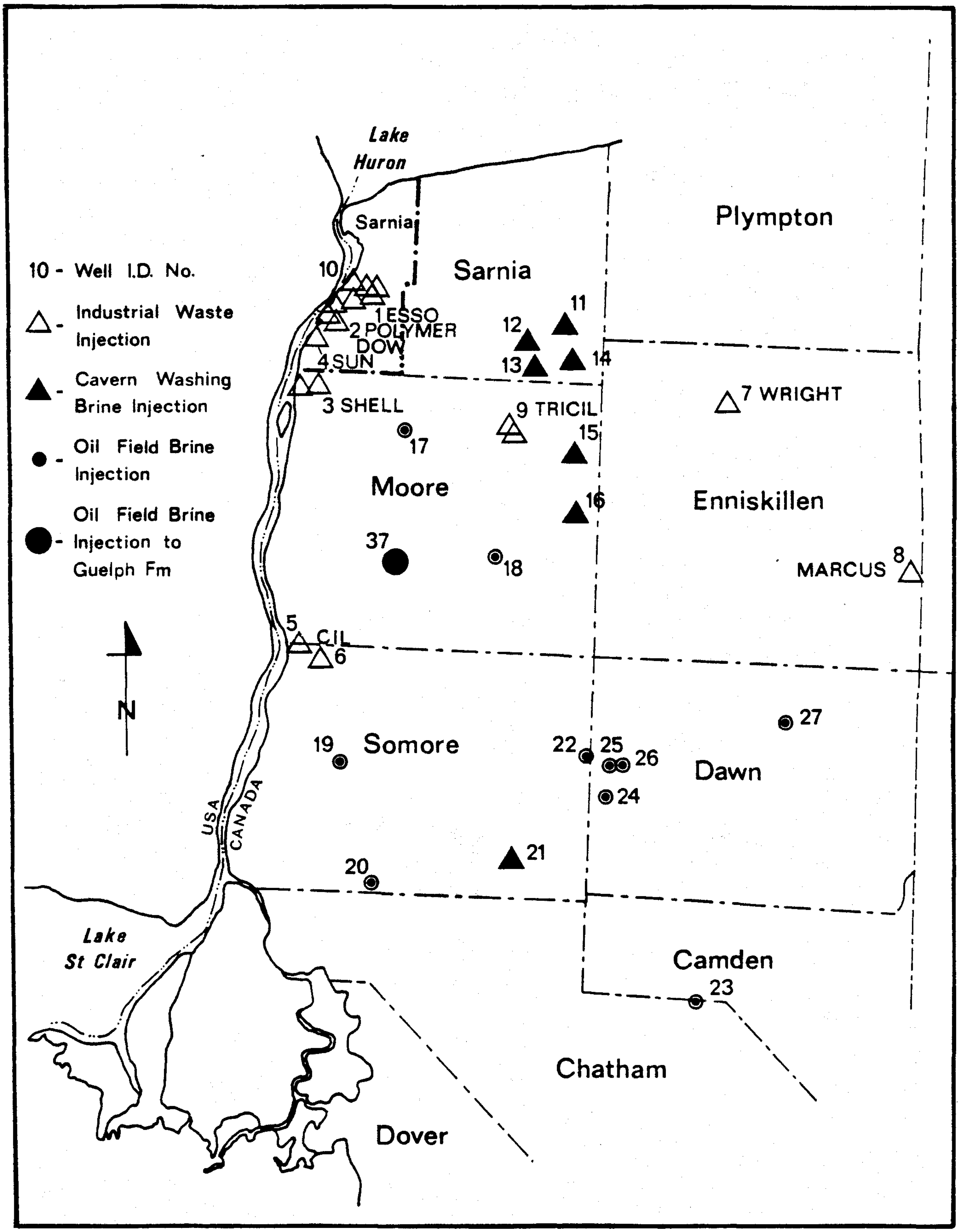

FIGURE VII-3. Injection wells.

Of concern to the Ontario Ministry of the Environment and the Federal Department of the Environment is the past practice of injection of industrial wastes into the Detroit River geologic formation, and the potential for contamination of the freshwater aquifer. Because of high pressures used for injection and the large volumes of wastes disposed, the potential exists for contaminants to migrate from the disposal unit to the freshwater aquifer and hence, to the St. Clair River. The possible pathways of migration include the following:

1. Numerous bore holes, many of them abandoned and unplugged, provide open conduits through the bedrock confining units;
2. Poorly constructed injection wells could allow waste to migrate along the outside of the casing;
3. Faults, fractures and joints are likely to exist in the bedrock confining units. It is possible the pressurized waste could travel great distances via these fractures; and
4. The permeability of the confining shale and limestone units may be of sufficient magnitude to allow pressurized wastes to migrate via pore spaces to the shallow aquifer.

In view of the possible migration pathways and the fact that there were documented cases of upwelling in the Sarnia area, which occurred between 1966 and 1972, there was the possibility that the groundwater system had been pressurized above its natural state. This being the case, it was possible that the displacement of formation fluids, or the upwelling of industrial wastes, may have contaminated the freshwater aquifer in the St. Clair River area or have migrated across the St. Clair River to Michigan.

Detailed studies of the fresh water aquifer and the movement of injected wastes were undertaken from 1986 to late 1988 by the federal and provincial governments, and industry. The preliminary results of these studies were reported by Intera Technologies Inc. (90). The executive summary of this report is reproduced below:

> "This report .... describes the results of a hydrogeologic study of the fresh water aquifer and deep geologic formations in the Sarnia Ontario area. The study was undertaken to assess the extent to which the St. Clair river and a thin sand and gravel aquifer (fresh water aquifer) located at the bedrock surface have been impacted by past practices of industrial waste disposal to the Detroit River Group of Formations located at 150 to 200 m below bedrock surface.... this study included: drilling, testing and installation of fifteen groundwater monitoring wells to the fresh water aquifer; drilling, testing and installation of one 300 m

deep borehole to the disposal formation in the Detroit River Group of formations; and quarterly groundwater sampling and hydraulic head monitoring of a 29 point monitoring well network of the fresh water aquifer and of the deep borehole. The computer modeling included a numerical simulation of groundwater flow in the fresh water aquifer and simulation of waste migration within the disposal zone. The potential size of contaminant plumes that may result from vertical migration through an open abandoned borehole between the disposal zone and the fresh water aquifer was also simulated using a computer model.

"The results of this study show that the fresh water aquifer is a thin, discontinuous aquifer located at or near the bedrock surface with an average hydraulic conductivity of 5×10^{-6} m/s. A buried bedrock valley of depth 60-80 m below ground surface and 30-40 m below surrounding bedrock is located about 500-1000 m east of the current channel of the St. Clair River. The fresh water aquifer has a higher hydraulic conductivity of about 1×10^{-4} m/s within the bedrock valley due to the presence of alluvial sands and silts. The freshwater aquifer is generally overlain by 30-70 m of low permeability clay till; however, below the St. Clair River the thickness of confining till in places may be a thin as 3 m.

"Groundwater flow within the fresh water aquifer toward the bedrock valley averages 0.57 m^2/yr per unit aquifer width. Within the bedrock valley some flow is directed down to deeper geologic formations and some of the flow is discharged to the St. Clair River. No groundwater flows under the St. Clair River within the fresh water aquifer to the U.S.

"Phenol contamination of the fresh water aquifer by injected industrial waste is evident on the Esso Petroleum Canada property near the St. Clair River and below the St. Clair River in the area of the CN Railway tunnel. Loading to the St. Clair from this 800 m by 600 m contaminated zone is calculated at 5.2 g/d which, given the volume of flow in the St. Clair River, is rapidly reduced to below detection levels. Chloride contaminant loading to the River from the same area is calculated at 50 kg/d.

"It is recognized that some undetected contaminant plumes may exist in the vicinity of disposal wells due to waste migration up abandoned boreholes. Assuming such plumes did exist adjacent to the St. Clair the total potential phenol loading to the River is estimated at 25 g/d. This would result in an increase in phenol concentration in the River of 1.9 ng/L which is about 500 times less than the minimum detection limit of 1 ug/L.

> "Industrial Waste characterized by Phenol (30,000 - 40,000 ug/L) volatile organics (e.g., benzene, toluene, etc., 200 - 5,800 ug/L) and naphthalenes (50 - 829 ug/L) is restricted to a narrow 11 m interval between 185.9 and 196.6 m depth in the upper section of the Lucas dolomite. Vertical migration of this waste through the pore space of the overlying and underlying rocks has been negligible and measured hydraulic heads show fluid flow in the adjacent rocks is now to the disposal zone. This study suggests that there is a relatively active flow system within the disposal formation today and that understanding the fate of 8,000,000 m^3 of waste disposed to the Detroit River Group will require knowledge of the current rates and directions of flow within the disposal zone.
>
> "The hydraulic head within the disposal zone is now 14 to 15 m below that in the fresh water aquifer and 8 m below the level of the St. Clair River. Therefore current flow directions are from the fresh water aquifer and St. Clair River to the disposal zone.
>
> "A significant finding of this study was the occurrence of high hydraulic conductivity limestone layers in the Hamilton Group of formations at 74 and 123 m depth that likely contain industrial waste at phenol concentrations of 6000 - 10,000 ug/L and hydraulic heads above those in the fresh water aquifer. The 2 m thick limestone layer at 74 m depth is of particular concern to this study because groundwater from this horizon likely discharges to the fresh water aquifer within the bedrock valley and this horizon flowed industrial waste in 1967 and 1969 at rates of 10 to 238 L/min. The extent of contamination in this and the 123 m depth horizon is not known but is likely significant as the only two monitoring wells to these horizons (from this and an earlier study) detected industrial waste. This waste was likely introduced to these limestone horizons from improperly completed disposal, cavern or abandoned wells."

6. Spills

A recent, well-publicized spill of perchloroethylene in the Ontario waters of the St. Clair River underscored the potential for accidental loss of large quantities of materials in this river system (36). This incident prompted a major investigation on the biological effects of spills and related discharges (91). The results of the study demonstrated that the waters, sediments, and biota of the St. Clair River system were adversely affected by discharges of contaminants to the river, and that the perchloroethylene spill aggravated an existing condition.

The perchloroethylene spill was not an isolated event. Rather, it was simply another incident in a long history of accidental spills. The data presented in Table VII-17 indicate that, on the Canadian side, 11 major oil spills of 10 tons or more (a total of 1,282 tons) and 21 major spills of other hazardous compounds (a total of 10,390 tons) occurred between 1974 and 1985.

The Michigan shoreline is considerably less industrialized than the Ontario portion of the river. However, between 1973 and 1979, there were 120 spills of petroleum related compounds from land based facilities and vessels which released over 18,500 L of these materials into the St. Clair River. An additional spill released 208 L of other hazardous substances to the river during this period.

Tables VII-17a and 18 provide information on spill occurrences during 1986. In 1986, a total of 48 surface water spills to the St. Clair River were reported. There were 17 U.S. spills including 3 chemical, 4 non-PCB oil, and 10 raw sewage. Sixteen chemical, and 22 non-PCB oil spills to the Canadian waters of the St. Clair were reported. Very recently, (May 1988) a spill of acrylonitrile (maximum 12,000 kg) occurred at Polysar Sarnia, but the chemical was not detected in the St. Clair River.

Although improvements in water and sediment quality have been made in the St. Clair River system in recent years, spills from vessels and land-based facilities continue to threaten the suitability of the river for fish and wildlife populations.

7. Contaminated Sediments

The sediments along the Canadian shore are significantly contaminated with a variety of chemicals (58,59,67). But compared to chemicals in water and suspended sediments, much less than one percent of the contaminants moving along the river are transported by bed sediment movement (67). The total mass of contaminants such as HCB and OCS in Canadian shoreline sediments in the river is comparable to the annual loadings of these contaminants (37,59). Unless a significant percent of this material is being desorbed each year, it is unlikely that contaminated sediments contribute significantly to the loading in the water column. However, because no measurements have been made, it is not possible to come to a definite conclusion at this time.

Another way sediments can act as source of contaminants is through the biological community. Benthic organisms have been shown to accumulate contaminants from sediments in the river (50). These organisms serve as a food source for higher trophic levels such as fish. Thus contaminated sediments can act as a source of higher body burdens of chemicals in biota in the system. Sediments from the Sarnia industrial area are lethal to Hexagenia, Hydallela, and fathead minnows.

TABLE VII-17

Spills of hazardous materials in excess of 10 tons into the Ontario waters of the St. Clair River and its tributaries, 1974 - 1985[a].

Source	Substance Spilled	Year	Amount (Tons)	
			Spilled	Unrecovered[b]
Suncor	Bunker & oil	1976	150	30
Suncor	Bunker & oil	1976	300	0
CNR	Bunker & oil	1977	86	17
Esso Petroleum	Gas Oil	1978	29	0
Hall Corp. (Vessel)	Bunker & Oil	1980	21	13
CNR	Bunker & Oil	1981	21	4
Esso Petroleum	Gasoline	1981	348	0
Esso Petroleum	No. 2 fuel Oil	1984	116	23
Esso Petroleum	No. 2 fuel Oil	1984	16	3
Imp. Bedford (Shell)	Catalytic cracker	1985	75	1
Esso Chemical	Slop Oil	1985	120	0
Total			1,282	91
Polysar	Latex	1975	17	17
Polysar	Latex	1976	18	18
Polysar	Latex	1980	87	87
Polysar	Latex	1980	20	20
Total			142	142
Dow	Styrene	1974	4,504	2,700
Polysar	Styrene	1978	411	80
Total			4,915	2,780
Dow	Hydrochloric Acid	1974	21	21
Dow	Sodium hydroxide	1975	28	28
Dow	Sodium chlorate	1979	4,080	4,000
Dow	Sodium chloride	1981	379	76
Polysar	Sulphuric acid	1981	13	13
Suncor	Hydrochloric acid	1982	16	0
Esso Chemical	Sodium hydroxide	1983	19	4
Esso Petroleum	Brine	1984	164	33
Total			4,720	4,175
Polysar	Lignin liquor	1975	159	33
Esso Petroleum	Phenolic wastewater	1975	239	239
Suncor	Process water	1975	91	73
Eagle Transport	Xylene	1975	11	2
Dow	Ethylene Glycol	1976	13	0
Esso Petroleum	Waste Water	1982	46	46
Dow	Perchloroethylene	1985	54	4
Total			613	397

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a - Data from (36).

b - Estimate based upon reports of percent recovered.

TABLE VII-17a

Spills from Canadian sources to the St. Clair River (1986).

(chemicals)

DATE	SOURCE	CHEMICAL	VOLUME	RECEIVING WATER	LOCATION	RESOLUTION	RECOVERED AMOUNT
86/03/28	Dow Chemical	Polyethyene Powder	-	St. Clair River	Sarnia	-	-
86/03/29	CIL	30% Phosphoric Powder	150 kg phosphorus	St. Clair River	Courtright	-	-
86/05/11	Suncor Refinery	Toluene	204L	St. Clair River	Sarnia	-	-
86/06/12	Dow Chemical	Styrene Benzene	2 kg each	St. Clair River	Sarnia	-	Storm overflow
86/06/12	Dow Chemical	35% Ethylene Glycol	2273 L	St. Clair River	Sarnia	-	-
86/07/12	Dow Chemical	Unknown	-	St. Clair River	Sarnia	Samples taken	-
86/07/25	Imperial Oil Refinery Fueling Dock	Diesel Fuel	3500 L	St. Clair River	Sarnia	Booms deployed	Tug fueling leak
86/07/30	Dow Chemical	Ethyl Benzene Styrene	181 L	St. Clair River	Sarnia	Plume modelling	-
86/07/31	Imperial Oil Refinery Fueling Dock	Diesel Fuel	204 L	St. Clair River	Sarnia	-	100%
86/08/07	Polysar	Tertiary Butyl Alcohol	272 L	St. Clair River	Sarnia	-	-
86/08/12	Fiberglas Canada	Phenolic Resin	227 L	Cole Drain	Sarnia	-	-
86/08/12	Dow Chemical	Benzene	25 kg	St. Clair River	Sarnia	Plume modelling	-
86/08/13	Polysar	Halo-Butyl Rubber	900-1360 L	St. Clair River	Sarnia	Booms deployed	-
86/11/24	Fiberglas Canada	Phenol Dyes Formaldehyde	90 L	St. Clair River	Sarnia	-	-
86/11/29	Polysar	Calcium & Zinc Stearates	5-10 kg	St. Clair River	Sarnia	Booms deployed	100%
86/12/18	Polysar	Stearic Acid	20 L	St. Clair River	Sarnia	-	-

TABLE VII-17a. (cont'd)

(non-PCB oils[1])

Date	Source	Volume	Receiving Water	Location	Resolution	Recovered Amount	Comments
86/04/10	Shell Refinery	4.54 L	Talfourd Creek	Corunna	Booms deployed	-	-
86/04/18	Suncor Refinery	45.4 L	St. Clair River	Sarnia	Booms deployed	36.3	9 litres lost to River
86/05/07	Shell Refinery	9.08 L	St. Clair River	Sarnia	Booms deployed	9.08	All materials recovered
86/05/16	Imperial Oil Refinery	9.08 L	St. Clair River	Sarnia	-	-	Oil not recoverable
86/05/18	Polysar	13.62 L	St. Clair River	Sarnia	-	-	-
86/06/05	Ontario Hydro	10 L	St. Clair River	Courtright	-	-	-
86/06/11	Shell Refinery	13.5 L	Talfourd Creek	Corunna	Booms deployed	-	Overflow due to heavy rain
86/06/11	Shell Refinery	1818 L oily water	Talfourd Creek	Corunna	Booms deployed	-	Overflow due to heavy rain
86/07/02	Imperial Oil Refinery	-	St. Clair River	Sarnia	Booms deployed	-	-
86/07/07	Imperial Oil Refinery	-	St. Clair River	Sarnia	Booms deployed	-	-
86/07/12	Imperial Oil Refinery	4.5 L	St. Clair River	Sarnia	Booms deployed	-	De-oiler heat exchanger leak
86/07/12	Polysar	4773 L	St. Clair River	Sarnia	Booms deployed	-	Overflow due to heavy rain
86/07/12	Shell Refinery	4096 L	Talfourd Creek	Corunna	Booms deployed	-	Overflow due to heavy rain
86/07/20	Polysar	4091 L	St. Clair River	Sarnia	-	-	Biox bypass due to heavy rain
86/08/02	Shell Refinery	9 L	Talfourd Creek	Corunna	Booms deployed	-	Overflow due to heavy rain
86/08/07	Shell Refinery	36 L	Talfourd Creek	Corunna	Booms deployed	-	Stormwater runoff
86/08/08	Shell Refinery	2.2 L	Talfourd Creek	Corunna	Booms deployed	-	Stormwater runoff
86/08/29	Polysar	9,000 L	St. Clair River	Sarnia	-	-	Pumps failed
86/08/05	Polysar	25,000 L	St. Clair River	Sarnia	-	-	Power failure
86/09/22	Polysar	4,000 L	St. Clair River	Sarnia	Booms deployed	-	Overflow due to heavy rain
86/10/03	Polysar	45-90 L	St. Clair River	Sarnia	Booms deployed	-	-
86/10/26	Imperial Oil Refinery	22 L	St. Clair River	Sarnia	Clean up initiated	- -	- -

[1] There were no reported spills of PCB contaminated oils.
[2] In addition there were 3 reports of oil sheens on the river.

TABLE VII-18

U.S. raw sewage spills (1986).

PEAS	Date	Source	Volume	Receiving Water	Location	Resolution	Recovered Amount	Comments
2922-86	8/15/86	City of Port Huron WWTP	24 hrs. at 6000 gal per hr	St. Clair River via Black River	St. Clair Co. Port Huron	---	none	
2931-86	8/16/86	City of Port Huron WWTP	24 hrs. at 200 gal per min.	St. Clair River via Black River	St. Clair Co. Port Huron	---	---	
D-001-86	9/23/86	Marine City WWTP	1900 gpm for ~ 24 hr	St. Clair River	St Clair Co. Marine City	Spill controlled and cleaned up.	80 gals	
2992-86	08/15/86	City of Port Huron WWTP	24 hr at 6000 gal per hr	St. Clair River via Black River	St. Clair Co. Port Huron	---	none	Stormwater caused partial bypass.
2931-86	08/16/86	City of Port Huron WWTP	24 hr at 200 gal per min.	St. Clair River via Black River	St. Clair Co. Port Huron	Station got flooded.	none	Stormwater caused partial bypass.
D-001-86	09/23/26	Marine City WWTP	1900 gpm ~24 hr	St. Clair River	St. Clair Co. Marine City	---	none	Stormwater caused partial bypass.
06-86	01/02/86	Mueller Brass	30-50 gal	St. Clair River via Black River	St. Clair Co. Port Huron	Pauls Road Oiling contacted for clean-up.	~20 gals	Clean up supervised by USCG.
2803-86	08/08/86	Mueller Brass	10-15 gal	St. Clair River via Black River	St. Clair Co. Port Huron	Pauls Road Oiling contacted for clean-up.	~5 gals	Company instituted in-plant controls to reduce # of spills.
1539-86	05/24/86	Detroit Edison	1 gal	St. Clair River	St. Clair Co St. Clair	Boom in place. (Barrel tipped over)	none	-
0166-86	11/19/86	Detroit Edison	120 gal	St. Clair River	St. Clair Co. St. Clair	Partially contained. USCG notified.	80 gals	-
	TOTAL		186 gal (704.91)				105 gals (398.1)	

8. Navigation

As stated earlier, ship traffic through the St. Clair River is considerable. These ship movements cause some minor sediment resuspension but should have little impact on the movement and effects of contaminants in the river. Periodic dredging is required in the lower channels of the river for navigation purposes. The material dredged from the Canadian channels is placed in a confined disposal facility (the Southeast Bend Cutoff Site, Seaway Island), because it exceeds open water disposal guidelines for oil and grease, and mercury. Periodic U.S. shoal removal in the upper reaches of the river of a few hundred m^3 of sediment are disposed in Lake Huron. A few hundred thousand m^3 of sediments are removed by the U.S. in the lower reaches of the river approximately every three years. These materials are placed in the Dickinson Island Confined Disposal Facility.

D. DATA REQUIREMENTS AND ASSESSMENTS

In answering the source/sink question for the St. Clair River, data sets from single laboratories were used. Thus, even if the analyses were biased high or low, the relative changes in concentrations would still be apparent. Some of the bottom sediment data for several parameters were combined and averaged. The laboratories that generated these data performed acceptably in the round-robins conducted by the Data Quality Management Workgroup (Chapter IV), and comparable data for the different studies were found for overlapping sampling stations.

For the point source study, the United States methods provided much lower detection limits (DL) for three organics than did the Canadian methods. For most chemicals, this did not impact the study because of the lower concentrations found in the U.S. sources for most organic parameters. However, for PCBs (U.S. DL 0.0001 ug/L; Canadian DL 0.1 ug/L), the difference in detection limits could affect the ranking of the PCB sources along the river. Fortunately, PCB discharges to the St. Clair River appear to be fairly low, so remedial measures for PCBs may not be required.

While sensitivity analyses were applied to most of the models used to simulate conditions in the St. Clair River, the quality of the initial data utilized in most modeling exercises is difficult to judge. Furthermore, Monte Carlo simulations and other uncertainty analyses are almost entirely lacking for the process models developed to date. These shortcomings render existing modeling tools less than fully useful for management authorities. Additional resources will undoubtedly be a priority to overcome these deficits.

E. MODELING AND MASS BALANCE CONSIDERATIONS

1. Dispersion Models

The St. Clair River, like the other connecting channels of the Great Lakes is the recipient of large volumes of effluents. Under normal circumstances, the apparent impact of these additions would be less noticeable because of the large volume of water conducted through this channel. However, because of the necessity to maintain broad channels for navigation, shore based discharge structures must be maintained relatively close to shoreward margins of the river. This fact dictates that only a relatively small portion of the total river flow is available for waste dispersal.

In an early study of lateral dispersion, Hamdy and Kinkead (92) adapted an existing numerical dispersion model to predict in-stream concentration of a conservative substance (chloride) from shore based discharge outfalls to the St. Clair River. These authors found that the nondimensional dispersion coefficient measured in the field was in a range of 0.93 - 1.0, based upon a shear velocity of 0.042 m/s and a depth of 10 m. This coefficient observed in the St. Clair River was substantially greater than the classic value of 0.23 normally used in dispersion predictions.

A simultaneous parallel study conducted by Akhtar and Mathur (93) used equations identical to Hamdy and Kinkead, but incorporated the classic 0.23 value for the nondimensional dispersion coefficient. When Akhtar and Mathur reran their model using the Hamdy and Kinkead value of 0.96, the transverse chloride distribution predicted by the model agreed reasonably well with observed values. The reported data suggest that the bulk of chlorides were contained close to the Canadian shoreline. Shoreward concentrations of 80 mg/L were observed, while concentrations declined to levels approaching zero 50 m off shore. Validation of the model was made against 1976 chloride data for the St. Clair River at the same sites. In this case, shoreward concentrations of nearly 100 mg/L were shown to decrease laterally to concentrations approaching zero 45 m off shore. The 1976 verifications were made against a point source loading for Cl^- of 2.6 kg/s, a function of a discharge rate of 3 m^3/s and an initial concentration of 860 mg/L.

In a report to the Water Resources Branch of the Ontario Ministry of the Environment, McCorquodale and Bewtra (94) provide a users manual for a model designed to assess the convection-dispersion and decay of vertically mixed pollutants from multiple outfalls. The authors state that this model was developed using OMOE field data on chlorides and phenols in the St. Clair River. While the model was intended to simulate phenol concentrations along the entire length of main channel of the St. Clair River, neither data nor model simulations are provided. No evidence of calibration, verification, or application of this model is available.

In the same short report to OMOE, McCorquodale and Bewtra (95) consider the dispersion and transport of phenols in the St. Clair River. These authors describe adapting a previously existing model (characterized only as "The Detroit River Model") to conditions existing in the St. Clair River.

Although this modified far-field model was used to simulate phenol concentrations in the St. Clair River from outfall A to the Delta, only estimations of pollutant loadings in the channels of the St. Clair River delta are provided. The authors report that 5 percent of the total flow and 14 percent of the total phenol load exit the St. Clair River by way of Chenal Ecarte. This loading approximates 4 kg/d of phenol. The South Channel is responsible for conducting 42 percent of the total flow and 81 percent of the total phenolic load (23 kg/d, phenol) from the St. Clair River. A total of 20 percent of the river flow, but less than 5 percent of the total phenolic load exists the St. Clair River via the Middle Channel. This burden represents only about 1.4 kg/d of phenol. While the North Channel is responsible for conducting 33 percent of the total river flow, only a trace of the total phenol loading is found in this channel. The authors note that these values represent loadings without consideration for decay. If degradation rates were added, the phenol loadings to the channels could be reduced by as much as 30 percent.

Chan _et al_. (37) modeled the fluxes and the concentration distribution profiles in water column transects across the upper and lower St. Clair River for the contaminants hexachlorobenzene (HCB), hexachlorobutadiene (HCBD), pentachlorobenzene (QCB), and octachlorostyrene (OCS). The data they derived clearly demonstrated a plume of these contaminants for the Sarnia Industrial Area. Dieldrin concentrations, on the other hand, were quite consistent for all stations sampled, fluctuating about a mean of approximately 0.25 ng/L. The ubiquitous distribution of this contaminant suggests long-range transport as the likely mechanism involved in this widespread contamination. The authors report that similar concentration distributions to dieldrin were observed for several other organic substances including alpha and gamma BHC and PCBs.

A marked plume of contaminants was apparent, originating for the Sarnia area. This plume was observed for HCB, HCBD, QCB, and OCS. Very little of these compounds are present at the head waters of the St. Clair River. At Port Lambton, however, peak values were observed near the Canadian shoreline, with decreasing concentrations across the river. This observation corroborates the lateral distribution calculated for chloride by Hamdy and Kinkead (92). Chan _et al_. (37) report that downstream, however, Chenal Ecarte contained the highest concentrations, the South

Channel was described as having significant levels, and very low concentrations were observed in the North Channel. Unfortunately, no flow data are provided to enable an exact comparison of channel burdens with the various values provided by McCorquodale and Bewtra (95). However, if the normal flow value of 5,100 m^3/s for the St. Clair River provided by McCorquodale et al. (86) is used, and if the percent of total flow reported by McCorquodale and Bewtra (95) for Chenal Ecarte (5 percent of total), South Channel (42% of total), and the North Channel (33 percent of total) are accepted, a comparison of values may be made. This comparison is presented in Table VII-19 below.

An order of magnitude agreement between the percentage contributions of the contaminants in the two data sets exists when the differences in methodologies are considered. Chan et al. (37) measured HCB in centrifuged water samples at the Port Lambton stations. These samples represented `dissolved phase' HCB, since the majority of suspended solids had been removed. The authors note that 41 percent of the HCB observed at Port Lambton was in the dissolved phase. When the percentage contributions to total HCB loadings are adjusted for suspended solids concentrations, the sum of the channel values approach 100 percent of the total HCB loading rate of 1.63 kg/d reported by Nettleton (96).

Chan et al. (37) also used the observed contaminant concentrations and water depths to calculate the flux of each compound across the river cross section at Port Lambton. Good agreement of values was obtained when compared with Environment Canada and Ontario Ministry of the Environment district monitoring data. Between August and October of 1985, HCB fluxes ranged from 59 to 280 gm/day, QCB was observed from 22 to 31 gm/day, HCBD 240 to 1,700 gm/day, and OCS 5 to 15 gm/day.

These authors then calculated lateral mixing in the river channel using a transverse mixing coefficient derived by varying the coefficient until the calculated concentration profile matched the measured profile. The original calculation of this factor was made against the HCB data and applied to other measured parameters. With the exception of a single HCBD data set for 23 September 1985, excellent agreement with measured concentration profiles was achieved. This single data set demonstrated no plume-like distribution, but rather a relatively constant concentration across the river cross section. All other calculations demonstrated a plume which tended to remain near the Canadian shore of the St. Clair River.

These authors also note that future studies should consider special sampling procedures for modeling studies. They report that the results of the water/suspended sediment partitioning study showed that measurements should be made on both dissolved and suspended sediment phases, or on unfiltered water samples if contaminant fluxes or loadings are to be calculated.

TABLE VII-19

A comparison of burdens of chemical contaminants in the various channels of the St. Clair River Delta (kg/d).

Distributary Channel	Phenol Burden[a]	% of Total Phenol Load	HCB Burden[b]	% of Total HCB Load[c]
Chenal Ecarte	4.0	14	0.286	17
South Channel	23.0	81	0.740	45
Middle Channel	1.4	<5	--	--
North Channel	Trace	Trace	0.073	4

[a] - Data from (86).

[b] - Data from (37).

[c] - A total of ± 45% of HCB loadings are unaccounted for, since Chan *et al.* (37) used centrifuged water to measure HCB at the Port Lambton stations. They note that 41% of the HCB observed at Port Lambton was in the 'dissolved phase'.

2. Hydrodynamic Model

A river transport model has been constructed by McCorquodale *et al*. (86) which has potential for application to the St. Clair River. This model has been variously referred to as the University of Windsor K-E model and the University of Windsor K-E River Mixing Model (96). This model is a steady state, depth average, turbulent mixing model designed to simulate complex river systems with multiple outfalls. Nettleton (96) reports that velocity distributions and dispersion characteristics of the St. Clair River were computed with this model. The model divides the St. Clair River into 14 segments, estimating the flow in each segment using U.S. Army Corps of Engineers data adjusted to interpolated sections in each segment based upon a normal flow rate of 5,100 m^3/s (187,000 cfs).

Nettleton reports that the model was calibrated by adjusting parameters for the lateral profile of the velocity to provide predicted results similar to those measured. This author writes that in addition to velocities and dispersion coefficients, this model also provides the lateral locations of river streamlines in the various river segments. Nettleton concludes that, based upon the results of this and other OMOE applications of the hydrodynamic model, it would appear that the model is well suited for use in the St. Clair River. At the present time, however, there is no report of verification of this model.

3. Chemical Transport Models

Nettleton (96) reports that, to date, chemical transport modeling for the St. Clair River has been accomplished only for the contaminant hexachlorobenzene (HCB). Two models were used to study the chemical transport of HCB. One of these models, the University of Windsor Hydrodynamic Model discussed above, calculates the depth averaged total contaminant concentrations in two dimensions in the water column. The U.S.EPA TOXIWASP model (97), estimates the dissolved, sediment sorbed, and biosorbed concentrations of the contaminant in both the water column and the sediment bed of the river.

The University of Windsor transport model was run with both average and maximum loadings using both average and minimum flow rates. The best agreement with measured field data was achieved using average flows and maximum loadings of HCB. Nettleton (96) reports that, under these conditions, the total loading rate of HCB to the St. Clair River System was 1.63 kg/d. He notes that in excess of 97 percent of this total loading results from a single point source, the Dow Chemical First Street sewer complex.

Comparisons of the river model predictions of HCB concentrations with measured values were reported to be in good agreement (86).

The magnitudes of predicted concentrations were generally within the probable error of field data measurement (96).

The TOXIWASP model is a multiple cell model which divides the water column and bed into segments both vertically and horizontally. The principal mass transfer mechanisms considered by this model include contaminant advection and dispersion, sediment settlement and resuspension, volatilization and biological degradation of the contaminant, and point and nonpoint sources of contaminant to the water column, including sediment bound materials.

In relation to the St. Clair River, this model was run using only one layer of water column and bed sediments. The river was divided horizontally into four flow panels. Both "fine" and "coarse" grid patterns were used. The "coarse" grid considered the entire river to the Delta area, while the "fine" grid was used to concentrate on the analysis of the river in the vicinity of the outfalls.

Nettleton (96) reports that comparisons between water column concentrations of HCB predicted by TOXIWASP with those measured in the field were satisfactory. He notes that both the trends and the magnitudes of the predicted values are in good agreement with the measured field data. Bed sediment predictions occasionally tended to over-predict both magnitudes and trends when compared with field data. However, both magnitude and trend predictions appear to be within the estimated field measurement accuracy.

Nettleton concludes that it would appear that both the University of Windsor transport model and the TOXIWASP model can predict the chemical transport of HCB relatively accurately within the St. Clair River. He notes, however, that these results must be regarded as preliminary. Confirmatory results (and presumably model verification) await the final assembly of the 1986 St. Clair River Municipal Industrial Strategy for Abatement data base.

4. Unsteady Flow Model

An unsteady flow model for the St. Clair River from Lake Huron to Lake St. Clair was developed by Derecki _et al_. (98). This model simulates hourly and daily flow rates of the river. Unlike other single-stem river models, the unsteady flow model provides flow separations in the vicinity of Stag and Fawn Islands and in the North, Middle, South, and Cutoff Channels of the St. Clair River Delta. The model predicts stage, discharge, and velocity data required to simulate the fate and transport of toxic substances.

Derecki *et al*. (98) suggest that the model has been calibrated. This calibration consisted of adjusting the roughness coefficients of the river channel. These coefficients were derived from 14 sets of flow measurements conducted by the U.S. Army Corps of Engineers between 1959-1979. No evidence of validation of this model is available.

5. Other Models

In a departure from the usual academic modeling format, Nettleton and Hamdy (91) have created a user-oriented model for assessment of effects of spilled contaminants. The modeling format is termed `The St. Clair River Spill Manual'. This device was developed to provide a convenient, easily used, rapid assessment methodology for predicting the downstream effects of spilled contaminants on water intakes. A total of 21 outfalls located in the Chemical Valley near Sarnia are considered in this manual. Using this well-designed instrument, assessments of impact are possible all along the Canadian shoreline and at five Michigan intake sites, including St. Clair, East China Township, Marine City, Algonac, and Old Club. The Marysville intake was found to lie outside of all the plumes observed, and is, therefore, not considered in the manual.

Users desiring to assess impacts of a spill need only know the type and total mass of contaminant spilled, the duration of the event, and the total river flow at the time of the spill. If decay characteristics are known, there is a possibility to incorporate this information into the analysis.

With these data available, the manual is then consulted to ascertain the peak contaminant concentration expected, and times of arrival and departure of the spill plume at a given water intake. This adaptation and coupling of two mathematical models in a specific user-oriented fashion will undoubtedly be extremely useful to managers charged with the responsibility of providing of safe drinking water.

6. Model Applications

A major application of these hydrodynamical dispersion models and fate and transport models, after calibration, is for the analysis of hypothetical effluent discharge scenarios proposed in remedial studies. This analysis can be approached in two ways: i) effluent loadings may be established based upon treatment technology, and the models used to ascertain the resulting short and long-term changes expected in the quality of the downstream water/sediment/biota of the receiver; or ii) the models can be used to estimate appropriate effluent criteria assuming known ambient water quality criteria downstream of the outfall.

As an example, effluent loading criteria for HCB discharged to the St. Clair River from Dow Chemical can be determined (Table VII-20). There are two important reasons to develop effluent criteria for HCB: i) it has been shown to impact exposed sediment and biota within the effluent plume due to its chemical characteristics (e.g., large K_{OW}); and ii) when reduced via the appropriate industrial treatment, other related contaminants should also be reduced from the effluent.

For this example, three criteria are used in the analysis for HCB. The first is the 6.5 ng/L freshwater aquatic life guideline for concentrations in the water column. The second criterion is that HCB concentrations in the sediment are not to increase by more than 1 ng/L above the background level. The third criterion is that HCB concentrations in biota, as a result of bioconcentration, is not to increase more than 50 ug/L above the background level. The second and third criteria are arbitrarily selected (for demonstration purposes) for protection of the sediment and biota under long-term steady state conditions.

The calculations (as summarized in Table VII-20) are performed for two selected mixing zone lengths. The first mixing zone is to the south property line of Dow Chemical (about 1,200 m downstream of Dow's First Street sewer complex). In this case, the total HCB load is assumed proportional among the various outfalls as measured in 1986. The second mixing zone is two Dow's Second Street outfall (about 300 m downstream of the First Street complex). In this case, all loading is assumed to be discharged via Dow's First Street complex.

In this particular example, the arbitrary biota criterion for the shorter mixing zone would result in the most stringent effluent loading.

TABLE VII-20

Loads required to limit zones of effect for HCB discharged from Dow Chemical.

Criterion No.	Loads (kg/d) to limit the zone of effect to:	
	Dow's south property line (1,200 m)[1]	Second Street outfall (300 m)[2]
1. **Water (6.5 ng/L)**	0.106	0.065
2. Sediments (1 ppm above background)	0.517	0.317
3. Biota (50 ug/L above background)	0.041	0.025

Notes:

1. Assumes load is proportioned - 83, 2, 5, 10% to Dow's 1st, 2nd, 3rd and 4th street outfalls, respectively.

2. Assumes load is entirely from Dow's 1st Street outfalls.

F. OBJECTIVES AND GOALS FOR REMEDIAL PROGRAMS

1. Water Quality, Sediment, and Biota Standards, Guidelines and Objectives

Setting goals and objectives based on water quality, sediment, and biota guidelines is difficult because guidelines do not exist for many of the contaminants found in the St. Clair River. The guidelines and objectives that do exist are chemical specific and do not take into consideration the cumulative toxicity of exposure to multiple contaminants. However, comparing media concentrations to relevant guidelines or objectives which exist allows the identification of areas and ecosystems likely to be impacted by contaminants.

One of the goals of the UGLCC Study is to protect and maintain the channels for the highest attainable use. If this goal is achieved near industrial and municipal point sources of contaminants, then impacts to the river and downstream water bodies should be greatly reduced. During the study, water samples collected near point sources exceeded many of the Ontario Provincial Water Quality Objectives (see Tables VII-2 & 3) for the protection of freshwater aquatic life. Objectives are available for several chemicals of concern in the St. Clair River. However, for some chemicals found to be impacting the river, such as octachlorostyrene and hexachloroethane, there are currently no surface water objectives.

Objective 1. **Develop water quality guidelines or objectives for OCS, hexachloroethane and other chemicals not currently possessing water quality objectives.**

Objective 2. **Reduce surface water concentrations of organic and inorganic contaminants found to be impacting the St. Clair River surface water quality to concentrations below the most restrictive water quality guidelines with virtual elimination as a goal.**

Several sets of sediment criteria are available with which to compare sediment contaminant concentrations in the St. Clair River. These include the Ontario Ministry of the Environment Guidelines for Dredge Spoils for Open Water Disposal, the GLWQA Guidelines for Open Water Disposal of Dredged Materials, and the U.S.EPA Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments. Even though present sediment guidelines are generally inadequate, a comparison with contaminant concentrations in St. Clair River sediments indicates that there are several locations with which to be concerned. Many of these locations are along Sarnia's industrial waterfront, although there are impacted areas along other reaches of the river, as well. Guideline exceedences occur for oil and grease, lead, and mercury (Table VII-5). Sediment guidelines do not exist for many contaminants found in the sediments of the St. Clair River, including hexachlorobenzene, pentachlorobenzene and octachlorostyrene.

Objective 3. **Delineate more accurately, the extent of contaminated sediments in the St. Clair River, especially along Sarnia's industrial waterfront. Sediment contaminant concentrations should also be determined for the major St. Clair River tributaries; Talfourd Creek, the Black River, the Cole Drain.**

Objective 4. Develop sediment guidelines for organic chemicals of concern in St. Clair River sediments for those not currently having guidelines (e.g. HCB and OCS).

Objective 5. **Reduce the discharge (concentration and loading) of chemicals which are impacting St. Clair River sediments from known point sources to the lowest level achievable through the use of best available technology with virtual elimination as a goal.**

Fish consumption guidelines are available for only a few St. Clair River contaminants. The only exceedences occur for mercury and PCBs in the larger fish of some species (such as carp). There are no fish consumption guidelines for most of the chemicals of concern in the river.

Objective 6. **Reduce inputs (with a goal of virtual elimination) of mercury, PCBs and other chemicals to the St. Clair River which are resulting in concentrations of contaminants in fish exceeding guidelines.**

Objective 7. **Develop fish consumption guidelines for chemicals found in St. Clair River biota which do not currently have objectives, such as OCS and HCB, and reduce, to the extent practicable, inputs of these contaminants to the St. Clair River.**

It is necessary for regulations to move away from requirements and objectives based solely on concentrations towards those which include targets for reducing the total mass loading of pollutants entering the system. Basing effluent limitations on concentrations alone does not account for the long term effect of persistent contaminants which remain in sediments and biota. The discharge of persistent toxic substances should be reduced to as close to zero as possible (99), in keeping with the goals of the Great Lakes Water Quality Agreement. The only practical way of reducing/eliminating release of toxic substances to the environment is at the source of the release.

Several point sources which were identified as providing significant loadings of chemicals to the St. Clair River discharged in compliance with their concentration based discharge limitations. However, the magnitude of their effluent flow was such that significant loads were still provided to the St. Clair River. In other instances, significant discharges of chemicals originated from point sources that were not regulated with respect to that chemical (e.g. HCB, OCS and mercury from Dow Chemical and HCB and PAH from Polysar Sarnia).

Objective 8. **Develop mass loading limitations for the point source discharges of contaminants found to be of concern in the St. Clair River.**

Several municipal waste water treatment facilities, both in Canada and the United States, periodically exceeded discharge requirements for certain parameters during the study (e.g., Sarnia WWTP, Port Edward WWTP and St. Clair WWTP). Most municipal facilities are only required to control conventional parameters, such as total suspended solids, phosphorus and BOD5. Better control of operating conditions at these facilities and some upgrading may be required to ensure that they are discharging in compliance.

In some instances, municipal facilities were found to be significant contributors of unconventional and toxic substances which are not regulated, such as, phenols, PAHs, cyanide, zinc and iron, among others (e.g. Port Huron WWTP and Sarnia WWTP). Identification of the sources of these contaminants to the municipal facilities needs to be performed and programs to reduce such inputs developed if further control is required.

Objective 9. **Upgrade the technology and operating procedures at municipal waste water treatment facilities found to be exceeding discharge limits to ensure compliance with all effluent requirements.**

Objective 10. **Develop additional effluent requirements, in both mass loading and concentration form, at waste water treatment facilities identified as providing significant inputs of nonregulated contaminants impacting the St. Clair River.**

Objective 11. **Identify the sources of unconventional and toxic substances entering the municipal facilities (i.e. industrial contributors) and reduce such inputs.**

Urban nonpoint sources in Canada, such as stormwater and combined sewer overflows, increase the river contaminant burden for several parameters including oil and grease, PAHs, lead and iron. A thorough evaluation of this pollution source on the United States side of the river was not carried out for the UGLCC Study, but is needed.

Objective 12. **Upgrade or redesign municipal facilities operating CSOs, such as the Port Huron and the Sarnia WWTPs, to ensure that CSOs do not occur.**

Objective 13. **Identify the original sources of contaminants contained in urban runoff (e.g. atmospheric sources and spills) and take regulatory and management steps to reduce or eliminate contaminant input.**

Rural and urban industrial nonpoint sources have been poorly characterized for the St. Clair River. Contaminant loadings determined for the Black River and the Cole Drain showed these tributaries to be significant contributors of many contaminants including phosphorus, nitrogen, nickel, copper, zinc and cadmium (Black River) and PAHs, cyanide, and oil and grease (Cole Drain).

Although no contaminant loadings were determined for Talfourd Creek, the presence of herbicides and pesticides commonly used in agriculture and high concentrations of some metals supports the supposition that Talfourd Creek may be a significant contributor of contaminants.

Objective 14. **Develop programs within the agricultural community to reduce excessive use of phosphorus and pesticides. Develop new programs and support existing ones which provide instruction on the use of conservation tillage techniques and livestock waste management.**

Several waste disposal sites have been ranked as having a high potential to pollute the river. Several other waste disposal sites appear to need additional information to assess their present and future hazard. Improved contaminant and leachate control and treatment systems may be required for some sites, others may require more intensive remediation. Sludges from municipal and industrial wastewater treatment plants are either incinerated or placed in approved land disposal facilities. The transport of contaminants in surface runoff or groundwater leachate plumes from the disposal facilities has not been fully assessed.

The ultimate fate of injected wastes disposed in the past by pressurized injection in Ontario and by continuing pressurized injection in Michigan is unknown.

Objective 15. **Determine the actual state of containment of the waste sites having a potential to contaminate the St. Clair River and its tributaries and monitor groundwater and surface water discharges. For those sites providing contaminant inputs to the St. Clair River, remedial and enforcement actions should be undertaken.**

Objective 16. **Further delineate the impacts, location and migration trends of past and present liquid waste injection into disposal wells, particularly the role of the buried valley in transporting wastes to the St. Clair River.**

Chemical and oil spills into the river are a continuing problem which require increased diligence. The feasibility of constructing spill containment facilities at several of the major industries which frequently experience spills should be analyzed on a case by case basis. Improved spill prevention plans and worker training as well as better monitoring devices are other methods of reducing spills at industrial sites.

Objective 17. **Eliminate chemical and oil spills to the St. Clair River. Management plans and prevention structures of industries regularly experiencing spill events should be studied and modified, if necessary.**

2. Habitat Goals

At present, portions of the river support a naturally diverse assemblage of aquatic organisms generally indicative of an unimpaired habitat, while in other portions of the river contaminant discharges have extirpated or reduced the abundance of pollution intolerant benthic invertebrates that typically have key trophic roles and contribute substantially to the maintenance of fish populations. Contaminant controls are required to make the entire river habitable.

Observable negative impact on benthic communities is apparent for about 12 km downstream of Sarnia's industrial waterfront. Because most sediments in the river are transient, reduced contaminant discharges should lead to fairly rapid restoration of the habitat. To restore sediments along the 4-5 km industrial waterfront, from the Cole Drain to Suncor, may require dredging or suction removal. Some of the sediments in this area are aggregated with a black tarry substance and show little tendency to move down the river. There are several other smaller localized impact zones along the river (described earlier) which will require the same type of discharge control strategies for clean-up.

Objective 18. **Maintain the existing high quality wildlife habitats throughout the river and delta area.**

Objective 19. **Restore a healthy biotic community in the 12 km reach of the St. Clair River along the Sarnia industrial waterfront.**

3. Uses to be Maintained and Restored

At present, the river is inhabited by a variety of aquatic organisms. Because of contaminant discharges to the river, selected regions are inhabited by few, if any, species, or species that have a high pollution tolerance. Pollution control improvements will make the entire river a suitable habitat for diverse aquatic species.

The river is also used extensively for sports fishing. Fish from the river contain a variety of contaminants for which fish consumption guidelines have not been developed. The fish obtain their chemical body burden from direct uptake from water and through consumption of contaminated lower food chain organisms. Reduction of discharges to the river would result in a lowering of contaminant residues in fish and minimize any potential adverse impact to fish consumers. These improvements would undoubtedly lead to more recreational use of the river and downstream lakes for fishing and other tourism activities.

The river is used by several communities as a drinking water source. Not all contaminants found in the St. Clair River have drinking water guidelines. Although drinking water requirements are more extensive than water quality guidelines, development of such requirements is needed. The control of chemical discharges to the river would reduce any potential health effects to drinking water consumers.

Objective 20. **Ensure that the quality of fish, waterfowl, other wildlife and drinking water is suitable for human consumption by addressing the sources of contaminants.**

Bacteria concentrations increase along the course of the St. Clair River from head to mouth. Areas along the river which are used for swimming have been posted, at times, due to bacterial contamination.

Objective 21. **Reduce the bacterial contamination of the river to concentrations below public health guidelines for body contact.**

G. ADEQUACY OF EXISTING PROGRAMS AND REMEDIAL OPTIONS

1. Projection of Ecosystem Quality Based on Present Control Programs

Trend Analysis

The pollution situation in the St. Clair River has improved steadily over the years. Benthic surveys conducted along the Canadian shoreline in 1968, 1977, and 1985 showed the seriously degraded zone had decreased from over 44 km in 1968, to 21 km in 1977, to 12 km in 1985 (49). Yearly sportfish analysis by the Ontario Ministry of the Environment in the St. Clair System has shown that PCB and mercury concentrations in fish have steadily declined since the 1970s (36). Restrictions in use to closed systems, then finally banning PCBs, are the reason for the PCB declines. Mercury discharges to the river have declined dramatically since Dow Chemical (the major source) changed its chlorine production process from mercury electrodes to the diaphragm process.

Phenol violation zones (water concentrations above 1 ug/L) along the Canadian shoreline near Sarnia's industrial waterfront and downstream have decreased significantly in size since 1979 because of improved wastewater treatment (78). Also, the discharge of hexachlorobenzene and octachlorostyrene have been moderated by the addition of a carbon treatment system at Dow's Scott Road Landfill and by dredging of the Cole Drain (78).

Because of the transitory nature of bottom sediments in the St. Clair River, the use of sediment cores to infer historical contaminant trends is difficult and perhaps impossible. But a detailed radiochemical analysis of one sediment core collected downstream of Dow showed that some of the material had been there for at least 10 years. The uppermost recent layer of this study core was more contaminated with HCB and OCS than the deeper older layers. This observation is probably due to the direct contamination of the sediment with nonaqueous waste material lost from the Dow site (36). Thus, it is possible that effluent discharges of these chemicals have decreased in recent years yet the sediments are more contaminated due to this direct contaminant contact. Dow has made several modifications to its site and have installed a nonaqueous waste recovery system in the river. The amount of material lost to the river has decreased significantly since the time of the UGLCC Study (100).

Superimposed on the large steady wastewater discharges to the river are intermittent discharges which likely cause considerable variability in water quality. Sampling in the river for the UGLCC Study was too infrequent to pick up this variability. But some studies showed that the concentrations of several contaminants in the river increased after rainfall events (41,42). Precipitation leads to contaminant loadings in urban runoff and combined sewer overflows. Also, contaminated stormwater from several industrial sites is discharged directly to the river. Stormwater at other industrial sites goes through wastewater treatment lagoons prior to discharge. This can cause overloading of low capacity systems. Several industries in the area have increased their lagoon capacities to eliminate this problem (100). Precipitation events also lead to increases in leachate discharge from the waste disposal sites in the area.

Pollution control during rainfall events appears to require special measures. Better housekeeping practices by industry would lead to a lowering of contaminant concentrations in stormwater. Also, improved stormwater storage and treatment systems, and better leachate treatment for landfills would reduce contaminant loadings from these sources. The urban pollution loadings could also be reduced by better collection and treatment methods.

Another variable source of contaminants to the river is spills. Forty-eight spills occurred in 1986 (65). Large spills can have a severe impact on biota near the source, and even well downstream because of the panelled nature of the flow in the river. The regular occurrence of spills to the St. Clair must be stopped if the river is to be restored.

The St. Clair River system should respond quickly to reduced chemical loadings. The water residence time from Lake Huron to Lake St. Clair is only 21 hours. Surficial bottom sediments remain in the river for less than one year. There are a few pockets of deeper sediments over bottom undulations, and some of the deeper sediments along Sarnia's industrial district seem to be congealed together with black, tarry material. Some of these sediments may require removal, but it is possible that they will gradually disappear through natural weathering processes.

Mass Balance Model Scenarios

No mass balance models were constructed for the St. Clair River because of insufficient data. Before useful mass balance models can be constructed for the river, more detailed information on loading from various point and nonpoint sources, loadings during precipitation events, and loadings from ambient water measurements will be required. Ontario's Municipal and Industrial Strategy for Abatement (MISA) program should provide sufficient information on Ontario industrial and municipal contributions. However, data for the U.S. sources and tributary/ambient water measurements will still be required to provide sufficient data for a mass balance model.

Calculations show that the majority of contaminant discharge to the river for most chemicals originates from point sources in Canada. Net inputs to the river occur for HCB, OCS, PAHs, chloride, mercury, and lead. Other parameters not on the UGLCCS list; benzene, toluene, perchloroethylene, and pentachlorobenzene, also have sources along the river. Thus, even though a complete mass balance model was not produced during the UGLCC Study, the study still provided sufficient information to prioritize sources and begin the cleanup task.

2. Assessment of Technical Adequacy of Control Programs

Adequacy of Present Control Technology

The largest users and dischargers of water on the St. Clair River are four coal-fired power plants (89,170 x 10^3 m^3/d): Detroit Edison's St. Clair, Marysville, and Belle River Plants and Ontario Hydro's Lambton Generating Station. For the most part, water discharged is once-through cooling water. The effects of this warm-water discharge on the ecosystem was not assessed during the UGLCC Study. The maximum temperature of discharge water was within government guidelines most of the time. The cooling water at all facilities is normally chlorinated to prevent slime buildup on the condenser tubes. The impact of the chlorine residuals on St. Clair River biota should be limited to near-field effects, because chlorine will quickly react and disappear in the river. The impact of chlorine residuals from the power plants was not accessed for the UGLCC Study.

Other contaminant sources from the power plants are storm runoff from the coal piles and stormwater losses of fly and bottom ash. All plants have settling basins to minimize the losses of these potentially toxic solids. The suspended solids concentration in the effluents was within government guidelines. Analysis of the contaminant concentration on these suspended solids has not been performed, and seems to be needed before a proper assessment on their effects on the environment can be made. Fly ash may contain chlorinated dioxins and dibenzofurans, and coal fines will contain PAHs.

PCBs were used in capacitors and transformers in the electrical generating industry. Elevated PCB concentrations were found in the sediments downstream of Lambton Generating Station. PCB loadings from this facility need further evaluation.

The loadings of contaminants from the power plant effluents was difficult to evaluate because of the large cooling water dilution that occurs. More detailed studies appear to be needed to assess whether or not the current minimal wastewater treatment from these facilities is adequate.

The next largest effluent discharges to the river (1,150 x 10^3 m^3/d) are chemical companies. A list of the major chemical companies, their locations, and their wastewater treatment methods are listed in Table VII-21. Methods of treatment vary from primary, physical/chemical treatment to secondary biological treatment, depending on the nature of the product and wastewater generated.

In general, these companies are required to meet annual average discharge limits for ammonia, phenols, suspended solids, and oil and grease. All facilities complied with government discharge limits. But, many toxic and persistent contaminants are not controlled by government effluent permits. An excellent example of this is Dow Chemical which is the largest discharger of hexachlorobenzene to the St. Clair River. One of the effluent streams at Dow is biologically treated, but the largest HCB loadings are from effluents that go into the river after receiving only primary treatment. Biological treatment is not an appropriate method for HCB. Decreases in HCB effluent concentrations which occur during biological treatment are due to adsorption of HCB by the sludge. However, this simply transforms the phase of the material, and therefore does not really eliminate the problem from an ecosystem perspective.

Generally, biological treatment does not adequately treat persistent chemicals. Even though these companies are putting more emphasis and money into environmental control programs (100), much more effort is needed to minimize the formation of persistent toxic organics and/or to destroy them on-site. These persistent chemicals should not be discharged into the environment.

The next largest dischargers (543 x 10^3 m^3/d) to the St. Clair River are four petroleum refineries; Imperial Oil (Sarnia), Suncor (Sarnia), Polysar (Corunna), and Shell (Corunna). As with the chemical companies, these industries are regulated for ammonia, phenols, suspended solids, sulphide, pH and oil and grease. All companies are in compliance. The treatment for all companies involves oil separators, dual media filters, and biological treatment. Studies have shown that this treatment sequence efficiently removes not only the regulated parameters, but also the aromatic hydrocarbons and PAHs from the wastewater (66). Whether or not these chemically are biodegraded or simply transferred to the air or sludge is an important question that should be addressed.

Municipal wastewater treatment plants are the next largest dischargers (151 x 10^3 m^3/d) to the river. All plants except Sarnia and Point Edward have secondary biological treatment plus phosphorus removal. Sarnia and Point Edward WWTPs have only primary treatment plus phosphorus removal. Upgrading of these two plants would reduce the discharge of some contaminants to the river. The municipal wastewater treatment plants were significant

TABLE VII-21

Major industrial facilities on the St. Clair River.

Company	Location	Products	Treatment
a) <u>Canada</u>			
Canadian Industries Ltd.	Courtright	- fertilizer	- physical/chemical
Dow Chemical Canada Ltd.	Sarnia	- polyethylene - chlorinated hydrocarbons - vinyl chloride - polystyrene - propylene oxide	- physical/chemical - secondary biological treatment on selected streams
Dupont Canada, Inc.	Corunna	- polyethylene	- plastic bead skimming
Esso Chemicals Canada Ltd.	Sarnia	- polyethylene - polyvinyl chloride - benzene,toluene, xylene	- oil separators/dual media filters/carbon contactors
Ethyl Canada, Inc.	Corunna	- tetraethyl lead - ethyl chloride	- physical-chemical treatment on selected process streams
Novacor Ltd.	Corunna	- polyethylene resins	- process water recycle
Polysar Ltd.	Sarnia	- synthetic rubber	- secondary biological - physical/chemical for selected streams
b) <u>United States</u>			
Diamond Crystal Salt Co.	St. Clair	- salt	- sedimentation

sources for some of the persistent contaminants; for example, PCBs and trace metals. Since these materials are not readily degradable, efforts must be made to stop their discharge into the sanitary sewers at source.

Another significant source of industrial wastewater to the river is the Cole Drain (147×10^3 m^3/d). In dry weather, the flow in this open municipal ditch is largely industrial (65). Major discharges to the drain were: leachates from disposal sites along Scott Road owned by Polysar, Dow, Fiberglas, Imperial Oil, and the City of Sarnia (sewage sludge); Canadian National Railway yard runoff; Dome Petroleum; Esso Chemical (stormwater); Cabot Carbon, Fiberglas, and Polysar (stormwater). Dow Chemical has carbon treatment on the Scott Road landfill leachate, but this seems to be inadequate to prevent the discharge of HCB, OCS, and other persistent chlorinated organics to the drain. The Cole Drain is also a significant source of PAHs, cyanide, and oil and grease. Individual discharges to the ditch will need to be quantified before the source of these chemicals can be traced. It is apparent that much better treatment and control of effluents discharged to the ditch will be required.

Urban runoff has also been shown to be a significant source for some contaminants (82). At present, this water is completely untreated. Agricultural nonpoint sources are the most significant contributor of phosphorus to the St. Clair River (84,85). Improved tillage practices and reduced use of unnecessary commercial fertilizers would be the only way to reduce these inputs. Such a program would require extensive education of farmers in modern agricultural techniques.

Several waste disposal sites could potentially seriously impact the St. Clair River. These sites have been ranked by the Nonpoint Source Workgroup (88). Clay or synthetic liners, leachate collection systems, and monitoring well networks have not been required for most of the sites. For most sites, there is minimal or no treatment of waste or leachate.

3. Assessment of Regulatory Adequacy

Major industrial dischargers in the Sarnia area are subject to discharge limits specified in Certificates of Approval, Control Orders or the Ontario Industrial Effluent Guidelines. The industries are required to self-monitor on a regular basis and supply the OMOE with the data. It is a violation of the Environmental Protection Act to "knowingly give false information". The Ministry collects audit samples to check the validity of the self-monitoring data. Sampling visits are frequently arranged in advance. This could be a weakness in the system because surprise visits would be more effective.

The companies discharging to the St. Clair River are largely in compliance with the regulations. Since problems in the river still persist, this would seem to indicate that the laws and regulations are insufficient to provide environmental protection. If tougher regulations came into force, more environmental policing will likely be required. More frequent auditing of the self-monitoring data will also be necessary.

H. RECOMMENDATIONS

The UGLCC Study for the St. Clair River has revealed several problems which need to be addressed. Point source discharges, particularly in Sarnia's Chemical Valley, need to be reduced. These sources represent the largest contributors of many contaminants to the system, so remedial measures here will provide cost effective improvements in river quality. In addition, tributary contributions and urban runoff appear to be supplying significant loadings of certain contaminants. Sources of these contaminants need to be identified and addressed.

Comparison of river media concentrations to guidelines is a quick way of identifying areas of probable environmental impact or impairment. However, the ecosystem approach may give a better indication of contaminant impacts on the system as a whole. A multi-media perspective must be developed so that the overall impact on the system is assessed.

The following recommendations are designed to address the objectives identified in Section F. As these recommendations are implemented, monitoring programs should be undertaken to ensure the objectives are being met.

A. Industrial and Municipal Point Source Remedial Recommendations

1. Ontario and Michigan should incorporate the Great Lakes Water Quality Agreement's goal of the virtual elimination of all persistent toxic substances into their respective regulatory programs.

2. Polysar Sarnia should take action to significantly reduce benzene and phenols in the American Petroleum Institute (API) stereo separator effluent. The operation of the Biox treatment system should be optimized to attain the Ontario Industrial Effluent Objectives for total phenols and ammonia-nitrogen. Effluent requirements (in both concentration and mass loading form) should be instated for PAHs and HCB at the most stringent levels attainable through the use of the best available technology.

3. Dow Chemical should significantly reduce its discharge of organic chemicals to the river. The facility was a major contributor of 5 of the 7 organic groups studied. It is noted that current self-monitoring data is being made publicly available to demonstrate the effect of recent remedial efforts at this facility. Many improvements in operation have been implemented at Dow Chemical since the time of the UGLCCS survey. Self-monitoring data and other sampling results should be reviewed to determine if additional remedial actions are needed.

4. The sources of ongoing mercury discharges from Dow Chemical and Ethyl Canada should be identified and eliminated.

5. Ethyl Canada should improve the operation of its treatment plant to reduce concentrations of tetra ethyl lead to meet the GLWQA specific objective and the PWQO of 25 ug/L. In addition, enforceable mass loading limitations for lead should be instated at this facility. Volatiles, especially chloroethane, should also be significantly reduced in the effluent.

6. Polysar Corunna should reduce the concentration of chromium and zinc in the final effluent. This facility should consider substituting less persistent additives in the recycle cooling water system.

7. Effluent concentrations for chloride were generally below drinking water objectives, but the total point source loading to the system was very large (356 tonnes/day). Most was from facilities in the Sarnia area. The extreme loadings may be affecting aquatic organisms downstream of these facilities. Chloride concentration and loading limitations should be considered for those facilities discharging significant amounts of chlorides.

8. All potential sources of releases of heat exchanger fluids should be identified and controlled.

9. The Sarnia WWTP should be expanded and upgraded to secondary biological treatment with phosphorus removal. In conjunction with the upgrading, the Point Edward WWTP (a primary plant) should be considered for use as a pretreatment facility which would discharge to the Sarnia Plant. The loading of ammonia-nitrogen, total phenols, heavy metals, and organics to the St. Clair River would be significantly reduced by this action.

10. American Tape in Marysville should be evaluated to ensure compliance with their NPDES permit, Michigan Water Quality Standards and BAT requirements for toluene and xylene in its discharge.

11. The City of Marysville should be evaluated to ensure compliance with their NPDES permit and Michigan Water Quality Standards for toluene in its discharge.

12. The National Pollution Discharge Elimination System permit for the Marine City WWTP should be evaluated to ensure compliance with Michigan Water Quality Standards for cyanide. The pretreatment program should be reviewed to ensure that cyanide is adequately regulated. Acute and chronic bio-

assays for cyanide may be required at this facility.

13. A survey should be conducted at the St. Clair County-Algonac WWTP to evaluate the efficiency of the treatment system. An ammonia-nitrogen effluent limitation should be considered for the facility. Nitrogen loading to the river and Lake St. Clair may be reduced by these actions.

14. The City of St. Clair WWTP should be resurveyed to ensure that the expanded plant is operating effectively.

15. A study of industrial contributors to the Port Huron WWTP should be undertaken to identify the source or sources of CN- and PCBs to this facility. Pretreatment requirements for all industrial contributors should be examined, and modified if needed. Effluent requirements for CN- and PCBs should be considered for inclusion in the facility's NPDES permit.

16. Biomonitoring studies should be conducted at the major dischargers to determine whole effluent toxicity at these facilities. This study evaluated the point sources only on a parameter-by-parameter basis, with no attempt made to determine the impact of any additive or synergistic effects the parameters may exhibit.

B. Nonpoint Source Remedial Recommendations

17. Sources of PAHs and total cyanide to the Cole Drain, Sarnia, should be identified. If the sources are exceeding applicable effluent guidelines, they should be remediated.

18. The loadings via surface water runoff and groundwater discharge from landfills in the Scott Road area to the Cole Drain need to be determined and treated as necessary.

19. Licensing requirements for sludge disposal facilities should ensure that surface water and groundwater are properly monitored and treated.

20. A and B Waste Disposal, Hoover Chemical Reeves Company, and Wills St. Dump Site were all scored under the Superfund Hazard Ranking System (HRS) apparently without consideration of groundwater quality information. The State of Michigan should determine, based upon USGS chemistry information, the State priority for action at each site. Development of more complete groundwater information on-site would allow the State the options of pursuing Federal action under Superfund by rescoring the site under the new HRS (when it is approved), or pursuing remediation under Act 307 (MERA). Furthermore, the facilities needs for RCRA permitting need to be assessed, or reassessed.

21. The proximity of Eltra Corp. Prestolite to the St. Clair River, and the nature of wastes on site call for careful evaluation of impacts on groundwater and on the St. Clair River prior to facility closure under RCRA authorities. In the event that a satisfactory evaluation of groundwater contamination and runoff impacts upon the St. Clair River are not secured, a Site Investigation (SI) under Superfund authorities should be undertaken. The SI should include assessment of both groundwater and surface runoff impacts upon the St. Clair River.

22. The State of Michigan needs to restrict access of dumpers to Winchester Landfill. The State's development of groundwater information for this site would assist in scoring by the HRS.

23. Michigan and Ontario municipal combined sewer overflows should be intensively surveyed to determine their contribution of pollutant loadings to the river. In the long term (due to the enormous cost), combined sewers in all municipalities should be eliminated. In the interim, the municipalities should institute in-system controls to minimize the frequency and volume of overflows.

24. The Michigan Pollution Emergency Alerting System and spill reports from the Ontario Spills Action Centre should be improved so that all information on recovery, volume (if known), and final resolution are fed back to the central reporting system to complete each report for inventory purposes.

25. Spill management programs at all facilities should be reviewed and enhanced to reduce the frequency and magnitude of spills to the St. Clair River with the goal of eventually eliminating all spills.

26. Aggressive educational programs on the use of conservation tillage techniques and pesticide, fertilizer, and manure application techniques should be provided to farmers to reduce rural runoff contaminant contributions. Stricter legislation to control such application should be developed and enforced.

C. Surveys, Research and Development

27. Water quality guidance needs to be developed binationally for OCS, individual or total PAHs, hexachloroethane and chlorides. In addition, Canada needs to develop guidance for hexachlorobutadiene, and the U.S. needs water quality guidance for hexachlorobenzene, phosphorus and pentachlorobenzene. The Great Lakes Water Quality Agreement needs to develop specific objectives for all of these parameters.

Fish consumption and sediment guidance are needed for HCB, OCS, PAHs, alkyl lead, and other chemicals found to be of concern in this study.

28. More data are needed to assess the impact of PAHs on the St. Clair River. Ambient water concentrations, and point and nonpoint source loadings should be measured. Monitoring should be detailed enough to allow for the finger printing of sources.

29. The importance of contaminant loadings during rainfall events needs to be evaluated.

30. The loadings of all chemicals with high bioconcentration and bioaccumulation potential should be reduced to minimize contaminant body burdens in resident and spawning fish.

31. Assess the significance of mercury contamination to biota from sediments relative to ongoing discharges and develop remedial actions as necessary.

32. Industrial and municipal facilities discharging to St. Clair River tributaries should be surveyed to determine their contribution of contaminants to the St. Clair River. In particular, contaminant loadings from Talfourd Creek in Ontario and the Black River in Michigan should be determined.

33. The potential PCB source in the vicinity of the Lambton Generating Station should be investigated and quantified.

34. The loadings and sources of PCBs, PAHs, oil and grease, lead, ammonia, and phosphorus from the unnamed creek in Michigan across from the Lambton Generating Station should be determined and controlled to ensure compliance with Michigan Water Quality Standards.

35. The lead source to the Black River in Michigan should be located and controlled.

36. Sources of bacterial contamination to the river should be traced and eliminated.

37. A waterfowl consumption advisory should be considered by Ontario and Michigan for the St. Clair River.

38. A study on the magnitude of contaminant input to the St. Clair River from Michigan urban runoff should be undertaken, and an additional, more refined study on Canadian urban runoff should also be performed. Management control options for urban runoff should be developed.

39. Contamination from waste disposal sites, identified as high priority by the Nonpoint Source Workgroup (88), need to be further investigated with regard to contaminant pathways, including surface water runoff and groundwater seepage, and environmental impacts.

40. Continued monitoring of water levels and water quality in the freshwater aquifer in the Sarnia area is required.

41. The potential for transboundary migration and contamination of the St. Clair River and/or the fresh water aquifer in the Sarnia area from industrial waste in the 74 m and 123 m depth limestone layers of the Hamilton Group should be investigated. Of particular concern, is the 74 m depth horizon which likely flows into the fresh water aquifer in the deeper sections of the bedrock valley.

42. To understand the fate of the industrial waste disposed to the Detroit River Group, additional deep boreholes to the disposal formation are required to quantify the current directions and rates of groundwater movement.

43. Michigan should co-operate with Ontario in the deep well studies. A number of deep wells are needed in St. Clair County to supplement the information from the Ontario studies. If evidence of impacts upon Michigan groundwater is developed, a variety of authorities, including Superfund, may be applicable for remediation of identified problems.

44. The potential biological consequences of increased chloride concentrations in the St. Clair River and downstream should be examined.

45. Better methods for analysis of PCBs in the St. Clair River need to be undertaken.

46. Studies on the bioavailability of particle-bound contaminants, and contaminant desorption from suspended and bottom sediments are required to make a better assessment of the impact of in-place pollutants.

47. Studies on the effects of multicontaminant exposure to aquatic life.

48. Studies to better understand the fate and transport of sediment-borne contaminants are needed. These studies should include profiling the age and contamination of sediments in St. Clair River and delta depositional areas.

I. LONG TERM MONITORING

1. Purposes for Monitoring and Relationships Between UGLCCS and Other Monitoring Programs.

A presentation of the purposes for monitoring and surveillance activities is included under Annex 11 of the 1978 GLWQA, and a discussion of considerations for the design of a long term monitoring program can be found in Chapter 7 of the Report of the Niagara River Toxics Committee (1984). Because the focus of the UGLCC Study was toward remedial actions to alleviate impaired uses of the Connecting Channels System, long term monitoring recommendations will likewise focus on the evaluation of trends in environmental quality in order to assess the effectiveness of remedial actions. In general, post-UGLCCS monitoring should be sufficient to 1) detect system-wide trends in conditions noted by the UGLCCS, and 2) detect changes in ambient conditions which have resulted from specific remedial actions. Monitoring programs should be designed to specifically detect the changes intended by the remedial actions so as to ensure relevance in both temporal and spatial scales.

Two major programs sponsored by the IJC also contain plans for long term monitoring: the Great Lakes International Surveillance Plan (GLISP) and the Areas of Concern Remedial Action Plans (AoC-RAPs). The GLISP for the Upper Great Lakes Connecting Channels is presently incomplete, pending results of the UGLCC Study, but it is expected to provide monitoring and surveillance guidance to U.S. and Canadian agencies responsible for implementing the provisions of the WQA that include general surveillance and research needs as well as monitoring for results of remedial actions.

The St. Clair River is one of the AoCs, and a RAP is being developed jointly by Michigan and Ontario. The RAP will present details of uses impaired, sources of contaminants, specific remedial actions, schedules for implementation, resources committed by Michigan and Ontario to the project, target clean-up levels, and monitoring requirements. Results and recommendations coming from the UGLCC Study will be incorporated extensively into the RAP, which will then be the document that influences State and Provincial programs in the St. Clair River. The recommendations for long term monitoring that are presented below are intended for consideration and incorporation into either or both the GLISP and RAP for the St. Clair River.

2. System Monitoring for Contaminants

Water

Knowledge of the concentrations of the principal contaminants in the water of the St. Clair River should be used to indicate general exposure levels for the biota, to identify changes and trends over time in the concentration levels, and to be used for general assessment of contaminant impacts. The parameters to be monitored include HCB, OCS, total phenols, cyanide, mercury, lead, total volatiles and chlorides. Monitoring stations should be located where elevated concentrations of the contaminants are known or predicted from dispersion models. Suggested locations include the head of the St. Clair River and at Port Lambton, particularly on the Canadian side. Sampling frequency should be influenced by the variability in contaminant sources. Spring high flow conditions and late summer low flow conditions would be expected to bracket the normal seasonal variability in flow that could influence measured contaminant concentrations.

A mass balance approach to contaminant monitoring will help to identify any changes in the contaminant mass over time, and it will provide the basis for targeting future remedial actions by providing a comparison of the magnitude of the sources. A mass balance analysis should be conducted approximately once every five years, assuming that some effective remedial action has been implemented against one or more sources such that the total loadings of contaminants, or the relative contribution of the sources to the loading, has changed. The sources to be measured should include:

1) Head and mouth transects. The number and location of stations should relate to measured and predicted plume distributions. Suggested locations include the head of the St. Clair River and at Port Lambton. The Port Lambton transect will be consistent with past dispersion measurements and modeling work, and will help delineate contaminant loading into Lake St. Clair. Both dissolved and particulate fractions should be analyzed. The quantity of suspended sediment flux should also be measured.

2) Municipal and industrial point sources. During the survey, the sampling must be frequent enough to accurately reflect the likely loading fluctuations from the major point sources. The sources include the major outfalls of Sarnia WWTP, Cole Drain, Polysar Sarnia, Polysar Corunna, Dow Chemical, Suncor, Ethyl Canada, CIL Inc., Port Edward WWTP, and Marine City WWTP.

3) Tributaries. Efforts should be focused on seasonal and storm event loadings of contaminants to the St. Clair River from Talfourd Creek and the Belle, Pine and Black Rivers. A channel near Fawn Island also diverts some of the Sydenham River drainage to the St. Clair River during severe spring runoff events. Tributary mouth stations should be sampled and analyzed for both dissolved and sediment-associated contaminant loadings.

4) CSOs and Urban Runoff. To provide an estimate of contaminant mass loadings expected during storm events, occasional studies on selected urban drainage areas should be conducted. Some estimates have been made for Sarnia, Ontario. Similar estimates should be made for other urban areas along the river.

5) Groundwater inflow. The quantity and quality of potential contaminant releases from waste disposal sites adjacent to the St. Clair River or its tributaries should be determined. Permits should require groundwater monitoring, an assessment of surface water runoff and determination of overall loadings to surface water. Characterize the distribution, composition and movement of deep well injected waste. Evaluate the impacts of Michigan and Ontario injection pressure regimes on the movement of the waste.

6) Sediment transport. Preliminary studies indicate that less than 1% of the contaminants in the St. Clair River are transported by bed-load sediments movement. However, the quantity of contaminants being desorbed from the sediments should be determined in order to assess loadings from these in-place polluted sediments.

7) Atmospheric deposition. Direct atmospheric deposition of contaminants to the St. Clair River is expected to be minor. Deposition to the drainage basin and subsequent runoff into the river or its tributaries, however, could be an important source for some contaminants. Estimates of contaminant mass in both wet and dry deposition to the drainage basin should be made when unidentified non-point sources are found to be a major contributor of any of the contaminants of interest.

Sediments

Monitoring of sediments for concentrations of contaminants should be conducted periodically throughout the St. Clair River in order to assess both the trends in surficial contaminant concentrations and the movement of sediment-associated contaminants within the River. The grid used by the U.S. Fish and Wildlife Service during the 1985 survey would be appropriate for consistency in sampling sites and sediment composition. An analysis of sediment chemistry including bulk chemistry, organic and inorganic contaminants, and particle size distribution should be conducted every 5 years, in conjunction with a biota survey (see "habitat monitoring" below). In the St. Clair River, particular attention should be given to sediment concentrations of chlorinated organics (PCBs, HCB, OCS, HCBD), benzene, phenols, oil and grease, and heavy metals, including mercury.

Because the grid stations are distributed throughout the river reach and are associated with appropriate habitat for a sensitive benthic invertebrate (Hexagenia), the periodic survey will allow assessment of 1) contaminant concentrations in the river sediments throughout the river reach, 2) relative movement of the contaminants within the river sediments between surveys, and 3) correlation of contaminant concentrations with benthic biotic communities.

The sediments at any stations established at the mouths of tributaries to the St. Clair River should be monitored for organic and inorganic contaminants on an annual or biannual basis when significant remedial actions are implemented within the watershed of the tributary. In order to trigger the more frequent sediment monitoring program, the remedial actions should be expected to measurably reduce loadings of one or more particular contaminants via the tributary.

Biota

Long term monitoring of concentrations of contaminants in biota will provide a time series useful to track the bioavailability of contaminants to selected representative organisms. Three long term monitoring programs are already in place in the Great Lakes basin and should be expanded into the St. Clair River.

i) Annual or Bi-Annual Monitoring of Sport Fish.

This program should focus especially on PCBs, mercury and/or other contaminants (e.g. dioxins and dibenzofurans) that are considered to be known or suspected health hazards. Because many of the fish species in the river are transitory, efforts should be made to identify and sample those species that have an extended residence time in the river as well as those that are most sought by anglers. The monitoring should be continued regardless of the differences that may be observed between acceptable concentrations or action levels that may be established by government agencies and the measured contaminant concentrations in the fish flesh. As a link between human health concerns and integrated results of remedial programs to reduce contaminants in the UGLCC System, this program is critically important.

ii) Spottail Shiner Monitoring Program.

This program is designed to identify source areas for bioavailable contaminants. In locations where spottail shiners or other young-of-the-year fish contain elevated levels of contaminants, additional studies should be conducted to identify the sources of the contaminants. Some upstream studies in tributaries may be required. Spottails should also be employed to confirm that remedial actions upstream to a previous survey have been effective in removing or reducing the loading of one or more contaminants.

iii) Caged Clams Contaminants Monitoring.

Caged clams should continue to be used at regular time intervals, perhaps in conjunction with spottail shiners, to monitor integrated results of remedial actions to reduce contaminant loadings to the water. Clams may be located at tributary mouths and downstream of suspected source areas. Repeated assays from the same locations should confirm results of remedial actions.

3. Sources Monitoring for Results of Specific Remedial Actions

Remedial actions intended to reduce concentrations and/or loadings of contaminants from specific point sources generally require monitoring for compliance with the imposed criteria or standards. The monitoring may be conducted by the facility or by the regulating agency, whichever is applicable, but attention must be given to the sampling schedule and analytical methodology such that mass loadings of the contaminants can be estimated, as well as concentrations in the sampled medium. Monitoring of the "nearfield" environment, i.e., close downstream in the effluent mixing zone, should be conducted regularly to document reductions in contaminant levels in the appropriate media and to document the recovery of impaired ecosystem processes and biotic communities. Such monitoring may be required for a "long time", but over a restricted areal extent, depending on the severity of the impact and the degree of reduction of contaminant loading that is achieved.

For the St. Clair River, eleven actions were recommended that would affect specific sources of contaminants, and that would require site specific monitoring for compliance or other effects of the action at the following locations: Marine City WWTP (cyanide concentration), St. Clair County-Algonac WWTP (ammonia-nitrogen limits), American Tape in Marysville (xylene and toluene), City of Marysville WWTP (toluene), Sarnia WWTP (phosphorus, ammonia-nitrogen, total phenols, heavy metals and organics), Cole Drain, Sarnia (PAHs, cyanide, oil and grease), Polysar Sarnia (benzene, phenols), Dow Chemical (several organic chemicals), Ethyl Canada (lead, volatile organics, mercury, and chloroethane), and Polysar Corunna (chromium and zinc).

Other recommendations for specific contaminant sources involve an assessment of the present conditions or a study to quantify concentrations or loadings: survey the St. Clair County-Algonac WWTP and the City of St. Clair WWTP to document the efficiency of the treatment system, intensively survey CSOs in Michigan and Ontario for determining the contribution of pollutant loadings to the River, establish biomonitoring studies at a major point source contributors, assess impact of PAHs on St. Clair River and estimate their loadings, measure contaminant loadings during rainfall events, obtain better estimates of the mercury losses from the Dow site, quantify loadings of contaminants from urban nonpoint sources, evaluate contamination from waste disposal sites, etc. Each of these items requires a specific program of data collection and analysis. Additional needs for longer term monitoring may be identified as a result of these studies.

4. Habitat Monitoring

Habitat monitoring should be conducted to detect and describe changes in the ecological characteristics of the St. Clair River through periodic analysis of key ecosystem elements. The following items are recommended:

a) The abundance and distribution of the mayfly <u>Hexagenia</u> should be determined every five years. The grid used by the U.S. Fish and Wildlife Service during the 1985 survey would be appropriate for consistency in sampling sites each survey. An analysis of sediment chemistry, including bulk chemistry, organic and inorganic contaminants, and particle-size distribution, should be conducted for samples taken concurrently with the <u>Hexagenia</u> survey. These data will provide information on the quality of the benthic habitat for a common pollution-sensitive organism that would serve as an indicator species of environmental quality.

b) Quantification of the extent of wetlands along the St. Clair River should be conducted every five years, in conjunction with the <u>Hexagenia</u> survey. Aerial photography or other remote sensing means would be appropriate to discern both emergent and submergent macrophyte beds that are important as nursery areas for larval fish and other wildlife. Verification of areal data should be conducted by inspection of selected transects for plant species identification and abundances. Changes in wetland areas should be correlated with fluctuating water levels and other natural documentable influences so that long term alterations in wetlands can be tracked and causes identified.

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CHAPTER VIII

LAKE ST. CLAIR

A. STATUS OF THE ECOSYSTEM

1. Ecological Profile

Watershed Characteristics

The St. Clair system including the St. Clair River and Lake St. Clair is a significant waterway economically, biologically and physically. Together with the Detroit River, the system forms the connecting channel between Lake Huron and Lake Erie.

Located on the international boundary between the United States and Canada, Lake St. Clair borders Lambton, Kent and Essex counties in Ontario, and Macomb and Wayne counties in Michigan. It has a shoreline length of approximately 272 km plus the delta shoreline area. It possesses a maximum natural depth of 6.5 m, a maximum length of 43 km, a width of 40 km and an area of about 1,115 km^2. In Ontario, wetlands and agriculture dominate the shoreline, while in Michigan the entire shoreline is highly urbanized. Because of its modest depth, the lake has no commercial harbors. To accommodate heavy commercial marine traffic, however, a navigation channel has been dredged to a depth of 8.3 m running in a northeast-southwest direction between the St. Clair cutoff in the St. Clair River Delta and the head of the Detroit River (Figure II-4).

The eastern shoreline of the lake is low lying and characterized by agricultural and recreational land uses. Low barrier islands less than 170 m in width and probably not more than 1 m above lake level parallel the shoreline and are colonized by marsh vegetation. The wetland zone, which is approximately 1 km wide, extended farther inland (east) in the past. Approximately 40% of the low plain has been ditched and drained since 1916. The coastal barriers provide a line of defense from wave attack to the lagoon and wetland zone. The annual net erosion rates on the south shore of Lake St. Clair are in excess of 2 m/yr (1). However, other coastal reaches on the south shore are actually accreting at rates of up to 0.4 m/yr.

On the western shore, permanent residential homes occupy about 30 km of lake shoreline, with industrial and commercial uses occupying only 2 km of shoreline. Most of the shoreline is in private ownership, but 12 km is publicly owned and dedicated to recreation and wildlife preserves.

Despite the various intensive and conflicting land and water uses to which the St. Clair system is subjected, the system continues to provide recreation to many Americans and Canadians. Typically more walleye, bass, muskellunge and centrarchid panfish are taken from Lake St. Clair each year than from any of the Great Lakes or other Great Lakes connecting channels. These anglers and boaters are served by more than 140 commercial, municipal and private marinas in Michigan and Ontario.

Hydrology

The physics of Lake St. Clair is important in determining the distribution and fate of contaminants and other substances in the sediment and water column. The St. Clair River contributes 98% of the water to the Lake St. Clair basin, with the remaining 2% being contributed by other lake tributaries, including the Clinton, Thames and Sydenham Rivers. The average discharge of the St. Clair River from 1900 through 1981 was 5,200 m^3/s with a range from 3,000 m^3/s to 6,700 m^3/s. Outflow from the lake, which is through the Detroit River to Lake Erie, is only about 3% greater than the inflow from the St. Clair River. Average flushing times for the St. Clair River, Lake St. Clair and the Detroit River are 21 hours, 5 - 7 days and 19 hours respectively (2).

Flows in the system are controlled principally by the inflows from Lake Huron and the outflows to Lake Erie, which in turn depend largely on the difference in water levels between these two lakes. Fluctuations of water levels and flows do occur at the head and mouth of both the St. Clair and Detroit Rivers in response to seasonally fluctuating water levels in the upstream and downstream lakes as well as wind set-ups on each of the lakes during periods of high winds and storms. Ice jams are a common occurrence on the St. Clair River and often reduce the river flow, thereby both raising the level of Lake Huron and lowering the level of Lake St. Clair. For example, in 1984 an ice jam reduced the monthly average flow to about 2,520 m^3/s, which caused a drop of 0.4 m in lake level.

Lake St. Clair has an established elevation of 174.65 m above sea level, but the average lake level from 1900 through 1983 was

174.87 m. The lake had a maximum elevation of 175.64 m, and a minimum elevation of 173.71 m.

The St. Clair River empties into Lake St. Clair through a large delta consisting of three main channels in the upper delta (North Channel, South Channel and Chenal Ecarte) and a number of secondary channels in the lower delta. The delta area, commonly referred to as the St. Clair Flats, extends 18 km from the open waters of Lake St. Clair towards the St. Clair River. Channel depths are extremely variable, but the three active distributaries average 500 m wide and 11 m deep. At the mouths of the channels, depths decrease abruptly due to river mouth bars 2 to 4 m below mean lake level. The North Channel, the South Channel and the Chenal Ecarte contribute 53%, 42% and 5% of the river flow to Lake St. Clair respectively (3).

Wind forces largely determine the water mass distribution and circulation patterns in the lake. In general, the main surface movement to the lake's outflow in the Detroit River appears to be along the south shore for southwest to north winds, and along the west shore of the lake for northeast to south winds. Two distinct water masses have been identified: a northwestern mass consisting primarily of Lake Huron water flowing from the main channels of the St. Clair River, and a southwestern mass of more stable water enriched by nutrient loadings from Ontario tributaries and shoreline development. The margins of the masses may shift according to wind direction and speed, but the overall discreteness of the distributions is maintained.

Habitats and Biological Communities

The St. Clair system contains one of the largest coastal wetlands in the Great Lakes. Topographic maps and navigation charts indicate there are 13,230 ha in Lake St. Clair and the St. Clair Delta. The wetlands include the following major types:

1. Open water wetlands have variable water depths and thus support submersed plants in deeper waters and emergent aquatic macrophytes in more shallow water. They commonly occur in interdistributary bays and shallower waters along the perimeter of Lake St. Clair.

2. River channel wetlands are composed largely of submersed species but occasionally emergent macrophytes occur on point bars.

3. Beach and shoreline wetlands are represented by a mix of species.

4. Cattail marsh wetlands colonize broad zones located at the lower St. Clair Delta and at the mouth of the Clinton

River. Stands of hybrid cattails (Typha x glauca) are associated with clayey and organic sediments. Shallow openings are colonized by floating and submersed species.

5. Sedge marsh wetlands are mainly composed of tussocks of sedges.

6. Abandoned river channel wetlands support emergent and submersed aquatics.

7. Wet meadow wetlands contain low, woody plants interspersed with grasses.

8. Shrub wetlands are dominated by mixed shrubs, water tolerant trees, and understory plants typical of wet meadows.

In general, all wetland types occur in the St. Clair Delta area. A sedge marsh wetland dominates the shallow regions. Where water depths exceed 0.3 m the sedges are replaced by cattail marsh, which is extensive, especially in Ontario. In deeper water, the cattail marsh gives way to open water wetlands dominated by the hardstem bulrush. This zone of emergents is less dense lakeward, where submersed macrophytes occur in bays at low density. The size, location and structure of the wetland plant communities shift in response to the periodic changes in water levels of Lake St. Clair.

Benthic macroinvertebrates also exhibit spatial zones within Lake St. Clair. In one recent study of benthic invertebrates and sediment chemistry, six community assemblages were identified. Two communities were associated with the periphery of the lake and in Anchor Bay, three communities were found in the deeper waters, 2 to 7.5 m deep, and one grouping was found in the lower reaches of the St. Clair River and Thames River.

Local Ecological Relationships

i) Nutrient Cycling

Lake St Clair is a highly productive north-temperate lake. The distribution of nutrients and chlorophyll within the lake are influenced primarily by lake currents and the flow of Lake Huron water through the delta system. Concentrations of chemical variables and chlorophyll tend to increase across the lake from northwest to southeast. Because of nutrient inputs from agricultural drainage, sewage discharge and greater stability in water mass, the southeastern area is more eutrophic than the remainder of the Ontario section of the lake. The northwestern water mass consists primary of Lake Huron water flowing from the main channels of the St. Clair River. The southeastern water mass consists of more stable water enriched by nutrient loadings from

Ontario tributaries, and can be considered to be mesotrophic, bordering on eutrophic.

Thermal and chemical stratification do not occur and oxygen concentrations remain near 100% saturation throughout the lake. Moderate alkalinity, low specific conductance and low pH variability indicate Lake St. Clair is a well-buffered, hard water lake. The input of high quality water from Lake Huron, through the St. Clair River, maintains the water quality and the biota in the open waters of Lake St. Clair similar to conditions in southern Lake Huron.

ii) Food Webs

The primary producers in the St. Clair system are phytoplankton and macrophytes. At least 71 species of phytoplankton and 21 taxa of submersed macrophyte have been identified from the St. Clair system. According to Edwards *et al*., (2) about 215,330 tonnes of plant biomass are produced in the St. Clair system each year, of which about 25% and 75% originates in the St. Clair River and in Lake St. Clair respectively. The estimated phytoplankton biomass, 96,900 tonnes, represents about half the total plant biomass produced in the system. Because of the short flushing time of the system, however, most of the phytoplankton probably passes into Lake Erie before it is utilized by other trophic levels. Most of the periphyton and macrophytic biomass dies back in the fall, over-winters on the bottom, and moves downstream in spring just after ice break-up. Additional allocthonous organic matter which is added to Lake St. Clair from municipal sewage treatment plant equals approximately 25% of the total annual primary production of all vegetation in Lake St. Clair.

Lake St. Clair has relatively low densities of limnetic zooplankton. In general, cladocera (28 species) are present in higher densities than cyclopoid copepods (5 species), and cyclopoids are more abundant that calanoid (7 species) or harpacticoid (4 species) copepods. The overall low abundance of limnetic zooplankton in Lake St. Clair has been attributed to well-developed macrophyte beds and the rapid flushing time of Lake St. Clair.

In excess of 300 taxa of macrozoobenthos have been reported from Lake St. Clair. Oligocheata, Chironomidae, Gastropoda, Ephemeroptera, Trichoptera and Amphipoda comprise the most significant biomass of macrozoobenthos. Nymphs of the mayfly *Hexagenia* may reach densities up to 3,000 nymphs/m^2. Species richness is greatest among the Chironomidae, Trichoptera and Oligochaeta.

iii) Trophic Relationships

Details of the relationships between the flora and fauna in the St. Clair system, beyond the generalized limnological interactions commonly thought to occur, have yet to be determined. The St. Clair River and Lake St. Clair are major sources for submersed and emergent plants that provide substrate for periphyton and for invertebrates that are fed upon by fish and waterfowl. They also provide cover for young fish. As detritus, the plants serve as food for macrozoobenthos. Poe *et al.*, (4) showed that a percid-cyprinid-cyprinodontid fish community was dominant in Lake St. Clair in vegetatively complex areas occupied by many plant species, and that a less diverse, centrarchid community dominated in the areas with fewer plant species.

High productivity of benthic macroinvertebrates in Anchor Bay and around the delta of the St. Clair River in Lake St. Clair is probably related to the large accumulations of macrophytes in those areas. The macroinvertebrates are probably not food limited for at least half the year.

iv) Links to the Great Lakes

The St. Clair system provides important spawning and nursery habitat for fishes that are permanent residents and for others from Lake Huron and Lake Erie which enter the system to spawn. Of the approximately 70 species of fish recorded as residents or migrants in Lake St. Clair, at least 45 have spawned in the St. Clair system. Large numbers of lake herring and lake whitefish from Lake Erie historically migrated into Lake St. Clair to spawn over the large *Chara* beds along the western side of the lake.

Lake sturgeon were also historically abundant and supported a commercial fishery, but overfishing reduced the population and now only a limited recreational fishery is permitted. The shallow marshes of the St. Clair Flats are the only known nursery areas for the species in Lake St. Clair.

Walleyes and yellow perch spawn in Anchor Bay of Lake St. Clair, along the south shore of the lake, in the Clinton, Sydenham and Thames Rivers, and in the St. Clair delta. Stocks that were depressed from historical levels have rebounded in the past decade and major spawning runs now occur in the St. Clair system. Yellow perch populations of southern Lake Huron and the St. Clair system are closely linked. Many of these fish apparently overwinter and spawn in Lake St. Clair and the St. Clair delta, and then spend the rest of the year in the St. Clair River and Lake Huron.

Smallmouth bass and muskellunge support important recreational fisheries in Lake St. Clair and have extensive spawning grounds in the lake. Smallmouth bass spawn along the shoreline of the lake from the Thames River and the southeast edge of the lake, north into the St. Clair delta, and along the north and west shorelines of the lake to the head of the Detroit River. Virtually all of the delta and the shoreline of Anchor Bay are also nursery areas for smallmouth bass. Muskellunge spawning areas extend more or less continuously along the shoreline of the lake across the St. Clair delta, into Anchor Bay, and intermittently along the west shoreline to the head of the Detroit River. Marshes of the St. Clair delta are the only recorded muskellunge nursery areas.

Exotic fish species which now inhabit Lake St. Clair, as well as the Great Lakes, include the common carp (Cyprinus carpio), the alewife (Alosa pseudoharengus), the rainbow smelt (Osmerus mordax) and the white perch (Morone americana). The carp have recently made up much of the commercial fish catch, and the smelt plus alewife together are the most abundant fish larvae in the St. Clair system. The white perch, first captured in Lake St. Clair in 1977, now provide an important recreational fishery.

The extensive wetlands of Lake St. Clair are also an important concentration and nesting area for waterfowl. Major concentration areas extend from the lower St. Clair River to the middle of Lake St. Clair. The coastal wetlands and shallow waters of Lake St. Clair make it a critical resting and feeding habitat. Species whose primary migration corridor traverse Michigan with a resting stopover in the vicinity of lake St. Clair include the American goldeneye, bufflehead, canvasback, hooded merganser, ruddy duck and Canada goose. Important species of ducks that nest in the St. Clair area include mallards, blue-winged teal, black ducks, redheads and wood ducks.

Climate

The climate of the region is characterized by mild summers and cold winters. Average annual air temperatures range from a high of 23.6°C in July to a low of -4.4°C in January. Monthly precipitation ranges from a high of 8.10 cm to a low of 3.6 cm. In winter, temperatures are commonly below 0°C and ice occurs on most of the lake. Water temperatures during the summer months are near 21°C. Precipitation is mainly rain and is evenly distributed throughout the year.

2. Environmental Conditions

Water Quality

i) Tributaries

Because the St. Clair River provides 98% of the water to Lake St. Clair, the mass loading of contaminants to the Lake is mainly from this single input. Additional loadings from other tributaries do occur, however, and local impacts have been observed due to degraded tributary water quality. In the following discussions, references to Lake St. Clair tributaries exclude the St. Clair River.

Tributary water quality data from six tributaries (Thames, Sydenham, Puce, Belle and Ruscom Rivers in Ontario, and the Clinton River in Michigan) in 1984 and 1985 indicated the presence of eight pollutants (PCBs, HCB, OCS, P, Cd, Cl, N and Pb) that were designated as parameters of concern for the UGLCC Study. In these streams, P, Cd, Pb and Cl concentrations ranged from 0.014-0.94, 0.002-0.0022, 0.003-0.58 and 11-349 mg/L respectively (Table VIII-1). Estimated daily loadings from each river are presented in Table VIII-2. Expression of loadings on a daily basis is somewhat artificial, since true loadings from tributaries have been shown to be strongly flow-dependent and seasonal. However, expression in this manner should facilitate comparison with other sources of loadings presented in this report.

The organic contaminants, PCBs, HCB and OCS were usually not found in quantifiable concentrations in unfiltered water samples (5). PCBs associated with suspended sediments from the Belle, Sydenham and Thames Rivers were found in concentrations up to 1,560 ng/g, 60 ng/g and 61,190 ng/g respectively. Suspended sediments were not sampled from the other rivers.

The phosphorus concentration in water from all six tributaries exceeded the Ontario Provincial Water Quality Objective (PWQO) of 30 ug/L for rivers in all samples, except for some samples from the Sydenham River. Estimates of loadings from the tributaries ranged from 23.5 kg/d from the Puce River to 2,021 kg/d from the Thames River. All sampled Canadian tributaries together provided a loading of 3,052 kg/d, while the Clinton River contributed an additional 340 kg/d (Table VIII-2).

The largest nitrate + nitrite loadings to Lake St. Clair came from the Thames River (31,435 kg/d), Sydenham River (4,542 kg/d) and Clinton River (2,186 kg/d).

Concentrations of chlorides in unfiltered water ranged from 11 mg/L in the Sydenham River to 349 mg/L in the Clinton River. The Clinton River concentrations exceeded the 250 mg/L concentration set as the U.S.EPA Secondary Maximum Contaminant Level for aes-

TABLE VIII-1

Comparison of Canadian and U.S. tributary pollutant concentrations and loads for the study area (1984-1985).

	Canadian Tributaries[a]	U.S. Tributary[b]
Combined Drainage Areas (ha)	567,310[c]	190,004
Percent of Study area	47	16

Parameter (units)	Canadian Tributaries Monitored	Concentrations Water	Suspended Sediment (ng/g)	Average Loads (annual)[c]	Concentrations[d] Water	Suspended Sediment (ng/g)	Average Loads (annual)
PCBs ng/L	T,S,B,K	<QLD	<QLD-61,190	NS	X	X	X
HCB "	T,S,B	<QLD-4	<QLD-53	NS	X	X	X
OCS "	T,S,B	<QLD	<QLD-24	NS	X	X	X
P mg/L	T,S,B,R,P,K	0.014-0.94[f]	X	22.6 kg/ha[e]	0.06-0.69[f]	X	0.653kg/ha
N "	T,S,B,R,P	0.01-12.7	X	40 "	0.76-2.6	X	4.1 "
Cl "	T,S,B,R,P,K	11-220	X	287 "	41-349	X	360.5 kg/ha
Pb "	T,S,B,K	0.003-0.58[f]	X	0.07 " [e]	X	X	0.03 "
Cd "	T,S,B,K	.0002-.0008[f]	X	0.002 " [e]	.001-.0022	X	0.0016 "
atrazine ng/L	T	<QLD-30,000	X	16.0 g/ha	0.43 ug/L[h]	X	0.28 g/ha
alachlor "	T	<QLD- 6,900 [g]	X	0.7 "	0.63 " [h]	X	0.08 "
metolachlor "	T	<QLD- 8,000	X	6.7	0.32 " [h]	X	0.01 "
cyanazine "	T	<QLD- 5,000	X	NS	0.47 " [h]	X	0.048 "

NOTE:

a	Six Canadian tributaries include the Thames (T), Sydenham(S), Belle (B), Ruscon(R), Puce (P) and Pike (K) Rivers
b	U.S. tributary is Clinton River
c	Excluding Pike Creek
d	U.S. pesticide data for the period April 15 to August 15, 1985 only
e	Average Sydenham and Thames Rivers only
f	Concentrations exceeded water quality standards
g	Concentrations exceeded one or more proposed water quality standards for drinking water
h	Time weight mean concentrations
X	No data available
<QLD	Less than quantitative limits of detection
NS	Insufficient data for load calculations

TABLE VIII-2

U.S. and Canadian tributary loading of UGLCCS parameters into Lake St. Clair (kg/d).

Tributary	NO3-N	Cadmium	Chlorides	Lead	Phosphorus
Belle River (Canada)	516	-	6007	-	71
Puce River (Canada)	282	-	4535	-	23
Ruscon River (Canada)	647	-	4984	-	43
Sydenham River (Canada)	4542	0.696	50,483	11.2	893
Thames River (Canada)	31,453	1.82	190,318	123.1	2021
Clinton River (U.S.)	2186	0.83	187,661	15.6	340

Note:

Values are presented here in rounded form and may differ from that in the text. Loadings for other U.S. tributaries mentioned in the text were not calculated thetic effects, the Health and Welfare Canada Maximum Acceptable Concentration, and the Ontario Maximum and Maximum Desirable Concentration for aesthetics. The greatest loadings were provided by the Thames River (190,318 kg/d), Clinton River (182,661 kg/d) and Sydenham River (50,483 kg/d).

The range of cadmium concentrations in unfiltered water were 0.2-0.4 ug/L in the Belle River, 0.2-0.7 ug/L in the Sydenham and Thames Rivers, and 0.1-2.2 ug/L in the Clinton River. These concentrations were generally greater than the Great Lakes Water Quality Agreement (GLWQA) specific objective and PWQO of 0.2 ug/L, and some were greater than the chronic AWQC of 1.1 ug/L (assuming water hardness of 100 mg/L). Estimated loadings from the Clinton, Thames and Sydenham Rivers were .83 kg/d, 1.82 kg/d and 0.696 kg/d respectively.

The Belle, Sydenham and Thames Rivers all contained concentrations of lead in some samples that exceeded the chronic AWQC of 3.2 ug/L (assuming a hardness of 100 mg/L). The Thames River contained concentrations which also exceeded the acute AWQC of 82 ug/L, as well as the GLWQA specific objective and PWQO of 25 ug/L. Major loadings of lead were provided by the Thames River (123.1 kg/d), Clinton River (15.6 kg/d) and Sydenham River (11.2 kg/d).

The pesticides atrazine, cyanazine, metolachlor and alachlor were detected in Thames River water samples between 1981 and 1985 with a frequency of occurrence of 99%, 16%, 7% and 4% respectively at concentrations from less than detection limits to 3.0, 5.0, 8.0, and 3.0 ug/L respectively (Table VIII-1). In the Clinton River in 1985, the pesticides as ordered above were observed with frequencies of 95%, 73%, 2.7% and 21.6% respectively at concentrations from less than detection limits to 1.9, 0.2, 0.2 and 0.9 ug/L respectively.

Some U.S. agencies have proposed drinking water standards for the four pesticides discussed above. None of the measured concentrations of the pesticides in either of the rivers exceeded the proposed standards, except for the State of Wisconsin standard for alachlor (0.5 ug/L).

ii) Open Lake St. Clair Water

Water temperature in Lake St. Clair is determined in part by the shallow depth and short hydraulic retention time of the water. Highest temperatures are reached in August, and average about 22.5°C. Temperatures may be 2 to 4°C lower in Anchor Bay because of the greater inflow from the St. Clair River, and they may be 5 to 6°C higher in the coastal wetlands. The lake is too shallow to stratify thermally, and dissolved oxygen concentrations are usually at saturation.

In general, surface water temperatures at the outflow of Lake St. Clair exceed the upper limit (19°C) of the range selected for residence by adult rainbow trout from about late June through mid-September, and they exceeded the upper limit of the range (17°C) selected for residence by juvenile lake whitefish in Lake Huron from about mid-June through late September. Thus, Lake St. Clair may provide optimum thermal habitat for indigenous Great Lakes cold water fishes only during the cooler months of the year. Anchor Bay may contain suitable thermal habitat for cold-water fishes for a slightly greater portion of the year than the rest of the lake.

Because of the large contribution of water from the St. Clair River into Lake St. Clair and the relatively short residence time of water in the lake (5 to 7 days), the water quality of Lake St. Clair largely reflects that of the St. Clair River.

Concentrations of contaminants within the water may be inferred by comparing those in the incoming water with those in water at the head of the Detroit River. Studies of water from the St. Clair and the Detroit Rivers were conducted in 1985, with samples analyzed for a number of chemical parameters, including organochlorine pesticides (OCs), PCBs, and a variety of other chemicals of industrial origin including chlorobenzenes (CBs), hexachlorobutadiene (HCBD), hexachloroethane (HCE) and octachlorostyrene (OCS). Details of the analytical procedures were provided by Chan _et_ _al_., (6).

Organochlorine Pesticides and PCBs:

Concentrations of total PCBs in unfiltered water at the head of the Detroit River averaged 0.0014 ug/L from two surveys. This concentration was slightly above the Ontario Provincial Water Quality Objective (PWQO) of 0.001 ug/L. The difference in concentration of PCBs between the mouth of the St. Clair River and the head of the Detroit River was not significant, i.e., less than detectable and 0.0014 ug/L in two surveys of the St. Clair River, 0.00139 ug/L and 0.00144 ug/L in two surveys of the Detroit River. Because the concentrations of other organic compounds (HCBD, HCB, OCS and HCE) were lower at the Detroit River than at the mouth of the St. Clair River (7), however, a source of PCBs may exist within the Lake St. Clair basin. At the head of the Detroit River, the concentration of PCBs was greater on the U.S. side than on the Canadian side, suggesting that a source of PCBs may exist on the western shore of Lake St. Clair.

Concentrations for the organochlorine pesticides in the dissolved phase were in the low ng/L range or less along the St. Clair River. While there were some seasonal variations noted, no marked spatial variation was observed, either downstream or cross-river. Because concentrations were also similar at the head of the Detroit River, an argument similar to that for PCBs above can be made for the possible existence of a source for these pesticides in the Lake St. Clair basin.

Chlorobenzenes, Octachlorostyrene:

In contrast to the behaviour of the pesticides and PCBs noted above, increases in the concentration of HCBD, HCB, and OCS indicate significant sources of inputs of these industrial compounds to the St. Clair River, but the plume of contaminants remains close to the Canadian shore and does not disperse uniformly across the river. In the upper delta, concentrations were highest in the Channel Ecarte, which receives Canadian nearshore water. Because this stream contributes only 5% of the total river flow to Lake St. Clair, however, the major loading of these substances to the lake would come from the South Channel. Diminished, but measurable concentrations of these chemicals in the dissolved phase were observed at the head of the Detroit River in 1985, showing that some contaminant carryover from the St. Clair River occurred, but also that some significant loss processes occurred within the lake. Similar findings were reported for a survey conducted in 1984 (8). For example, loss processes in Lake St. Clair may account for up to 95% reductions in HCB and OCS between the St. Clair and Detroit Rivers (8).

Phosphorus, Chlorides and Metals:

Concentrations of total phosphorus, chlorides and metals in whole water and suspended solids from the mouth of the St. Clair River and the head of the Detroit River in 1984 are presented in Table VIII-3. All measured concentrations in water were below the relevant surface water standards or guidelines except for some observations of excessive iron in the Detroit River. Similarly, the mean concentrations of the following parameters that were measured at the head of the Detroit River in 1985 were below all relevant criteria, objectives or guidelines: total phosphorus, 8.6 ug/L; cadmium, 0.023 ug/L; zinc, 1.217 ug/L; mercury, 0.008 ug/L; copper, 1.29 ug/L; and nickel 0.966 ug/L. A significant increase (71%) in phosphorus concentration in both whole water and suspended sediments was observed between the mouth of the St. Clair River and the head of the Detroit River, thereby indicating that Lake St. Clair and/or its basin are a net source for phosphorus.

The metals and chloride exhibited variable responses across Lake St Clair in 1984. The concentration of total iron in both whole water and in suspended solids was greater at the head of the Detroit River than at the mouth of the St. Clair River, while that of zinc was greater only associated with suspended solids. Lead and mercury concentrations tended to be greater in the Detroit River than in the St. Clair River, but cross channel differences were detected. Chloride concentrations were not observed to be different in the two river reaches.

TABLE VIII-3

Concentrations of total phosphorus, chlorides and metals in whole water and suspended solids from the mouth of the St. Clair River and the head of the Detroit River, 1984, range and (mean)a.

Whole Water

Location	Fe mg/L	Pb ug/L	Hg ug/L	Zn ug/L	TP ug/L	Chloride mg/L
St. Clair River						
North Channel	0.054-0.220 (0.130)	<3	<0.01	0.5-3.0 (1.5)	6-12 (8.8)	5.77- 6.82 (6.30)
South Channel	0.063-0.170 (0.085)*	<3	<0.01	0.5-5.0 (2.4)	7-10 (8.5)	7.82-10.94 (9.06)
Detroit River						
West side	0.088-0.380	<3	<0.01	0.3-3.0	9-21 (14.0)	7.09-12.45 (9.0)
East side	0.130-0.920	<3	<0.01	0.5-1.0	12-20 (15.5)*	7.34-11.93 (9.1)

Suspended Solids

	Fe mg/g	Pb ug/g	Hg ug/g	Zn ug/g	TP mg/g	Sus.Solids mg/L
St. Clair River						
North Channel	16-22 (19.0)	10-26 (20.5)	0.03-0.14 (0.09)	74-86 (81.0)	0.5-1.0 (0.8)	5.6-12.7 (8.3)*
South Channel	14-18 (16)	25-49 (40)	0.16-0.35 (0.27)	70-110 (81.5)	0.6-1.0 (0.8)	5.6-11.1 (7.1)
Detroit River						
West side	21-31 (25.3)	39-62 (52.5)	0.06-0.17 (0.18)	110-130 (120)	1.2-1.6 (1.4)	4.6-22.2 (5.5)*
East side	21-34 (26.0)	36-40 (38.3)	0.17-0.47 (0.32)	93-130 (111)	1.2-2.2 (1.5)	5.3-16.3 (6.9)*

a from Johnson and Kauss (8).

* denotes median value instead of mean.

Biota

i) Plankton

In 1984, relatively high biomass concentrations of phytoplankton were recorded during early June (1.17 g/m^3) compared to that in late July (0.27 g/m^3)(9). In spring, the species composition was dominated by Diatomeae (67-90%), with significant contributions from Chrysophyceae and Cryptophyceae phytoflagellates. During summer, the community structure was equally composed of Chrysophyceae (34%) and Diatomeae (34%). From May through September, Chlorophyta (greens) contributed only once substantially, during late July (24%). The contribution from Cyanophyta (blue-greens) was relatively low.

Zooplankton abundance in Lake St. Clair in June and July, 1984, ranged from 35 to 93 organisms/L, and from 500 to 1,500 ug/L in total biomass (10). These densities are among the highest reported for the Great Lakes. Cladocerans were proportionately dominant in both numbers and biomass. This pattern of cladoceran predominance is in contrast to the other Great lakes in which copepods routinely dominate to a much greater extent. Lake St. Clair is a more typical cladoceran habitat than the other lakes, because it is shallow, more productive, and may not contain dense populations of planktivorous fish to which cladocerans are particularly vulnerable. In addition, the high flushing rate of Lake St. Clair may favor species with shorter generation times. Large zooplankters such as Holopedium and Leptodora were not abundant. Copepods comprised approximately 1/3 numerically and 40-50% by biomass of the zooplankton community.

ii) Macrophytes

At least 12 submersed plant taxa occur in Lake St. Clair (11,12). Common native taxa are Chara sp. (macroalga), Vallisneria americana, Potamogeton richardsonii, Elodea canadensis, Potamogeton sp. (narrow-leaved forms), and Najas flexilis. Chara sp. includes Nitella sp. and muskgrass, both of which overwinter as green plants. Nitella is often found in deeper water to a depth of 27 m where few other plants are present. Submersed plant stands in the lake are usually composed of 2-3 species, and most occur at depths less than 3.7 m. The 0.0 to 3.7 m depth interval in Lake St. Clair covers approximately 628 km^2, and plant coverage of the bottom within this depth interval is 35%. Estimated annual production of submersed aquatic plants in Lake St. Clair is 13,780 tonnes ash-free dry weight (13).

No detailed studies on species composition, distribution and relative abundance of emergent macrophytes in Lake St. Clair have been completed. The estimated total areal extent of emergents in the lake in the late 1970s was 9,170 ha (14). Estimated production of emergent aquatic plants in Lake St. Clair is 60,990 tonnes ash-free dry weight/yr (13).

The drift of live (chlorophyllous) submersed plant matter out of Lake St. Clair in the surface waters was measured in 1986 (15). Of the 6 submersed plant and macroalgae taxa present in drift samples collected from April through October 1986 immediately below Belle Isle near the head of the Detroit River, Vallisneria americana, Potamogeton richardsonii, and Myriophyllum spicatum occurred most frequently. Substantial drift occurred in all months. Drift biomass was lowest in April and highest in September at 14 and 1,183 g wet weight/1000 m^3 filtered). The submersed plant biomass leaving Lake St. Clair as surface drift during April to October, 1986, was calculated to be 32,052 tonnes wet weight or about 1,602 tonnes ash-free dry weight. This calculation may underestimate the biomass of macrophyte drift because the Detroit River discharge in 1986 was probably greater than the 1900-1980 average that was used for river flow. Concern exists that the drift of plant material containing contaminants may facilitate the dispersal of contaminants within the UGLCC Study area, including western Lake Erie.

iii) Benthos

Lake St. Clair supports a healthy and diverse community of benthic fauna. Nematoda, Amphipoda, Diptera (Chironomidae), Ephemeroptera, Trichoptera, Gastropoda, and Pelecypoda are abundant in the St. Clair River system. The taxonomic diversity of macrozoobenthos in Lake St. Clair (65 taxa) was lower than that in the St. Clair River (98 taxa) and the Detroit River (80 taxa), however (12).

In 1985, a total mean density of mayfly (Hexagenia) nymphs of 194 nymphs/m^2 was found throughout the UGLCC Study area, including 279 nymphs/m^2 in Lake St. Clair. The maximum density was also found in Lake St Clair at 3,099 nymphs/m^2. Nymphal production ranged from 165 to 2,321 mg dry wt./m^2/yr in the study area, with a maximum rate of 4,011 mg dry wt./m^2/yr at the single location studied in Lake St. Clair. The river production values were similar to the range of values reported in the literature, but production in Lake St. Clair was about twice the highest published value.

Macroinvertebrate taxa were identified at 47 sampling stations in Lake St. Clair in 1983 (16). Six benthic invertebrate communities were identified with different species assemblages (Table VIII-4). Two communities occurred generally in the shallow periphery of the lake, three communities were found in the deeper waters, and one was present in the St. Clair River and mouth of the Thames River (Figure VIII-1). Discriminant analysis suggested that the six communities were associated with different environmental conditions. The "shallow periphery" communities occurred at sites with coarser, sandy sediments and lower con-

TABLE VIII-4

Species composition (mean number per 516 cm2) of benthic communities in Lake St. Clair, May 1983. P denotes a mean density of less than one individual per sample. Communities are grouped by habitat type (16).

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	LAKE--SHALLOW		LAKE--DEEP			RIVER
AQUATIC CATERPILLARS:						
Pyralidae		P			P	P
BEETLES:						
Dubiraphia		P			P	P
TRUE BUGS:						
Corixidae	1.3	P				
CADDISFLIES:						
Cheumatopsyche		P				P
Hydropsyche		P				P
Ceraclea		P				P
Mystacides		P		P		P
Oecetis		P	P	P		P
Setodes		P				
Molanna	P					P
Neureclipsis						P
Phylocentropus			P		P	P
MAYFLIES:						
Baetisca		P				
Caenis	P	P				1.7
Eurylophella	P	P				
Serratella						P
Ephemera				P		
Hexagenia	P	P	16.9	17.0	44.2	3.3
Stenonema						P

TABLE VIII-4. (cont'd 2)

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	LAKE--SHALLOW		LAKE--DEEP			RIVER
TRUE FLIES:						
Ceratopogonidae	16.3	P	P		1.0	3.2
Chaoborus					1.3	
Chironomus	P	P	5.4	2.1	7.2	P
Cladopelma	P	P				
Cladotanytarsus		P				
Cryptochironomus	1.9	2.4	1.3	1.5	27.2	2.8
Demicryptochironomus	P	P	P	P	16.8	
Dicrotendipes			P		1.7	P
Harnischia				P		
Microtendipes			P			
Nilothauma		P				
Paratanytarsus						P
Phaenopsectra						P
Polypedilum	13.0	2.2	2.2		13.5	29.3
P. illinoensi	13.2	P				2.0
Pseudochironomus	P	7.5	3.3	P		24.9
Rheotanytarsus		P				
Stictochironomus	P	4.0	7.2	P	6.2	44.7
Tanytarsus				P		
Tibelos			5.7	P	8.8	98.5
Pothastia	P	P	P	P	P	
Epicocladius			P	P	P	
Heterotrissocladius		P	P			
Hydrobaenus	P		1.1		1.0	P
Cricotopus/Orthocladius	P	P				7.3
Parkiefferiella?	P	1.5	P	P	P	
Monodiamesa		P			P	P
Ablabesmyia		P	P	2.0	3.7	P
Clinotanypus		P		P	P	P
Coelotanypus	P	1.1	2.2	6.0	1.5	

TABLE VIII-4. (cont'd 3)

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	LAKE--SHALLOW		LAKE--DEEP			RIVER
Djalmabatista			P		P	
Procladius	P	P	6.6	5.2	16.7	7.5
Thienemannimyia-gp		P				P
Empididae	P					
CRUSTACEANS:						
Gammarus		5.4	14.5	P	2.0	22.7
Hyalella azteca		P	2.1			2.6
Asellus			4.4			1.2
Lirceus			P			5.3
CLAMS:						
Pisidium		2.8	P	1.1	6.5	4.8
Sphaerium		1.2	1.3	P	P	
Unionidae		P	P	P		
SNAILS:						
Bithynia	P		P	P		
Amnicola		P	1.9			
Probythinella		P	P	P	P	P
Somatogyrus		P	P	P		
Fossaria		P				
Lymnaea						P
Physa		P	P			10.3
Goniobasis		2.4	1.0	P		P
Pleurocera		P		P		
Valvata		P	P			P
LEECHES:						
Erpobdellidae			P			P
Glossiphonidae			P	P		P

TABLE VIII-4. (cont'd 4)

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	LAKE--SHALLOW		LAKE--DEEP			RIVER
POLYCHAETES:						
Manaynunkia speciosa		P	2.2	P	P	
WORMS:						
Lumbricidae			P		P	2.6
Stylodrilus herringianus		P	P		P	1.8
Naididae	P	P	P	P	1.3	P
Aulodrilus americanus				P		1.3
A. pleuriseta				P		
Branchiura sowberbyi			P	2.4		P
Isochaetides curvisetosus		P				
Ilyodrilus templetoni		P		P		P
Isochaetes freyi		P				P
Limnodrilus angustipenis			P			
L. cervix	P			P		3.9
L. claparedianus	P	P	3.6	P	P	1.0
L. Hoffmeisteri	P	1.9	5.7	4.2	14.5	10.1
L. maumeensis		P			5.7	P
L. udekemianus		P			3.0	1.0
Potamothrix moldaviensis	3.1	P		P	1.2	5.5
P. vejdovskyi	P	P	P			
Quistadrilus multisetosus					9.8	10.2
Spirosperma ferox	P	5.4	21.7	P	2.8	12.4
NEMATODES	P	3.3	11.2	11.5	12.2	P
FLATWORMS		P	P	1.1	2.8	13.9
MEAN NUMBER OF TAXA	6.8	10.4	15.4	10.2	18.8	20.9
MEAN DENSITY OF ORGANISMS	60.3	60.9	141.9	80.4	253.3	369.5

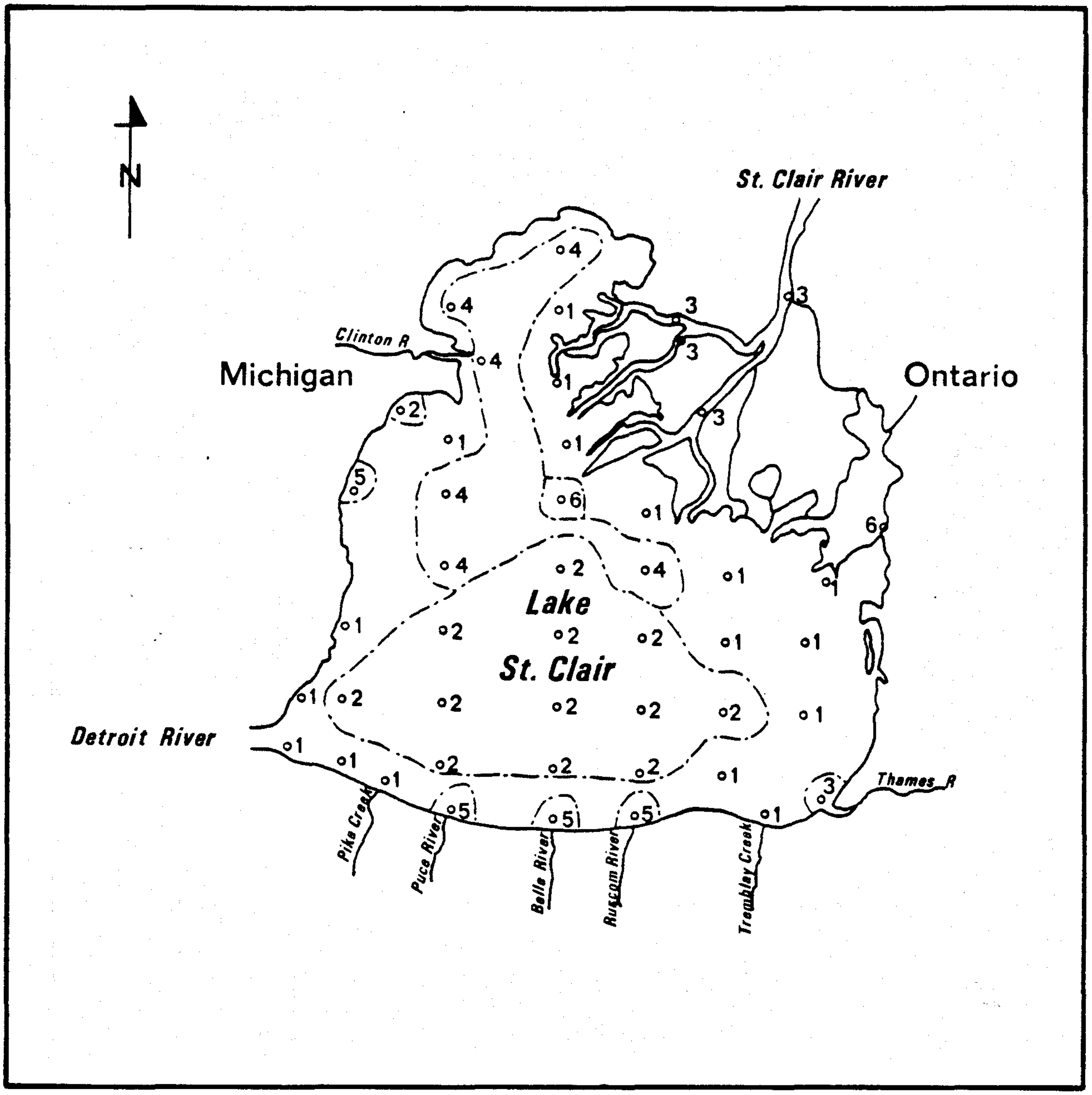

FIGURE VIII-1. Distribution of benthic invertebrate communities in Lake St. Clair, Anchor Bay and the St. Clair River, May 1983 (16).

centrations of metals, organic carbon and nutrients relative to the "deeper water" communities (Table VIII-5). Poor correlations were found between the measured physicochemical variables and the community separations, however, implying that one or more additional variables were influencing the community structure.

Based on the distribution of the benthic communities, mesotrophic conditions prevailed in the central basin of the lake and Anchor Bay and in the lower part of the St. Clair River, while oligo-mesotrophic conditions were present in the shallower nearshore areas of the lake and Anchor Bay. Neither the St. Clair or Thames rivers had any perceivable effect on the environmental quality of the lake. Impairment of environmental quality was observed at the mouths of the Puce, Belle, and Ruscom rivers and near a sewer outfall from St. Clair Shores, Michigan. The locally impaired environmental quality may be related to the discharge of oils and grease into the lake. In addition, reduced environmental quality related to organic matter enrichment was observed in deeper parts of the study area near the St. Clair River delta.

Concentrations of lead (up to 40 ppm), cadmium (up to 19 ppm) and octachlorostyrene (OCS, up to 0.15 ppm) in Lake St. Clair clams were generally highest in that portion of the lake which receives the majority of the St. Clair River discharge, i.e., adjacent to the South Channel outlet. There are no Michigan or Ontario guidelines or objectives for OCS or Cd in fish.

In contrast, the concentration of PCBs in clams, up to 0.7 ppm exhibited a different distribution with highest concentrations along the southwest shore of the lake rather than in the St. Clair River (17). By comparison, the GLWQA includes a specific objective of 0.1 ppm PCBs in whole fish. A positive correlation between clam tissue and sediment concentrations was observed only for PCBs and OCS, however, suggesting that sediment distribution patterns of lead and cadmium may not provide much information on contaminant exposure of clams.

iv) Fish

The fish community of Lake St. Clair is diverse and abundant, consisting mainly of warm-water and mesothermic species. Cold-water species are found in the lake, but not as year-round residents. Of the more than 70 species recorded as native or migrants, 34 use the lake for spawning (18). Most of the 28 native species spawn in shallow water along the delta (St. Clair Flats) or other shoreline areas or in tributaries to the lake. Of the exotic species, rainbow smelt and sea lamprey spawn in tributaries, and alewives, carp, goldfish and gizzard shad spawn in bays, marshes and other shallow areas.

Because of the proximity of Lake St. Clair to large urban populations, recreational fisheries are active year-round. In Michigan

TABLE VIII-5

Mean values (geometric mean) of physicochemical sediment variables associated with the benthic communities in Lake St. Clair, May 1983. All units are expressed as mg/kg unless otherwise stated. Communities are grouped by habitat type (16).

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	Lake-Shallow		Lake-Deep			River
Fe (g/kg)	6.14	6.79	8.96	14.16**	12.96**	9.43
Al (g/kg)	2.31	2.73	5.43	8.87	8.65	4.83
Cd	0.10	0.12	0.28	0.40	0.50	0.38
Cr	8.75	9.67	15.26	23.89	24.42	12.93
Cu	2.89	3.81	10.24	17.86	22.56	15.06
Hg	0.01	0.07	0.17	0.49**	0.32**	0.23
Ni	4.26	4.61	9.26	15.69	15.97	9.68
Pb	2.35	3.62	13.69	23.11	24.46	15.07
Zn	13.69	20.33	41.17	62.03	65.68	50.92
Oil and Grease (g/kg)	0.59	0.31	0.53	0.79	1.09*	0.26
Loss-On-Ignition(%)	0.65	0.59	1.62	2.45	3.77	3.30
Total Organic Carbon	1.42	2.36	11.50	15.62	24.82	19.87
Total-P (g/kg)	0.20	0.21	0.25	0.48*	0.44*	0.38
Total Kjeldahi-N (g/kg)	0.22	0.22	0.51	0.79	1.18*	1.05*
Grain Size (phi units)	1.58	1.86	3.90	4.65	4.30	3.76

Based on the U.S. EPA Guidelines for Pollution Classification of Great Lakes Harbour Sediments (22):

* Means that the sediment is considered moderately polluted

** Means that the sediment concentration exceeds the Ontario Ministry of the Environment's Guidelines for Open Water Disposal (22).

waters, yellow perch (59%) and walleye (18%) were the main species harvested by boat anglers in 1983-1984. In Ontario waters in 1986, the main species were walleye (59%), yellow perch (24%) and smallmouth bass (4.6%). Yellow perch dominated the ice fishery.

PCB concentrations in edible portions of walleye and yellow perch were approaching 0.25 ppm and 0.05 ppm, respectively, in 1985 (7). These concentrations are below the U.S.Food and Drug Administration (U.S.FDA) action level of 2 ppm, but the concentration in walleye exceeded the GLWQA specific objective of 0.1 ppm for whole fish.

The concentration of mercury in the edible portions of walleye, northern pike, white bass and yellow perch were approaching 0.3 to 1.0 ppm in 1985. These concentrations of mercury do not exceed the U.S.FDA action level of 1 ppm, but they do in some cases exceed the Ontario objective.

Habitat Alterations

Of an estimated 22,366 ha of wetlands that existed in Lake St. Clair in 1873, more than 9,000 ha were lost to shoreline development by 1968. Losses are most evident in the Clinton River, the St. Clair delta and the eastern shore of the lake. In all three areas, the margins of the wetlands have been modified. On the eastern shoreline the wetlands at one time were approximately 2.5 km wide, but now they are about 0.8 km in width.

In Ontario, wetlands are currently being lost to agriculture. The wetlands from the Thames River north to Chenal Ecarte dwindled from 3,574 ha in 1965 to 2,510 ha in 1984 (19) Draining for agriculture accounted for 89% of the wetland loss, whereas marina and cottage development consumed the remaining 11%. During the record high lake level in the early 1970s, about 1,000 ha of emergent shoreline marsh from Mitchell Bay southward to the Thames River were also temporarily lost (20). This loss was tempered in part by the flooding of transition vegetation which occurred on the upland (east) margin of the wetlands.

The St. Clair delta and the Anchor Bay area in Michigan are also subject to flooding, but the recent wetland losses there are due mainly to diking and filling for urban development. In the Clinton River area, wetland losses occurred from both landward and lakeward boundaries and the remaining wetlands are now isolated from Lake St. Clair.

Navigation-related dredging has also altered aquatic habitat within Lake St. Clair. In the 1950s, the minimum channel depth in the St. Clair River, South Channel and Lake St. Clair was dredged to 8.2 m as part of the Great Lakes-St. Lawrence Seaway.

Navigation dredging projects have altered the flow regimes of Lake St. Clair and replaced productive shoal water habitat with less productive channel habitat. Bulkheading, dredging and backfilling by landowners has also resulted in the loss of significant amounts of littoral habitat in the system. The loss of shoal and littoral waters, along with the removal of gravel and the lack of delta growth represent loss of habitat that is utilized by many Great Lakes fishes to satisfy spawning and other early life history requirements.

Bottom Sediments

i) Physical Characteristics

The thickness and grain size distribution of bottom sediments is an important aid to understanding the transport, accumulation and resuspension of polluted sediments in Lake St. Clair. Based on a coring survey completed in 1986, the modern sediment thickness corresponds roughly with lake depth (21). The maximum thickness of over 30 cm is generally confined to the St. Clair River delta and a narrow band extending from the delta southwest toward the head of the Detroit River (Figure VIII-2).

Analysis of grain size distribution, based on 1984 data (21), indicated the most common size interval in sediment samples to be 0.063 to 0.125 mm (3-4 PHI units). This size particle occurred as a band trending NW-SE across mid-basin and in the north and eastern portions of Anchor Bay. Coarser unimodal sediment (0.125 to 0.500 mm, 1 - 3 PHI units) was present opposite the Chenal Ecarte and Clinton River mouths on the northeast and west coasts, and in the central portion of Anchor Bay. Coarser bimodal sediments with gravel and sand modes occurred along the south and southwest shores. Size modes finer than sand (0.063 mm, 4 PHI units) were found only in a small area in the western part of the central basin.

The distribution of sediment composition based on percentage gravel, sand and silt-clay (mud) was similar to that observed for the modal size distribution. Gravel content was generally less than 1% with the exception of the south and southwest margin of the lake where it ranged from 5 to 45%. Sand was the major component of the surface sediments and ranged from 30 to 100%. The highest percentages of sand occurred at the mouths of the delta distributary channels and in the south and southwest area of the lake. Percent silt and clay (muds) ranged from 1 to 68% with highest percentages in the west-central part of the basin (Figure VIII-3).

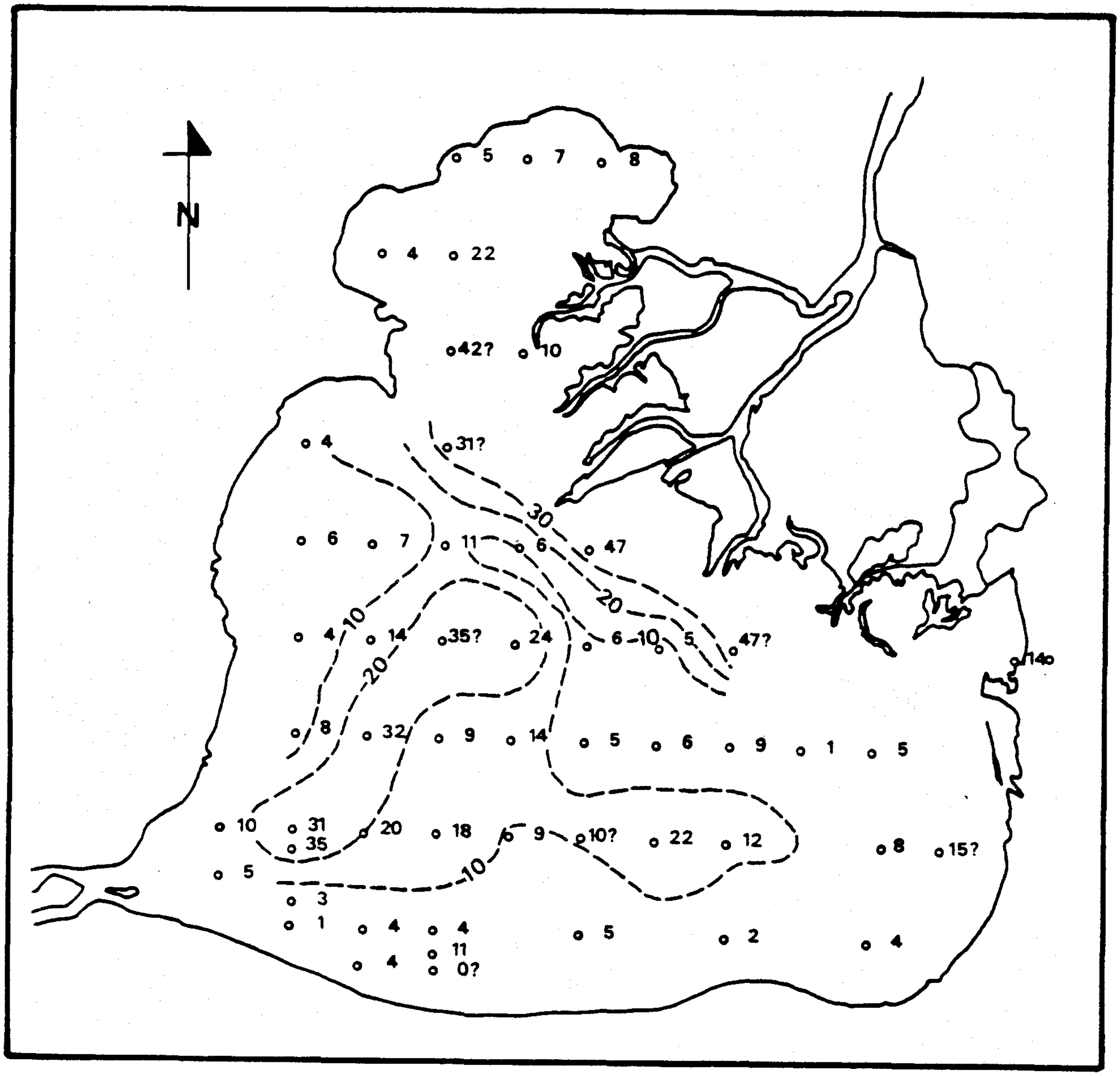

FIGURE VIII-2. Thickness of modern sediment (cm).

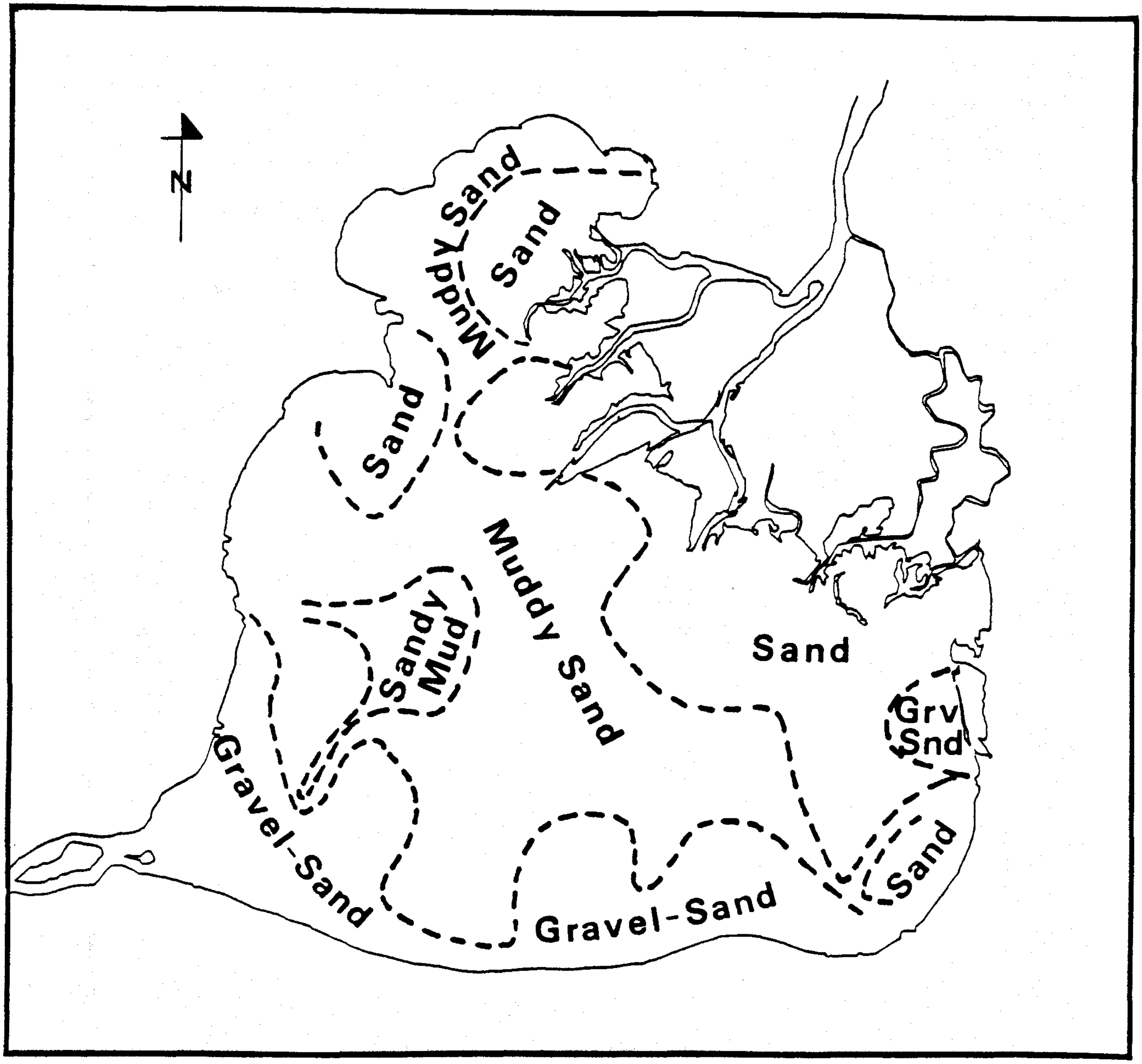

FIGURE VIII-3. Distribution of sediment types.

ii) Evidence of Historical Inputs of Contaminants

Organic Contaminants:

Distributions of hexachlorobenzene (HCB), octachlorostyrene (OCS), polychlorinated biphenyls (PCBs), hexachlorobutadiene (HCBD), pentachlorobenzene (QCB) and total DDT plus degradation products in Lake St. Clair surficial sediments (0-1 cm) in 1985 are shown in Figure VIII-4. The data were derived from the sampling pattern identified in Figure VIII-5. The highest contaminant concentrations were found near the centre of the lake in the region of greatest water depth, thickest layer of recent sediments over glacial clay, and greatest accumulation of fine-grained sediment. Some minor accumulation of contaminants also was found in Anchor Bay at the northern end of the lake. For the most part, the sediments in the rest of the lake were sandy, and contained low concentrations of organic contaminants. Although the mean contaminant concentrations were not particularly high compared to other areas in the Great Lakes Basin, with the possible exception of HCB, the maximum concentrations reached significant levels for many of the Sarnia-source contaminants (Table VIII-6).

In most, but not all, instances, higher concentrations of PCBs were found at greater depths in the sediments in 1985, corresponding qualitatively with the loading history of PCBs. The highest concentrations, 0.06 ppm, exceeded the Ontario Ministry of Environment (OMOE) Guidelines for Dredged Spoils for Open-Water Disposal and the IJC Guidelines for In-water Disposal of Dredged Materials of 0.05 ppm. However, these concentrations did not cause the lake to be classified as "polluted" by U.S.EPA Pollutional Classification Guidelines for Great Lakes Harbour Sediments where sediments containing greater than 10 ppm PCBs are classified as "polluted". PCBs were also found in the Cottrell Drain and at the mouth of the cutoff channel of the Clinton River at concentrations of 2.0 and 0.6 ppm, respectively. Up to 0.03 ppm PCBs were found in the Sydenham River, based on two samples.

Two localized areas of high HCB sediment concentrations were found in Lake St. Clair in 1985. One was in the central portion of the lake, and another was in the eastern section, northwest of the mouth of the Thames River. The maximum concentration found was 0.17 ppm. HCB was also detected in sediments of the Milk River (0.003 ppm), Marsac Creek (0.002 ppm), Swan Creek (0.002 ppm), Sydenham River (0.007 ppm) and the Thames River (0.001 ppm). No specific guidelines exist for HCB in sediments.

The highest concentration of OCS, 0.021 ppm, was found in the central portion of the lake. OCS was detected in sediments of the Sydenham River (0.001 ppm), but information on OCS in sediments of U.S. tributaries is not available. No specific guidelines exist for OCS in sediments.

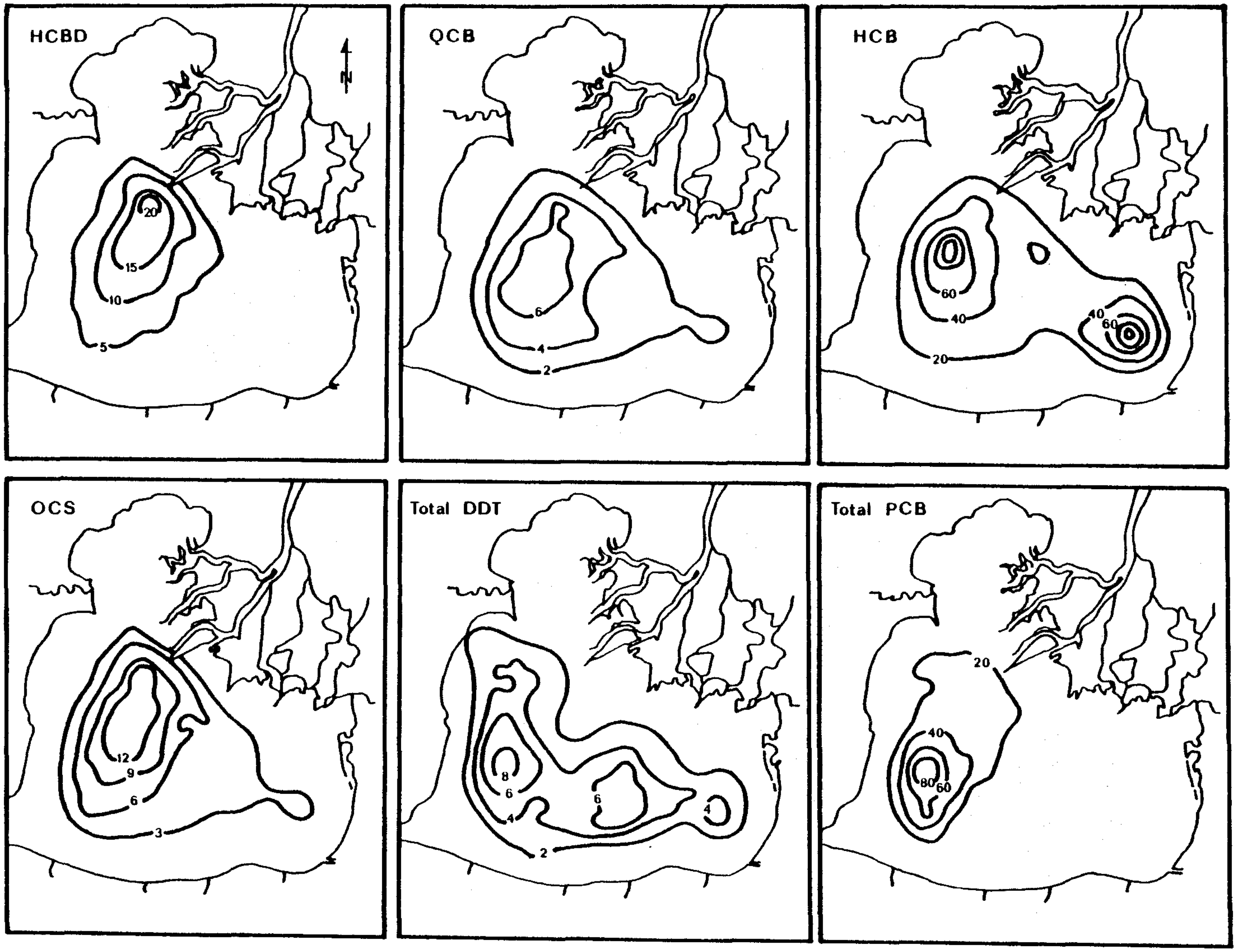

FIGURE VIII-4. Distribution of contaminants in Lake St. Clair surficial sediments (mg/kg).

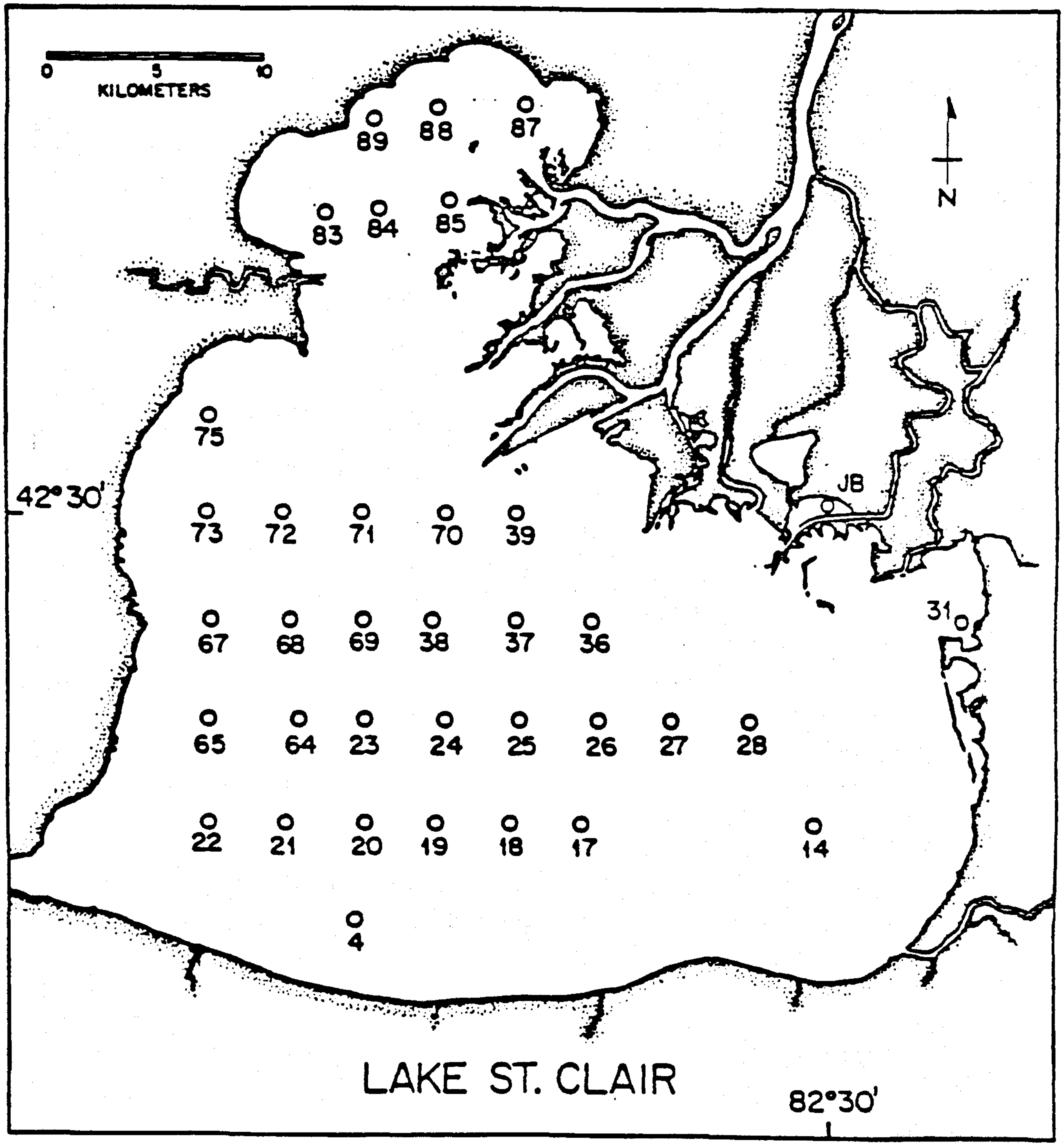

FIGURE VIII-5. 1985 Lake St. Clair sediment core stations.

TABLE VIII-6

Chlorinated organic compounds in surficial (0-1 cm) sediments of Lake St. Clair (ug/kg).

Compound	Range	Mean
Hexachlorobenzene (HCB)	0.4-170	32
Octachlorostyrene (OCS)	ND-21	4.8
PCBs	ND-21	19
Hexachlorobutadiene (HCBD)	ND-32	5.4
Pentachlorobenzene (QCB)	ND-8.7	3.2
Total Trichlorobenzene (TCB)	ND-28	4.3
Total Tetrachlorobenzene (TeCB)	ND-20	3.7
Total DDT and metabolites (SDDT)	ND-12	3.8

Information on PAHs in Lake St. Clair sediments or in Canadian tributaries was not available. In U.S. tributaries, PAHs were found in surficial sediments at concentrations ranging from 0.4 to 14.3 ppm. The highest concentrations were found in the Milk River (14.3 ppm), Cotrell Drain (13.8 ppm), Clinton River (12.1 ppm) and Frog Creek (10.7 ppm). No specific guidelines exist for PAHs in sediments.

Cyanide of a concentration up to 0.7 ppm was found in the Clinton River sediments. In Lake St. Clair sediments, three samples near the southeast shore and one sample south of the Clinton River were reported to contain 0.5 to 0.8 ppm cyanide, although these values were reported to be below the analytical criterion of detection. These concentrations exceed the OMOE and IJC Guidelines of 0.1 ppm, and cause a classification of "heavily polluted" by U.S.EPA classification guidelines. Information on cyanide in Canadian tributaries was not available.

High concentrations of oil and grease (up to 3,700 ppm) were also found in the Clinton River. This concentration exceeds the OMOE and IJC Guideline of 1,500 ppm, and causes a classification of "heavily polluted" by U.S.EPA Classification Guidelines. Of 45 stations sampled in Lake St. Clair in 1985, the sediments in only 3 contained between 597 and 637 ppm oil and grease. The rest contained less than 343 ppm, causing a classification of "unpolluted" by U.S.EPA Classification Guidelines. Oil and grease results from 1984 indicated levels between 635 and 707 ppm for Canadian tributaries. Somewhat elevated levels were determined from 1985 samples, with a peak of 3,131 ppm obtained from Sydenham River sediments. Concentrations from the Belle and Thames Rivers and Pike Creek were 433, 792 and 1,018 ppm, respectively.

Metal Contaminants:

Concentrations of metals measured in surficial (0-1 cm) layers of the sediment samples collected in 1985 (Figure VIII-5) indicated that some enrichment of cadmium and zinc has occurred over the average concentrations of metals in surficial sediments in Lake Huron (22). For Cd and Zn, 22 and 21 samples respectively, of 36 samples collected, had concentrations elevated above the Lake Huron averages of 1.4 and 62 ug/g respectively (Table VIII-7). The concentrations generally remained below OMOE, IJC and U.S.EPA guidelines, however, except for the region near to the mouth of the Clinton River. Sediments from the Clinton River were found to contain up to 6.3 ppm Cd and 430 ppm Zn, both of which exceed U.S. Classification Guidelines for heavily polluted sediments of 6 ppm and 200 ppm respectively. The Milk River sediments also exceeded the guidelines with 380 ppm Zn.

Concentrations of chromium, copper, nickel and lead were mostly below the Lake Huron averages, and below OMOE, IJC and U.S.EPA

TABLE VIII-7

Concentrations of metals (mg/kg) and total carbon (weight percent) in surficial sediment samples from Lake St. Clair.

Station	Interval	Bismuth	Total Carbon	Cadmium	Chromium	Copper	Nickel	Lead	Antimony	Zinc
LSTCL-85-04	0-1	.182	3.94	2.70	43.1	23.0	32.6	34.3	.180	84.9
LSTCL-85-14	0-1	.273	4.84	2.22	61.3	34.2	34.0	31.6	.254	130.
LSTCL-85-17	0-1	.208	4.42	3.71	54.2	26.4	40.8	31.0	.281	103.
LSTCL-85-18	0-1	.185	4.73	2.87	39.4	26.1	33.3	37.8	.182	90.7
LSTCL-85-19	0-1	.160	4.02	2.10	36.8	20.7	32.4	30.6	.126	81.8
LSTCL-85-20	0-1	.236	3.89	1.35*	34.3	23.5	29.3	35.2	.170	84.4
LSTCL-85-21	0-1	.241	4.36	2.34	30.1	24.6	25.7	40.0	.160	80.4
LSTCL-85-22	0-1	.147	3.75	1.93	39.7	19.1	33.2	13.6	.234	60.0
LSTCL-85-23	0-1	.258	4.74	2.11	39.2	32.2	33.5	41.1	.173	92.8
LSTCL-85-24	0-1	.242	4.86	2.23	41.5	29.5	32.0	46.0	.287	91.8
LSTCL-85-25	0-1	.179	3.27	2.60	38.2	20.4	30.3	28.8	.156	83.6
LSTCL-85-26	0-1	.176	4.61	3.25	41.4	23.3	32.0	29.3	.176	89.1
LSTCL-85-27	0-1	.162	3.78	1.86	38.0	20.1	32.0	29.8	.151	82.1
LSTCL-85-28	0-1	.0587	1.06	1.48*	17.7	5.10	14.7	12.2	.0707	41.4
LSTCL-85-31	0-1	.0616	2.96	1.48*	22.9	9.46	20.4	11.8	.0796	39.7
LSTCL-85-36	0-1	.130	-0	2.23	28.8	16.4	25.8	26.7	.132	71.7
LSTCL-85-37	0-1	.109	3.11	2.23	25.6	14.6	22.4	19.5	.0935	62.9
LSTCL-85-38	0-1	.146	4.76	2.06	24.9	24.5	23.1	32.0	.155	73.8
LSTCL-85-39	0-1	.0578	2.38	1.67*	16.3	9.08	15.2	8.42	.0921	41.5
LSTCL-85-64	0-1	.180	5.18	2.74	34.9	33.0	31.2	33.4	.211	89.1
LSTCL-85-65	0-1	.0921	3.30	1.16*	23.8	14.5	20.8	21.0	.173	62.0
LSTCL-85-67	0-1	.137	2.96	1.66*	22.6	12.9	22.9	25.2	.129	57.7
LSTCL-85-68	0-1	.168	3.62	1.66*	20.9	23.3	26.1	29.5	.230	78.2
LSTCL-85-69	0-1	.226	5.27	2.44	36.3	33.0	29.8	33.2	.236	90.7
LSTCL-85-70	0-1	.0687	2.75	2.25	17.4	10.1	15.2	20.9	.0689	47.6
LSTCL-85-71	0-1	.152	5.13	1.02*	23.4	20.6	21.9	24.5	.197	82.0
LSTCL-85-72	0-1	.0921	2.48	1.22*	18.7	11.2	18.8	11.4	.122	47.4
LSTCL-85-73	0-1	.0644	.970	1.39*	18.2	6.86	14.7	12.7	.0645	38.0
LSTCL-85-75	0-1	.0734	.965	1.23*	18.4	8.69	15.9	17.5	.0652	50.4
LSTCL-85-83	0-1	.119	1.76	1.48*	21.0	10.3	17.4	13.0	.0858	41.8
LSTCL-85-84	0-1	.126	3.45	2.38	21.1	13.8	18.8	17.4	.148	55.7
LSTCL-85-85	0-1	.0382	1.27	1.66*	16.3	5.11	9.74	-.525*	.0481	31.8
LSTCL-85-87	0-1	.114	2.87	3.04	18.9	14.0	19.2	13.6	.138	84.7
LSTCL-85-88	0-1	.122	2.96	2.20	24.1	13.8	19.5	16.5	.162	57.0
LSTCL-85-89	0-1	.131	2.32	2.29	24.9	12.1	18.9	14.4	.144	49.1
LSTCL-85-JB	0-1	.125	4.89	1.36*	22.9	15.1	19.6	32.6	.110	69.7

* Below limit of detection
-0 = No data

Guidelines, except for an area near to the mouth of the Clinton River. The distribution of the metals in Lake St. Clair sediments did, however, indicate greater concentrations in the central, south and southeast areas than in the north and west areas. Concentrations of lead and copper in the Clinton and Milk Rivers, and of Ni in the Clinton River exceeded the OMOE and IJC Guidelines, and cause a classification of "heavily polluted" according to U.S.EPA Classification Guidelines.

Mercury (Hg) enrichment in the surface sediments was confined to central Lake St. Clair, where up to 1.2 ug/g dry weight was found. By comparison, surficial sediments in Lake Huron contain an average of 0.22 ug/g (22). Except for the central area, most of Lake St. Clair surficial sediments contained less than 0.3 ug Hg/g, the value for OMOE and IJC Guidelines. The concentration profiles of Hg in at least three cores in 1985 indicated lower concentrations of Hg at the surface of the cores than at a depth of 5-6 cm, thereby implying the deposition of less contaminated recent material. The background concentrations deep in the core, however, were less than 0.1 ug Hg/g. Concentrations of Hg in Clinton River sediments were found up to 0.7 ppm, exceeding the OMOE and IJC Guidelines, but not U.S.EPA Classification Guidelines for "polluted" sediments.

The depth-integrated concentrations of metals in cores from the same samples as above were generally similar to those in the surficial sections, except for significantly greater concentrations of Cd in the composited samples (Table VIII-8). Using the guidelines for OMOE evaluations of dredging projects for sediment contaminated by metals, which are roughly equivalent to U.S.EPA guidelines for moderately polluted sediments (22), the guidelines were exceeded in 100%, 75%, 36% and 8% of the cores for Cd, Cr, Ni and Cu respectively.

In a separate study of surficial sediments conducted in 1985 in which sampling sites were selected specifically to collect fine-grained sediments capable of supporting mayfly (Hexagenia) nymphs, sediment at only 2 of the 45 stations were heavily polluted with mercury. Sediments at 2-9 (4-20%) of the stations were moderately polluted with nickel, copper, chromium and zinc. Five to 10 (11-22%) of the stations sampled contained mercury, PCBs or copper in excess of OMOE guidelines for contaminated sediments. Concentrations of contaminants were generally highest in sediments at stations near L'anse Creuse Bay offshore of the Clinton River Cutoff Canal. A 1984-85 study of Canadian tributary mouths indicated that Provincial dredging guidelines were exceeded at a number of tributaries for chromium, copper, iron and nickel. An assessment of heavy metal concentrations measured on suspended solids (RSP) indicated a higher frequency of guideline exceedence.

TABLE VIII-8

Concentrations of metals (mg/L) in composited sediment samples from Lake St. Clair.

Station	Bismuth	Calcium	Cadmium	Chromium	Copper	Iron	Magnesium	Manganese	Nickel	Lead	Antimony	Zinc
LSTCL-85-04	.231	48500.	3.11	47.0	22.7	32100.	20100.	428.	32.8	24.3	.149	80.8
LSTCL-85-14	.194	47000.	2.83	42.8	24.3	29300.	15200.	392.	31.2	24.2	.174	84.9
LSTCL-85-17	.166	49500.	4.35	34.1	19.1	23500.	25700.	366.	25.0	17.7	.151	67.1
LSTCL-85-18	.180	54800.	4.19	31.7	17.4	22400.	24800.	367.	24.5	19.4	.168	62.9
LSTCL-85-19	.150	67300.	2.56	29.5	16.5	23800.	25500.	400.	24.2	17.4	.161	60.6
LSTCL-85-20	.193	47200.	4.10	33.1	16.5	23900.	25100.	348.	23.8	18.6	.172	63.0
LSTCL-85-21	.173	42000.	3.45	30.2	19.1	22900.	28100.	366.	25.0	19.3	.155	60.4
LSTCL-85-22	.179	63400.	3.46	33.0	19.1	25000.	20700.	300.	25.6	14.9	.193	62.8
LSTCL-85-23	.175	64600.	3.72	29.5	22.6	23500.	29300.	339.	28.1	23.4	.165	67.1
LSTCL-85-24	.226	57200.	4.63	30.7	20.9	23800.	27200.	347.	29.6	23.0	.140	69.5
LSTCL-85-25	.186	54700.	3.91	33.0	21.7	23800.	25500.	353.	27.7	22.6	.146	71.7
LSTCL-85-26	.132	62200.	4.35	28.1	15.6	22300.	23800.	359.	25.6	10.5	.164	56.1
LSTCL-85-27	.148	64700.	6.15	31.6	18.2	22600.	24000.	373.	25.0	18.6	.108	62.8
LSTCL-85-28	.158	71000.	2.74	40.5	21.7	33000.	15900.	446.	30.2	18.6	.121	71.6
LSTCL-85-31	.0906	37000.	3.01	14.8	6.88	12600.	13100.	260.	13.3	6.24*	.0789	31.7
LSTCL-85-36	.133	24500.	4.00	23.4	13.9	15600.	21900.	234.	18.8	20.2	.104	49.5
LSTCL-85-37	.172	50700.	4.43	35.0	18.2	24400.	22500.	332.	27.8	18.9	.135	62.5
LSTCL-85-38	.173	59800.	4.00	26.0	28.8	19000.	30100.	274.	20.9	30.3	.187	76.2
LSTCL-85-39	.087	27000.	3.38	15.5	7.77	10500.	14300.	147.	13.3	9.69	.0625	36.2
LSTCL-85-64	.243	53400.	4.00	35.1	25.2	25400.	30000.	353.	27.7	27.1	.219	80.6
LSTCL-85-65	.193	49800.	3.28	37.5	19.1	26900.	20700.	347.	29.8	12.5	.220	69.5
LSTCL-85-67	.159	27000.	2.12	32.8	18.2	26300.	17900.	307.	24.0	14.5	.193	69.5
LSTCL-85-68	.148	42200.	3.92	28.2	15.6	23000.	20500.	294.	23.6	9.29	.152	60.7
LSTCL-85-69	.250	53700.	4.90	42.5	40.1	27800.	27700.	360.	29.8	34.6	.231	98.5
LSTCL-85-70	.106	49500.	3.72	21.7	22.5	16200.	20400.	213.	17.7	21.3	.130	62.6
LSTCL-85-71	.120	52000.	3.27	24.5	16.4	19200.	25700.	286.	19.6	14.5	.182	64.8
LSTCL-85-72	.116	21900.	3.45	25.7	13.8	20100.	17700.	239.	20.8	15.3	.161	55.9
LSTCL-85-73	.144	33300.	4.00	28.8	13.9	23500.	13200.	293.	24.2	12.5	.133	51.6
LSTCL-85-75	.135	34500.	2.92	23.6	13.6	20200.	13800.	306.	20.9	12.1	.0750	51.6
LSTCL-85-83	.179	20700.	2.56	39.3	18.2	27700.	14500.	399.	29.7	12.1	.0952	56.0
LSTCL-85-84	.116	37200.	3.47	18.1	13.9	14800.	23000.	194.	18.3	12.1	.119	60.8
LSTCL-85-85	.0822	14400.	2.11	11.0	5.12	8590.	9710.	120.	10.1	4.0*	.0407	29.4
LSTCL-85-87	.167	35800.	4.36	28.8	16.5	21100.	20000.	240.	22.4	13.7	.206	62.8
LSTCL-85-88	.116	36500.	4.65	25.2	14.5	18100.	16200.	237.	21.6	13.5	.087	61.9
LSTCL-85-89	.221	29600.	3.20	31.3	15.7	21200.	11900.	281.	23.0	32.8	.173	58.5
LSTCL-85-JB	.102	20800.	3.56	17.6	10.4	11400.	10500.	134.	15.8	19.0	.0887	47.4

* Below limit of detection

Phosphorus Enrichment:

Total phosphorus concentrations in surficial sediments were higher in three discrete areas during the 1983 survey: the mouth of the cutoff channel of the Clinton river, the mouth of the Thames River and the south-central portion of the lake. Concentrations were below OMOE and IJC Guidelines (1,000 ppm), but are classified as either "moderately polluted" (420-650 ppm) or "heavily polluted" (>650 ppm) by U.S.EPA Classification Guidelines. In tributaries, the highest concentrations were found in the Clinton River (3,100 ppm), which exceeded all relevant guidelines.

iii) Evidence of Current Inputs of Contaminants

In sediment cores taken in 1985 from Lake St. Clair, PCBs, DDT and OCS exhibit higher concentrations deeper in the sediment than at the surface. Reduced surface concentrations apparently reflect the decrease in loading of the chemicals which has likely occurred in recent years. Both HCB and HCBD concentrations, however, increased near the top of the cores. This suggests that loadings of these chemicals to Lake st. Clair were evidently not dropping, and may even had been increasing in 1985. These results are consistent with those of a 1985 study within the St. Clair River that showed HCB and HCBD, (hexochlorobutadiene) concentrations in water to be elevated on the Canadian side of the mouth of the river (7).

Studies of sediments from the St. Clair River have shown that the ratios of HCB to OCS are useful for tracking the source of contaminants in that river (23). The HCB/OCS and HCB/QCB ratios were 1.3 and 4.0, respectively, for sediments near the Scott Road Landfill, a site which contains waste byproducts from Dow's early production of chlorine and chlorinated solvents. The HCB/OCS and HCB/QCB ratios in sediments just below Dow's outfall and where nonaqueous wastes have leaked into the river were 16 and 23 respectively. In sediment cores from the central area of Lake St. Clair in 1985, the ratio of HCB/OCS changed from 2 lower in the core to 9 at the surface. Similarly the HCB/QCB ratio increased from 4 near the bottom to 20 near the surface. These trends were thus consistent with decreasing waste losses from the Scott Road Landfill and an increase in the relative importance of Dow's current effluent discharge and waste losses from the plant site.

Localized Hot Spots of In-Place Pollutants:

A survey of metal contaminants in surficial sediments of Lake St. Clair conducted in 1983 included sampling sites closer to the nearshore areas than were the sites in the 1985 survey (24). In 1983, near the Cutoff Canal of the Clinton River, relatively elevated concentrations of Cu, Zn, Ni, Cd, Cr, and Pb were observed. Similar concentrations were also observed in the

Chenal Ecarte near Mitchell Bay. Distributions and concentrations of Cu, Zn, Pb and Cr across Lake St. Clair were similar to the findings of the 1985 survey, the nickel and cadmium concentrations were about half of those reported for 1985 sediments. The reason for this discrepancy has not been defined.

iv) Sediment Transport

Due to the strong hydraulic circulations, sediments from either tributary sources or from resuspension during severe storms are generally transported considerable distances, on the order of several km from their origin, before they either deposit to the lake bed or enter the outflow. Besides direct sediment transport by the lake circulation, it is possible that sediments are transported from nearshore zones to the open lake depositional basins by gravity currents associated with heavier turbid water. A thin layer of more turbid water was observed near the bottom at one open lake observation site. Evidence supporting this method of sediment transport is seen in the sediment concentration contours of zinc, copper and organic carbon, which indicate a source of these parameters at the mouth of the Thames River.

v) Sediment Burial

Since only 30 cm, at most, of sediment has accumulated in Lake St. Clair in post-glacial times, the lake must be considered as nearly nondepositional. However, the isotopic studies of bottom sediments (25) suggest that the burrowing activities of such organisms as Oligochaete worms can mix newly deposited sediment to an average depth of around 5 cm. At that depth the sediment could be buried for long periods of time. Mass budget studies of various tracers indicate residence time of sediments ranging from 3 to 6 years with a mean of 4 +/- 1 year. In the contaminant modeling studies, the burial process was quantified at a rate of 0.1 cm/yr throughout the lake. However, it should be noted that this burial rate inferred from the modeling studies leads to a sediment accumulation which is about two orders of magnitude too large. On the other hand, it is possible that precultural rates of burial were much less than the present rates of burial.

vi) Sediment Residence Time

Two sediment residence times are of concern: 1) the residence time of newly suspended or tributary input sediment in the water column, and 2) the sediment residence times of deposited sediments in the lake. Estimates of the time during which contaminants bound to sediments could exchange with the water column are based on measured and inferred settling rates of suspended particles in Lake St. Clair. The settling velocities of the fine-sized components of suspended sediment which presumably originate from nearby deposits range from 2 to 5 m/d, but are mainly about 4 m/d. Thus once suspended, particles remain in suspension for somewhat less than a day before being deposited. This is probably a maximum residence time in the water column since the particles were separated before analysis. Flocculation of particles could decrease the residence time of particles to several hours. This notion is supported by the application of the simple sediment model to five time series of suspended sediments, neglecting horizontal transport. The mean settling velocity inferred from the model was 21 m/d.

An approximate residence time for deposited sediments may be estimated from the strength of the hydraulic flow and the settling time. If, for example, fine sediment particles are resuspended for 8 hours on the average, then they would be transported by the main hydraulic flow about 2 km towards the outflow before being deposited as the storm event subsides. For particles deposited in the depositional basin, at least 12 storm events would be required to move them a distance of 20 km to the outflow area. Because the physical measurements of suspended sediments were unable to distinguish between local resuspension in deep water and the transport by the lake circulation from shallower areas, it is impossible to estimate the number of storms per year capable of resuspending fine sediments in the deeper zones of the lake. It is probably safe to say that there would be at least two storms per year of sufficient strength to initiate sediment resuspension in the deeper area. Therefore, one might conclude that strongly adsorbed contaminants would take about 6 years to move to the outflow area.

There are several processes which could lengthen this residence time. As the sediments travel towards the outflow, there would be a progressively shorter wind fetch. Consequently, the wave energy available for resuspension would decrease towards the outflow region in the prevailing wind direction. This finding was supported by the wave, wind and sediment data of Hamblin et al., (26) who showed that suspended sediment levels are high in the Detroit River inflow area only during major storms from the northeast. Those storms which are from the prevailing wind direction do not result in appreciable export of suspended sediment from the lake.

The one-dimensional bottom sediment model of Robbins and Oliver, (27) shows erosion of sediment becomes progressively more difficult as erosion proceeds because of compaction. Therefore, while there may be several storms per year capable of initiating sediment resuspension, it is possible that major storms occurring only once in 20 years or even 100 years can erode appreciable amounts of bottom sediments.

Due to the many uncertainties at this time in the understanding of the physical processes involved in estimating the residence time for strongly attached contaminants on fine sediment particles, estimates of the residence times can be better achieved through budget methods.

Residence times for bottom sediments in Lake St. Clair based on long term budgets of radioactive tracers, mercury and various organic contaminants are given in Table VIII-9. Residence times range from 3 to 6.2 years with a mean of 4 +/- 1 years. Some of these estimates were based on the assumption that there is no exchange with the overlying water during resuspension events.

TABLE VIII-9

Sediment reservoir residence times inferred from radionuclide storage as of 1985 and changes in mean contaminant levels from 1970 to 1974 (25).

Constituent	Residence Time(yr)
Cesium-137	6.0
Excess lead-210	3.0
Mercury	4.0
DDE	3.6
TDE	4.6
DDT	2.9
Total PCBs	6.2
Mean	4+/-1

B. SPECIFIC CONCERNS

A summary of specific concerns for Lake St. Clair, based on the following discussion may be found in Table VIII-10. Included are the specific concerns, the use impairments prompting the concerns, the media affected, and the geographic scope of the use impairment.

1. Conventional Pollutants

Due to the agricultural base of the Lake St. Clair geographic area's counties, the nonpoint source pollutants of greatest concern are suspended sediments, nutrients and pesticides. These concerns were documented in 1985 through the small watershed assessment process (28). These pollutants can impair the use of Lake St. Clair area resources for drinking water supplies, fisheries and wildlife, recreation, industrial shipping and agriculture.

Nutrients and Eutrophication

Nonpoint source water quality problems are aggravated or pronounced by variations in stream-flow. During high flow periods, most surface waters display their poorest quality, with significant increases in biological oxygen demand, nutrients, pesticides and sediments from nonpoint sources. When low flows occur, the nonpoint source material deposited during high flow events have an impact because they are no longer diluted. Scouring and the deposition of sediments is also a significant nonpoint source impact. Both water quality and water quantity are therefore important to consider in devising control and management plans. The input of relatively clean, low nutrient water from Lake Huron via the St. Clair River, and the short flushing time of Lake St. Clair has prevented nutrient concentrations from increasing and has kept eutrophication to a minimum.

Although phosphorus concentrations in Lake St. Clair *per se* do not appear to be a problem, the lake basin does contribute phosphorus to the water which enters Lake Erie via the Detroit River. The Water Quality Agreement specifically calls for "improved measurement of tributary loadings to the Lower Lakes for the purpose of providing improved nonpoint source loading estimates". Because tributary loadings of nutrients have been shown to exceed those from atmospheric or point sources, accurate tributary loading data are important to identify total loadings from the lake basin. Michigan and Ontario have target nonpoint source loadings of phosphorus to Lake Erie to meet as part of their phosphorus loading reduction program, and the contribution from the Lake St. Clair basin may be significant.

TABLE VIII-10

Specific concerns in Lake St. Clair, uses impaired, media affected, and geographic scope of the perceived problem.

CONCERN	POTENTIAL USE IMPAIRMENT	MEDIA	GEOGRAPHIC SCOPE
Phosphorus	use associated with eutrophication of Lake Erie	water	tributaries
Pesticides	potential reduction of plant productivity	water	wetlands
	toxicity to benthic community	sediments	tributaries
Oil and grease	toxicity to benthic community	sediments	whole lake
Heavy metals	toxicity to biota	sediments water	tributaries
Mercury	toxicity to biota	sediments	whole lake
	human health hazard (when consumed)	fish	whole lake
PCBs	human health hazard (when consumed)	fish ducks	whole lake Walpole Island
	toxicity to benthic community	sediments	tributaries
PAHs	human health hazard	sediments	tributaries
Phthalate esters	human health hazard	sediments	tributaries
Habitat alterations	lowered wildlife production	biota sediments water	wetlands

Beach Closings

In 1986, there were eight U.S. bathing beaches on Lake St. Clair in Macomb and Wayne counties (29). All were monitored for water quality, and none were temporarily closed due to water quality problems. This issue does not appear to be a problem.

Aesthetics

In the nearshore regions, the water is brownish-green. Over the navigation channel the water colour tends to cloudy-green, but the water is clear green near the centre of the lake away from the navigation channel. Noxious odors and floating mats of algae are generally not present. Mid-summer water transparency ranges from 0.6 m near the shore to about 2.6 m near the open lake. Aesthetics is therefore not a major issue concerning Lake St. Clair.

2. Toxic Organics and Heavy Metals

Ambient Waters

For compounds that persist and bioaccumulate, loadings into the Great Lakes are of concern regardless of the concentrations at which the compounds are delivered. Even when loadings occur at concentrations below detection limits, such compounds can bioaccumulate and exert significant ecosystem effects. Such compounds have received extensive study within the Great Lakes. Most of the current generation of pesticides have short environmental half-lives and have little tendency to bioaccumulate. They are present, however, at much higher concentrations than most of the persistent organics (30). Their ecological effects have received very little study in comparison with studies of persistent organics.

The most commonly applied agricultural pesticides were the herbicides atrazine, alachlor, metolachlor and cyanazine. Data and tables have been provided (5,31). Maximum measured concentrations of these pesticides in the Thames and Clinton Rivers in 1985 and unit area loads from the watershed to these rivers are summarized in Table VIII-1. The 1985 Thames River estimated loading rates for atrazine, metolachlor and alachlor were 6,892 kg (16 g/ha), 2,875 kg (7 g/ha), and 299 kg (0.7 g/ha) respectively (Table VIII-1). Atrazine was detected in 93% of all samples. Alachlor, which was banned in 1985, was detected in approximately 15% of the samples collected in 1984 to 1985. During April through August, 1985, the Clinton River estimated loading rates for atrazine, metolachlor, alachlor, and cyanazine were 52.2 kg (0.28 g/ha), 1.3 kg (0.1 g/ha), 14.2 kg (0.08 g/ha), and 9.1 kg (0.05 g/ha) respectively. The unit area loadings of atrazine and metolachlor from the Thames River watershed were therefore approximately 1 to 2 orders of magnitude greater than those from the Clinton River watershed.

In general, the 1985 concentrations of pesticides observed in the Michigan tributaries would have little effect on fish or aquatic invertebrates, but could affect photosynthetic rates of some algae and rooted aquatic plants. However, the 1985 pesticide loads for the Clinton River is very likely to be significantly less than the average load for this river, due to the near absence of runoff events following pesticide applications in this watershed.

Biota

In edible portions of Lake St. Clair fish, PCBs have declined generally and with the exception of carp, channel catfish and muskellunge, all species have not exceeded the Health and Welfare Canada guideline of 2.0 ppm. Mean PCB concentrations in muskellunge have increased since 1980 (32).

Measurements of DDT in Lake St. Clair fish have not exceeded the Health and Welfare Canada guideline of 5 ppm in any of the 13 species tested. As with the PCB data, highest concentrations were detected in channel catfish and carp, and they were lowest in yellow perch.

Concentrations of HCB and OCS in channel catfish from Lake St. Clair are greater than those from southern Lake Huron. In carp, OCS concentrations are greater in fish from Lake St. Clair than in those from southern Lake Huron. Chlorinated dioxins and dibenzofurans have been detected in Lake St. Clair channel catfish and carp, but not in walleye.

A survey of contaminants in spottail shiners from 1977 through 1986 indicated that the highest contaminant burdens were associated with the south channel of the St. Clair River. Shiners from Mitchell Bay were less impacted, and those from the southeastern part of the lake near the mouth of the Thames River and from the southern part of the lake near the mouth of the Detroit River were not measurably impacted by contaminant loadings from the St. Clair River. Concentrations of PCBs, HCB, OCS, DDT and Chlordane in spottails from Lake St. Clair were generally similar to those in southern Lake Huron, except for elevated levels of PCBs and HCB in fish from the South Channel.

Current mean concentrations of mercury in walleye, northern pike and carp fillets are less than 25% and yellow perch and white bass less than 20% of 1970 levels (33). Mercury concentrations in muskellunge, however, did not decline between 1975 and 1985 (32).

Despite declining concentrations of contaminants in the fish, a Public Health Fish Consumption Advisory exists for both U.S. and Canadian waters. As of 1987, the Advisory included "No Consumption" for largemouth bass over 14", muskellunge and sturgeon. "Restricted consumption" of no more than one meal per week for the general population was advised for larger specimens of walleye, white bass, smallmouth bass, yellow perch, carp, rock bass, black crappie, largemouth bass, bluegill, pumpkinseed, freshwater drum, carp-sucker, brown bullhead, catfish and northern pike. Nursing mothers, pregnant women, women who expect to bear children and children age 15 and under were advised to not eat the fish listed because of the potential for effects of contaminants on the infant or child.

For 1988, Michigan will retain the advisory as issued for 1987. Ontario, however, will reduce the advisory such that no "No Consumption" category will be issued. The advise toward pregnant mothers and their children will still remain in effect.

A comparison of the abundance of mayfly (Hexagenia) nymphs in the UGLCC Study area where visible oil did and did not occur in the sediments indicated substantially lower densities ($61/m^2$) in the presence of visible oil than in the absence of visible oil ($224/m^2$).

The annual production of Hexagenia nymphs was measured in the UGLCC Study area along with sediment concentrations of oil, cyanide, Hg, Cd, Cr, Cu, Ni, Pb and Zn. Production averaged 2,086 mg dry wt./m^2/yr at 3 locations where sediment levels of contaminants were not in excess of guidelines established by the U.S. and Canada for distinguishing polluted sediments. Elsewhere in the study area, the guidelines for polluted sediments were exceeded by as many as 7 contaminants at a single location, and production averaged only 364 mg dry wt./m^2/yr. In Lake St. Clair, where production was highest, only Hg exceeded the guideline.

Wildfowl:

Recent analyses (34) have indicated elevated levels of pentachlorobenzene (QCB), PCBs, HCB and OCS in duck populations resident in the St. Clair River marshes near Walpole Island. Mean OCS concentrations of 115 ppb and PCB concentrations ranging from 1.5 to 4 ppb were found in nonmigratory mallards in samples of breast and liver tissue. At present no wildfowl consumptions advisories exist for HCB, OCS and QCB. While a comparison of the PCB concentrations with the Wisconsin guidelines (35) of 3 ppm do not indicate a major health concern and consequent loss of use of the wetland habitat, there is considerable evidence that organic compounds moving down the St. Clair River are being trapped within the wetland region. Wildfowl consumption advisories are being considered by the appropriate governmental agencies in the

Lake St. Clair region (Ontario Ministry of Natural Resources, Michigan Department of Natural Resources and Canadian Wildlife Service).

Sediments

Results of sediment surveys in Lake St. Clair that were conducted within the last few years indicate that some accumulation of contaminants has occurred in the deeper, thicker bottom sediments, but no particular areas or hot spots of highly contaminated sediments were located. The data showed that sediments in several tributaries to the lake contained much greater concentrations of pollutants than were found in the open lake deposits. Therefore, the areas requiring further attention for possible remedial actions were within the regions of tributary discharge.

In 1985, bottom sediments from 12 U.S. tributaries to Lake St. Clair were analyzed for UGLCCS parameters of concern and other contaminants. The data are presented in Table VIII-11 and summarized below.

i) Pesticides

DDT and its metabolites were found in 9 of the 12 tributary sediment samples. The maximum concentration was found in the Milk River (383 ug/kg). The p'p forms of DDT predominated, and DDT and DDE generally were more prevalent than DDD. The p'p forms were detected in 10% of sediment samples from the mouths of Ontario tributaries.

Other chloro-organic pesticides were also found in 9 of 12 tributary sediment samples. Gamma-chlordane was the pesticide most commonly found, ranging from 2 ug/kg in the Clinton Cutoff Canal to 196 ug/kg in Cottrell Drain. The sample from the Milk River contained the greatest number of pesticide compounds identified, including the only occurrence of Aldrin outside of the Detroit River tributaries. With exception of a single sample containing 2, 4-D from Pike Creek no other pesticides or herbicides were measured in bottom sediments from Ontario tributaries.

Hexachlorobenzene (HCB) was found in only 6 samples at levels of 1 to 7 ug/kg.

ii) Organic Contaminants

PCBs were found in 9 of 12 tributary samples with concentrations up to 1,974 ug/kg in the Cottrel Drain. Most of the PCB was found as aroclor 1254, although in the Cottrel Drain aroclor 1248 was dominant. Aroclor 1260 was found only from the Milk River sediments.

TABLE VIII-11
Contaminants in Lake St. Clair tributary sediments (mg/kg), 1975.

	Location*											
Parameter	CCT-11	CCT-12	CCT-13A	CCT-14A	CCT-15	CCT-15A	CCT-16A	CCT-17	CCT-18A	CCT-19	CCT-20	CCT-21
Calcium	27000	30000	22000	24000	38000	36000	17000	17000	20000	31000	10000	5000
Magnesium	4400	4300	4200	4400	4500	4700	4100	4300	4200	4600	4500	3200
Sodium	170	120	100	150	170	170	190	220	230	130	100	100
Potassium	1400	700	200	1700	2000	1600	1400	4500	1900	2100	1400	200
Arsenic	9	7.5	1.6	7.5	6.5	9.5	3.4	4.9	5.3	6.7	5.3	1.3
Barium	150	46	11	69	93	150	64	120	94	130	66	10
Berylium	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1
Bismuth	9.5	11	11	12	11	10	8.8	25	25	0.7	0	0
Cadmium	2.2	1.1	0.3	1.9	1.3	6.3	0.2	0.2	0.5	0.2	0.4	0.2
Chromium	63	21	15	68	45	140	21	40	32	32	21	4.7
Cobalt	11	6	3.1	13	11	15	7.8	12	7.4	15	11	3
Copper	110	39	10	58	78	130	22	71	48	28	42	4.8
Lead	410	130	14	130	110	240	56	81	140	36	40	10
Manganese	400	260	110	610	460	670	350	350	270	550	310	47
Molybdenum	1.6	1.2	1	1.2	1.2	2.1	1.2	1.4	1.7	2.5	1.6	1
Nickel	51	20	10	83	40	100	31	37	19	43	29	6
Silver	2.6	0.3	0.3	1.2	1	3.5	0.3	0.6	1	0.4	0.3	0.3
Strontium	45	39	21	33	52	53	32	46	42	65	22	6.3
Vanadium	25	15	7.2	27	25	26	20	51	27	36	25	5.5
Zinc	380	150	34	220	190	430	140	140	170	110	100	19
Tin	15	6.6	4	6	4.5	11	4	4.9	5.5	4	4	4
Aluminum	12000	5000	2000	13000	14000	13000	9000	24000	11000	19000	12000	1800
Lithium	23	11	5	26	29	27	16	40	19	42	25	3.5
Selenium	1.1	0.4	0	0.7	0.6	0.6	0	0.3	0.4	0.3	0.5	0
Iron	24000	12000	4000	28000	24000	32000	16000	30000	18000	36000	20000	3000
Yttrium	9.7	5.8	2.2	11	11	11	7	13	8	13	11	2.2
Mercury		0.2	0.1	0.3	0.3	0.7	0.1	0.2	0.4	0.1	0.1	
COD	54000	14000	18000	35000	81000	38000	30000	51000	30000	33000	39000	11000
Oil and Grease	3290	2010	650	1230	2400	3700	650	650	2250	650	650	650
Ammonia		90	75	300	310	230	150	240	190	240	70	17
TKN		1300	800	6900	4300	2900	1700	3600	1700	1900	3100	770
Phosphorus		600	430	3000	1300	3100	2000	1600	1500	1100	820	220
Cyanide	0.1	0.1	0.1	0.2	0.4	0.7	0.1	0.3	0.3	0.1	0.3	0.1
Total Solids	45.85	55.45	77.13	34.01	29.12	41.1	53.2	40.1	44.4	45.1	37.4	65.5
Total Volatiles	8.07	6.41	0.74	7.67	8.37	7.8	4.7	7.3	8	4.6	6.9	1.8
Total PCBs (ug/kg)	198	1974	199	596	226	185		85	635	31		
Total PAHs "	14300		13800	800	1400	12100	3600	800	400	10700		
Total DDT "	383		271		87	30	146	72	8	33	25	
HCB "	3									2	2	
G. Chlordane	57	196	2	-	-	17	6		13	3	5	
DN-Butylphthalate	400	2000	200	4000	1600	-	200	2600	1900			
BIS(2-Ethylbenzyl) phthalate (ug/kg)	5600	4200	3000	3400	4400	16200	900	1200	10400			

*11-Milk River, bridge, 12-Cottrell drain, North Channel, 13a-Clinton River cutoff upstream, 14a-Ventre Beuf Drain/Black Creek, 15-Clinton River, 15a-Clinton River upstream, 16-Vase Creek upstream, 17-Salt River, at mouth, 18a-Frog Creek, upstream, 19-Marsac Creek 20-Swan Creek, mouth, 21-Unnamed trib., East of Swan Creek.

PAHs were found in 9 of the samples, with the maximum total PAHs being reported in sediments from the Milk River (14,300 ug/kg). Elevated concentrations were found also in the Cottrel Drain (13,800 ug/kg), Clinton River (12,100 ug/kg), and in Frog Creek (10,700 ug/kg). Most samples were dominated by 3-, 4- and 5-ring PAHs. Naphthalene was found only from the Clinton River. Cottrel Drain, Milk River and Frog creek had the highest number of individual PAH compounds with 11, 9 and 8 respectively.

Phthalate esters were found in 9 of 12 samples. Occurrences of all the four phthalate esters that were found throughout the UGLCC Study area were found in the Lake St. Clair tributary sediments, including the 4 highest concentrations of di-n-butyl phthalate (in sediments from the Ventre Beuf Drain/Black Creek, Salt River, Cottrel Drain and Frog Creek) and the only occurrences of diethyl phthalate in the UGLCC Study area. Bis(2-ethylhexyl)phthalate was found in 9 of 12 samples with concentrations up to 16,200 ug/kg in the Clinton River.

iii) Metals and Conventional Pollutants

Several tributary sediment samples contained concentrations of metals and conventional pollutants in excess of U.S.EPA Guidelines (22) for nonpolluted sediments. These guidelines, number of tributaries with exceedences of the guidelines, and the rivers with maximum concentration of each parameter are presented in Table VIII-12. Most of the maximum concentrations occurred in either the Clinton River or the Milk River. The Ventre Beuf Drain/Black Creek sediments contained elevated concentrations of the agricultural contaminants, ammonia, TKN and phosphorus.

3. Habitat Alterations

The delta marshes, estuaries, lagoons and channel wetlands that fringe the shores of Lake St. Clair in both Michigan and Ontario are among the most biologically productive areas in the Great Lakes system. Because they occur in the proximity of a densely populated, highly industrialized and intensively farmed region, the wetlands have suffered losses in both quality and quantity (36). The remaining wetlands perform many important hydrological and ecological functions, including providing habitat for fish, furbearers and waterfowl.

Although portions of the wetlands have been permanently lost or severely degraded, the prospects for future preservation of remaining wetlands and for at least partial rehabilitation of selected areas are reasonable good. Wetland legislation and other policies designed to protect the environment are in place or under consideration. A comprehensive discussion of the Lake St. Clair wetlands, including their ecological features, human

TABLE VIII-12

Exceedences of U.S. guidelines for heavily polluted sediments for metals and conventional pollutants in U.S. Lake St. Clair tributaries.

Parameter	Guideline	# of tribs with exceedences[a]	maximum measured concentration	River with maximum
Cd	6 mg/kg	1	6.3 mg/kg	Clinton
Cr	75 mg/kg	1	140 mg/kg	Clinton
Cu	50 mg/kg	4	130 mg/kg	Clinton
Pb	60 mg/kg	7	410 mg/kg	Milk
Mn	500 mg/kg	3	670 mg/kg	Clinton
Ni	50 mg/kg	3	100 mg/kg	Clinton
Ag	-	-	3.5 mg/kg	Clinton
Zn	200 mg/kg	3	430 mg/kg	Clinton
Se	0.8 mg/kg[b]	1	1.1 mg/kg	Milk
Fe	25,000 mg/kg	4	36,000 mg/kg	Marsac Creek
As	8 mg/kg	2	9.5 mg/kg	Clinton
Ba	60 mg/kg	9	150 mg/kg	Clinton
Bo	-	-	25 mg/kg	Frog Creek Salt River
COD	80,000 mg/kg	1	81,000 mg/kg	Clinton
O&G	2,000 mg/kg	5	3,700 mg/kg	Clinton
NH_4	200 mg/kg	6	330 mg/kg	Milk
TKN	2,000 mg/kg	6	6,900 mg/kg	Ventre Beuf Drain/Black Creek
P	650 mg/kg	9	3,100 mg/kg	Clinton
CN	0.25 mg/kg	5	0.7 mg/kg	Clinton
TVS	8 %	3	8.4 %	Clinton

[a] U.S.EPA Guidelines for the Pollutional Classification of Great Lakes Harbour Sediments (22).

[b] Lake Erie background concentration (22).

impacts, and management issues has been presented by Herdendorf, et al. (36), to which the reader is referred for details beyond the scope of the UGLCC Study.

C. SOURCES

1. Municipal Point Sources

Identification

In 1986 there were 18 major (flow > 3.7×10^3 m^3/d or 1.0 U.S. MGD) municipal wastewater treatment facilities and 29 minor municipal facilities discharging to the basin (37). Only four of these, however, discharged directly to Lake St. Clair. Several of the U.S plants discharged to the Clinton River, Michigan, and most of the Canadian plants discharged to the Sydenham and Thames Rivers, Ontario. Total flow from municipal sources was 559×10^3 m^3/d.

The major facilities were predominantly activated sludge systems with phosphorus removal, while the minor facilities were predominantly lagoon systems or trickling filter plants. All U.S. plants were served by separated sewer systems. Three of the larger Canadian municipalities have some combined sewer systems which represent varying percentages of the total serviced area in each municipality (Chatham, Wallaceburg, and London).

The largest urban centre, London (population 277,000), has 25% combined sewers. Chatham, population 36,000, and Wallaceburg, population 12,000, each have 37% of their sewer systems combined.

In the U.S., five major municipal waste water treatment plants (WWTP) were identified and selected for sampling: New Baltimore WWTP discharges directly to Lake St. Clair, while the WWTPs at Mt. Clemens, Pontiac, Rochester and Warren discharge to the Clinton River. Three waste water treatment plants in Canada were selected for study: The Belle River-Maidstone WWTP discharges directly to Lake St. Clair, the Chatham WWTP discharges to the Thames River, and the Wallaceburg WWTP discharges to the Sydenham River. The sources were sampled for the 18 UGLCC Study parameters plus additional conventional pollutants, metals and organic contaminants. One to six day surveys were conducted at each facility between October 1985 and November 1986.

Based on the study of municipal dischargers, of greatest concern were the Wallaceburg WWTP, the Mt. Clemens WWTP and the Warren WWTP. Trace organics, heavy metals, phenols, ammonia and phosphorus were the notable pollutants contributed by these plants. All three received industrial wastewaters as a significant portion of their influent.

Classification

In terms of effluent loading for the sources surveyed, the following facilities were considered to be major contributors of the parameters studied:

1. Wallaceburg WWTP: Total copper, total nickel, total iron, and ammonia-nitrogen.

2. Chatham WWTP: Chloride, ammonia-nitrogen, lead, total suspended solids, and oil and grease.

3. Warren WWTP: PCBs, HCB, cyanide, total cadmium, total chromium, total zinc, total nickel, total cobalt, chloride, phosphorus, total organic carbon, and BOD.

4. Mt. Clemens WWTP: PCBs, phenols, oil and grease, total lead, total mercury, total iron, phosphorus, ammonia-nitrogen, total suspended solids and BOD.

All sources were in compliance with applicable guidelines or site-specific limitations for the study parameters, except for the Mt. Clemens WWTP which exceeded the Great Lakes Water Quality Agreement effluent limitation for total phosphorus of 1.0 mg/L. However, the following sources were discharging elevated concentrations of contaminants which were not subject to site-specific effluent limitations, requirements or guidelines:

1. Wallaceburg WWTP: Total cadmium, total chromium, total copper, total nickel, and ammonia-nitrogen.

2. Mt. Clemens WWTP: PCBs, total phenols, total mercury.

3. Warren WWTP: PCBs.

The Warren WWTP and the Chatham WWTP, although classified as major sources of the UGLCC Study parameters, were operating efficiently and were discharging low concentrations of all parameters, except PCBs at the Warren WWTP. Their ranking as major contributors was due to their flows being considerably larger than most of the other sources. The municipal waste water treatment facilities at Belle River, New Baltimore, Rochester and Pontiac were considered to be minor contributors of the parameters studied.

Extent of Contributions to the Problems

A summary of the major municipal point source loadings of the UGLCCS parameters to Lake St. Clair is presented in Table VIII-13. Included is information on analytical detection limits, flows, average concentrations, loads, and percentage of total point source contribution for each facility for each parameter. Municipal point source contributions of immediate concern were identified:

TABLE VIII-13

UGLCCS study point source loadings of UGLCCS parameters[1] to Lake St. Clair by major contributors.

PARAMETER	MDL(s) (ug/L)	FACILITY	MICH/ ONT	OUTFALL NAME(S)	FLOW $10^3 m^3/d$	AVERAGE CONCENTRATION[2] (ug/L)	kg/d	% TOTAL POINT SOURCE CONTRIBUTION
Total PCBs	0.001	Mt. Clemens WWTP	M	Final effluent	13.3	0.54	0.002	78.5
	0.001	Warren WWTP	M	Final effluent	109	0.019	0.0073	21.5
						TOTAL	0.0093	100
Hexachloro-benzene	0.001	Warren WWTP	M	Final effluent	109	0.0059	0.00059	70.2
	0.020	Chatham WPCP	O	Final effluent	39.4	0.0051	0.00020	23.8
	0.00001	Mt. Clemens WWTP	M	Final effluent	13.3	0.0048	0.00005	6.0
						TOTAL	0.00084	100
Octachloro-styrene	0.000001	Mt. Clemens WWTP	M	Final effluent	13.3	0.000044	0.00000045	100
						TOTAL	0.00000045	100
Total Phenols	10	Mt. Clemens WWTP	M	Final effluent	13.3	77.0	1.03	59.5
	10	Pontiac WWTP	M	Final effluent	46.9	9.6	0.451	26.1
	10	New Baltimore WWTP	M	Final effluent	5.11	27.0	0.138	8.0
	1	Wallaceburg WPCP	O	Final effluent	7.88	0.37	0.030	6.4
						TOTAL	1.73	100
PAHs		Wallaceburg WPCP	O	Final effluent	7.88	0.46	0.0036	100
						TOTAL	0.0036	100
Total Cyanide[3]	5	Warren WWTP	M	Final effluent	109	7.0	0.761	80.0
	5	Mt. Clemens WWTP	M	Final effluent	13.3	8.0	0.11	11.6
	5	Rochester WWTP	M	Final effluent	8.7	5.0	0.0435	4.6
	5	New Baltimore WWTP	M	Final effluent	5.11	7.0	0.0358	3.8
						TOTAL	0.950	100

TABLE VIII-13. (cont'd 2)

PARAMETER	MDL(s) (ug/L)	FACILITY	MICH/ ONT	OUTFALL NAME(S)	FLOW $10^3 m^3/d$	AVERAGE CONCENTRATION[2] (ug/L)	kg/d	% TOTAL POINT SOURCE CONTRIBUTION
Total Mercury	0.0001	Mt. Clemens WWTP	M	Final effluent	13.3	0.878	0.009	70.3
	0.0001	Warren WWTP	M	Final effluent	109	0.027	0.0023	18.0
	0.025	Chatham WPCP	O	Final effluent	39.4	0.033	0.0013	10.2
	0.025	Wallaceburg WPCP	O	Final effluent	7.88	0.025	0.0002	1.5
						TOTAL	0.0128	100
Total Copper	5.0	Wallaceburg WPCP	O	Final effluent	7.88	311	2.45	58.5
	1.0	Warren WWTP	M	Final effluent	109	5.7	0.619	14.8
	1.0	Pontiac WWTP	M	Final effluent	46.9	8.6	0.404	9.6
	1.0	Mt. Clemens WWTP	M	Final effluent	13.3	29.9	0.400	9.5
	5.0	Chatham WPCP	O	Final effluent	39.4	3.6	0.147	3.5
						TOTAL	4.42	95.9
Total Nickel	4.0	Warren WWTP	M	Final effluent	109	28.4	3.09	51.0
	5.0	Wallaceburg WPCP	O	Final effluent	7.88	309	2.44	40.3
	5.0	Chatham WPCP	O	Final effluent	39.4	10.5	0.42	7.2
						TOTAL	5.95	98.3
Total Cobalt	0.001	Warren WWTP	M	Final effluent	109	1.8	0.195	97.5
	0.001	Mt. Clemens WWTP	M	Final effluent	13.3	0.29	0.0041	2.5
						TOTAL	0.1991	100

TABLE VIII-13. (cont'd 3)

PARAMETER	MDL(s) (ug/L)	FACILITY	MICH/ ONT	OUTFALL NAME(S)	FLOW $10^3 m^3/d$	AVERAGE CONCENTRATION[2] (ug/L)	kg/d	% TOTAL POINT SOURCE CONTRIBUTION
Oil and Grease	100	Chatham WPCP	O	Final effluent	39.4	2,090	82.2	41.9
	2,000	Mt. Clemens WWTP	M	Final effluent	13.3	3,610	48.0	24.5
	100	Wallaceburg WPCP	O	Final effluent	7.88	2,990	23.6	12.0
	100	Belle River WPCP	O	Final effluent	5.47	3,860	21.1	10.8
	2,000	Rochester WWTP	M	Final effluent	8.7	2,400	20.9	10.7
						TOTAL	196	100
Total Cadmium	0.2	Warren WWTP	M	Final effluent	109	0.6	0.0652	69.0
	5.0	Wallaceburg WPCP	O	Final effluent	7.88	2.52	0.0199	21.1
	0.2	Mt. Clemens WWTP	M	Final effluent	13.3	0.7	0.00933	9.9
						TOTAL	0.0944	100
Total Lead	5	Chatham WPCP	O	Final effluent	39.4	11.2	0.443	42.3
	1	Mt. Clemen WWTP	M	Final effluent	13.3	20.3	0.271	25.9
	1	Warren WWTP	M	Final effluent	108.6	1.5	0.163	15.5
	1	Pontiac WWTP	M	Final effluent	46.9	2.1	0.0986	9.4
						TOTAL	0.976	93.1
Total Zinc	2	Warren WWTP	M	Final effluent	109	52.0	5.65	56.6
	2	Pontiac WWTP	M	Final effluent	46.9	38.2	1.79	17.9
	2	Mt. Clemens WWTP	M	Final effluent	13.3	84.0	1.12	11.2
	5	Wallaceburg WPCP	O	Final effluent	7.88	79.8	0.629	6.3
	2	Rochester WWTP	M	Final effluent	8.7	29.8	0.26	2.6
						TOTAL	9.45	94.6

TABLE VIII-13. (cont'd 4)

PARAMETER	MDL(s) (ug/L)	FACILITY	MICH/ ONT	OUTFALL NAME(S)	FLOW $10^3 m^3/d$	AVERAGE CONCENTRATION[2] (ug/L)	kg/d	% TOTAL POINT SOURCE CONTRIBUTION
Ammonia as N	100	Chatham WPCP	O	Final effluent	39.4	5,710	225	41.5
	10	Mt. Clemens WWTP	M	Final effluent	13.3	1,000	133	24.5
	100	Wallaceburg WPCP	O	Final effluent	7.88	12,800	101	18.6
	10	Rochester WWTP	M	Final effluent	8.7	6,200	54.0	10.0
						TOTAL	513	94.6
Total Iron	14.0	Mt. Clemens WWTP	M	Final effluent	13.3	1,030	13.7	27.2
	5.0	Wallaceburg WPCP	O	Final effluent	7.88	1,410	11.2	22.2
	5.0	Chatham WPCP	O	Final effluent	39.4	239	9.01	17.9
	14.0	Warren WWTP	M	Final effluent	109	60.0	6.52	12.9
	14.0	New Baltimore WWTP	M	Final effluent	5.11	840	4.29	8.5
	14.0	Rochester WWTP	M	Final effluent	8.7	269	2.34	4.6
	5.0	Belle River WPCP	O	Final effluent	7.9	220	1.73	3.4
						TOTAL	48.8	96.7
Chloride	1,000	Warren WWTP	M	Final effluent	109	76,000	8,260	31.6
	1,000	Pontiac WWTP	M	Final effluent	46.9	12,000	5,630	21.6
	500	Chatham WPCP	O	Final effluent	39.4	12,000	4,400	17.1
	1,000	Rochester WWTP	M	Final effluent	8.7	46,000	4,000	15.3
	1,000	Mt. Clemens WWTP	M	Final effluent	13.3	11,000	1,470	5.6
	500	Wallaceburg WPCP	O	Final effluent	7.88	16,700	1,320	5.1
						TOTAL	25,000	96.3
Phosphorus as P	10	Warren WWTP	M	Final effluent	109	370	40.2	32.4
	10	Mt. Clemens WWTP	M	Final effluent	13.3	2,400	32.0	25.8
	10	Pontiac WWTP	M	Final effluent	46.9	460	21.6	17.4
	100	Chatham WPCP	O	Final effluent	39.3	328	12.9	10.4
	100	Belle River WPCP	O	Final effluent	7.9	1,000	7.9	6.4
	10	Rochester WWTP	M	Final effluent	8.7	680	5.9	4.8
						TOTAL	121	97.2

[1] > 95% of total unless sources diffuse (based on data collected in 1985-86).

[2] Flow weighted.

[3] Canadian sources not analyzed.

i) Polychlorinated Biphenyls (PCBs): Although detected at only two Michigan sources, Mt. Clemens WWTP and Warren WWTP, the loading of 9.3 g/day to Lake St. Clair was high compared to the loadings estimated for the other UGLCCS areas. Both sources were discharging comparatively large concentrations, 0.019 ug/L at Warren WWTP and 0.540 ug/L at Mt. Clemens WWTP. Although PCBs were not detected in the Canadian sources, the analytical method detection limit was 1,000 times less sensitive for Canadian samples than for the U.S. samples.

ii) Total Phenols: The total loading was 1.73 kg/d. The elevated concentration at Mt. Clemens WWTP, 77 ug/L, was much higher than a comparable objective in Ontario of 20 ug/L for industrial discharges.

iii) Total Cadmium: The Wallaceburg WWTP effluent exceeded the Ontario Industrial Effluent Objective of 1 ug/L in two of the three samples collected. The concentration in both samples was 4 ug/L. The total loading from all sources was 94.4 g/d.

iv) Total Mercury: Mt. Clemens WWTP had an unusually high effluent concentration of 0.878 ug/L. The concentration was more than four times the Great Lakes ambient water quality objective for filtered mercury. The total loading from all sources was small, 12.8 g/d.

v) Total Copper: The Wallaceburg WWTP had effluent concentrations of 196 to 500 ug/L, 10 times larger than any other point source and two orders of magnitude greater than the Great Lakes Agreement ambient objective of 5 ug/L. The combined loading from all sources was 4.18 kg/d.

vi) Total Nickel: The Wallaceburg WWTP had effluent concentrations of 225 to 452 ug/L, well above existing ambient objectives such as the Great Lakes Agreement objective of 25 ug/L. The total loading from all sources was 6.06 kg/d.

vii) Total Phosphorus: Mt. Clemens had an effluent concentration of 2.4 mg/L during the survey, above the 1.0 mg/L permit limit and the Great Lakes Water Quality Agreement Effluent Objective. Facility self-monitoring reports indicated the 1.0 mg/L objective was frequently exceeded in 1986. The plant's interim permit did not contain a phosphorus limitation. Total loading from all sources surveyed was 123 kg/d.

viii) Ammonia-nitrogen: The Wallaceburg WWTP had two of three effluent concentrations above the Ontario industrial objective of 10 mg/L, i.e., 12.2 and 18.6 mg/L. The combined loading from all sources was 541 kg/d.

No significant contributions of non-UGLCCS parameters were identified.

2. Industrial Point Sources

There were 38 known point sources discharging to the Lake St. Clair Basin in 1986, and all were minor facilities. All industries were indirect dischargers to Lake St. Clair, except the Mt. Clemens, Michigan, water filtration plant, which discharged filter backwash directly to the Lake. The total flow from industries was not available. However, the majority of the industrial flow was once through cooling water or storm water. The ten Canadian industries were predominantly food processors and cement plants while the majority of the 28 Michigan plants were automotive parts manufacturers, with process water usually discharging to municipal WWTPs and cooling waters discharging to surface waters. Because there were no direct industrial dischargers to Lake St. Clair, no industrial sources were sampled as part of the UGLCC Study.

3. Urban Nonpoint Sources

Intermittent Stormwater Discharges

PCB concentrations on the U.S.(west) side of the head of the Detroit River were found to be greater than on the Canadian side (28). This finding was consistent with the observations of Pugsley et al. (38) that the highest concentrations of PCBs in clams and sediments from Lake St. Clair were found along the western shore. Johnson and Kauss suggest that the single high value of 1,630 ng/g that was observed on a single survey may be related to an episodic point or nonpoint source discharge that occurred during the survey. High total organic carbon (TOC) concentrations were also observed during the same survey, which may have resulted in increased adsorption of hydrophobic compounds.

Some municipal storm drains exist in Michigan communities on Lake St. Clair (39). New Baltimore has a single 8" drain that enters Frog Creek, a minor tributary to the lake. In Mt. Clemens, 13 storm drains, ranging in size from 12" to 54" in diameter, discharge into the Clinton River. Impacts of these drains on the receiving water quality have not been documented. However, seven of the drains in Mt. Clemens have received a preliminary "high priority" ranking by Michigan Department of Natural Resources (MDNR). Discharge priority ranking was based on indicators such as basin land use, basin area, and diameter of discharge. The process included many assumptions and estimation of relative impacts. Therefore, the ratings should be regarded as only an indication of potential impacts.

Estimates of the annual contaminant loadings to Lake St. Clair from Canadian urban runoff (stormwater and combined sewer overflow) are presented in Table VIII-14. These estimates were based on the mean measured concentration of contaminants in urban runoff from April 1985 to November 1986 in Windsor, Sarnia and Sault St. Marie, Ontario, and on previous estimates of the volume of urban runoff in the Canadian Lake St. Clair basin. Because of the uncertainties involved in the data used in the calculations, these estimates should be considered only as approximations. No similar loadings were calculated for the Michigan urban areas.

Combined Sewer Overflows

None of the U.S. municipalities have combined sewers, while three of the larger Canadian municipalities do have combined sewer systems. The larger urban centre, London (population 277,000) is serviced by 25% combined sewers. Chatham (population 36,000) and Wallaceburg (population 12,000) each have 37% combined sewers. Chatham and Wallaceburg are the largest major urban centers on the two largest Canadian tributaries of Lake St. Clair, Thames and Sydenham Rivers, respectively. The impacts of either the storm water discharge or of any combined sewer overflows on the quality of the receiving waters have not been documented.

4. Rural Nonpoint Runoff

Nutrients

Major sources of nutrients within the Lake St. Clair drainage area are fertilizer (commercial and manure spreading), livestock operations and soil erosion. Nutrients removed by leaching or transported by sediment and runoff may produce two pollution problems: groundwater contamination and accelerated eutrophication of surface waters.

Commercial fertilizer (and to a lesser extent, livestock manure) is applied to approximately 50% of the land in the Lake St. Clair geographic area. Approximately 90% of this land is situated in Ontario and receives approximately 300,000 tonnes (429 kg/ha) of commercial fertilizer annually. Over-fertilization has been identified for both Michigan and Ontario agricultural areas. Analysis of soil fertility and crop nutrient requirements relative to fertilizer applications reveal that many farmers are applying up to 3 times more phosphorus fertilizer than required in Canada, and up to two times the required rate in the U.S.

Livestock operations in the Lake St. Clair geographic area consist of dairy, beef, hog, sheep, chicken and horse operations. Beef and dairy cattle are the biggest producers of phosphorus, followed by hogs. A total of 61 tonnes/yr of phosphorus are

TABLE VIII-14

Estimate of contaminant loading to Lake St. Clair from Canadian urban stormrunoff[a].

UGLCCS Parameter	Loading kg/yr	Loading kg/d[b]
PCB	6.4	0.02
HCB	0.06	0.0002
OCS	0.11	0.0003
Phenols	693	1.9
PAHs(17)	282	0.8
Cyanide	139	0.4
Oil and Grease	219,000	600
Cadmium	320	0.9
Zinc	15,500	42.5
Mercury	3.3	0.009
Lead	10,700	29.3
Copper	2,700	7.4
Nickel	1,800	4.9
Cobalt	187	0.5
Iron	378,400	1036.7
Chlorides	7,995,000	21,904.1
Phosphorus	12,000	32.9
Ammonia-N	24,000	65.7

[a] Estimates calculated from average measured concentration in urban runoff from Windsor, Sarnia and Sault Ste. Marie (51) and from estimated volume of urban runoff in Lake St. Clair basin (52).

[b] Expression of contaminant loadings from urban runoff on a daily basis is somewhat artificial, since loadings are seasonally dependent. However, expression in these terms allows comparison with daily point source loads.

estimated to be delivered to the water courses from the livestock operations, 65% of which comes from Ontario counties.

Soil erosion contributes approximately 3.2 tonnes/yr of phosphorus from Michigan to the water courses. Based upon the percent of total cropland erosion occurring from wind, Macomb and St. Clair Counties should be targeted for accelerated conservation assistance.

Pesticides

Lake St. Clair geographical area is a region of potential problems regarding the movement of pesticides into the water course. These problems are a result of an estimated 3.5 million kg being applied to land in both Canada and the U.S. which has a high potential to transmit the chemicals via surface runoff, fine particulate matter carried by wind or water, and infiltration to groundwater. Based on soil texture and drainage, approximately 70% of the St. Clair geographical area in Canada has been identified as potential problem areas with respect to surface water contamination, and approximately 60% of the area possesses a high risk for pollutant transfer to groundwater systems (5).

5. Atmospheric Deposition

Loadings of contaminants to Lake St. Clair from the atmosphere are a nontrivial portion of the total estimated load of lead and phosphorus (see section E, modeling and mass balance considerations, for further discussion). The major sources of phosphorus are soil dust, leaf and insect debris, and industrial activity. A large percentage of the loading may be derived from entrainment of phosphorus-containing particles in agricultural areas. Lead and cadmium are introduced through combustion of fossil fuel, including exhaust from burning leaded gasoline in automobiles. From measurements in urban and rural locations close to Lake St. Clair, atmospheric deposition of lead was estimated to range from 4 to 8 kg/d and for cadmium from 0.8 to 1.1 kg/d (17).

The atmospheric loadings of P, NO_3, NH_3, Cd, Pb, Zn and Cl to Lake St. Clair for the years 1982 - 1985 were estimated from data collected at the Mt. Clemens station of the Great Lakes Atmospheric Deposition network. The thirty-year mean precipitation average was used to convert concentration values into loadings, as displayed in Table VIII-15.

Quantitative estimates of loadings of organic contaminants to Lake St. Clair are not available. Given the quantity of inorganic materials introduced to the lake from the atmosphere, however, an atmospheric source for organic pollutants is also likely to be important.

TABLE VIII-15

Atmospheric loadings of selected parameters to Lake St. Clair for 1982 - 1985. Mt. Clemens GLAD station is the source of data. Lake surface area is 1101.178 km^2 (430 mi^2).

	kg/yr		
	Nitrate(NO_3)	Ammonia(NH_4)	Total Phosphorus(TP)
1982	301,723	180,593	3,402
1983	441,810	342,466	5,952
1984	514,250	427,257	5,102
1985	445,242	305,124	3,928
AVERAGE	425,756	313,860	4,596

	Cadmium	Chloride	Zinc	Lead
1982	--	436,067	30,909	--
1983	226	252,170	14,773	5,179
1984	254	322,645	23,393	5,509
1985	299	323,492	13,769	3,825
AVERAGE	260	333,594	20,711	4,838

6. Groundwater Contamination/Waste Sites

Surface Waste Sites

Active and inactive waste sites within 19 km of the Connecting Channels were identified as part of this investigation. The majority of sites were landfills, hazardous waste disposal sites, and regulated storage sites. Other waste sites included transportation spills, leaking underground storage tanks and contaminated water wells. Underground injection wells were also identified.

Ranking of sites was based on their potential for contributing contaminants to the Connecting Channels via groundwater. Sites in the U.S. were ranked using the U.S.EPA DRASTIC System with additions and minor modifications. This system assesses the impact by evaluating the hydrogeology, waste material and the distance from Lake St. Clair for each site. Nine U.S. sites were ranked as confirmed or possible contamination sites within the Lake St. Clair groundwater discharge area (Table VIII-16). In general, these sites are in areas of sandy unconsolidated surficial materials and are near to the Connecting Channels. The water table is generally less than 4.6 m below land surface and priority pollutants and/or inorganic contaminants are on site or in the groundwater.

Waste disposal sites in the Ontario study area were also identified. Emphasis was placed on identifying sites that require monitoring or remedial investigations. Criteria for ranking and prioritization of the sites included geologic, hydrologic, hydrogeologic and geochemical information, on-site monitoring, waste characterization and containment, and health and safety. No sites in Kent County were identified that require immediate investigation or that posed a definite potential for impact on human health and safety. Three waste disposal sites in the area contain only building refuse, domestic waste and commercial garbage. These sites are small and not close to the lake. Therefore, no significant impact is expected from them.

Deep Well Injections

The Safe Drinking Water Act (SDWA) of 1974 requires U.S. EPA to provide for the safety of United States drinking water. The act contains a set of requirements which involves the protection of underground sources of drinking water from contamination by injection well activities. Seven U.S. injection facilities are presently authorized in the Lake St. Clair area, five of which are salt water disposal wells and two of which are hydrocarbon storage wells. Of the salt water disposal wells, two are currently in operation: Consumers Power injects to the Dundee Formation at 957 m and Lakeville Gas Association injects to the

TABLE VIII-16

Confirmed or possible contamination sites in the U.S. within the Lake St. Clair groundwater discharge areas.

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1. <u>Hwy M-29 and Michigan St.</u> This site is a gas station with a leaking underground tank on sandy materials near the St. Clair River and a shallow water table.

2. <u>Clay Township Sanitary Landfill</u> This landfill has accepted household and commercial wastes, and is near to the north Channel of the St. Clair River distributary system, sandy surficial deposits, and a shallow water table.

3. <u>Selfridge Air National Guard Base</u> (CERCLIS/RCRA/ACT 307) The Base site consists of 7 individual groundwater contamination sites: 3 landfills, 2 fire training areas and 2 ramps. The landfills contain residential and industrial wastes, solvents, and waste oils. The fire training areas contain flammable waste (JP-4), solvents, strippers and thinners. There have been fuel spills at the two ramps.

4. <u>Metro Beach Incinerator</u> This closed incinerator handled general refuse (most likely from the Metropolitan Beach Park), and is located on the Clinton River Delta within one-half mile from Lake St. Clair over a shallow water table and on silty-sandy surficial material.

5. <u>G and L Industries</u> (Act 307) Phthalate and lead are listed as pollutants for this fiberboard manufacturer in Mount Clemens, Mi., and groundwater contamination is indicated. The site is located on sandy soil near to a shallow water table and aquifer.

6. <u>County Line Landfill</u> This landfill accepted household, commercial and industrial wastes.

7. <u>Henning Road Landfill</u> (Act 307) The Landfill accepts domestic waste. Groundwater contamination is not indicated in the Act 307 listing.

8. <u>Sugarbush Road Dumpsite</u> (CERCLIS/Act 307) This site is a solid waste landfill with pollutants of concern being Pb, Ni, Cr, Cu and Zn. Surface water, air and soil contamination are indicated in the Act 307 listing. Groundwater contamination is not indicated, but there are no monitoring wells.

9. <u>Rosso Highway SAFB - Avis Ford</u> This landfill accepted foundry sand.

CERCLIS: Site is listed within the information system for Superfund and is considered for clean-up under the comprehensive Environmental Compensation and Recovery Act of 1980 (CERCLA).
RCRA: Site has current activity under the Resource Conservation and Recovery Act.
Act 307: Site is listed on Michigan's compilation of sites of known and possible environmental degradation.

Sylvania Sandstone at 733 m in Oakland county. One additional well is presently under construction in Oakland County. Two wells are temporarily abandoned: one to the Detroit River Group of formations at 276 m and one to the Sylvania Formation at 588 m Consumers Power Co. operates the two gas storage caverns in the Salina Formation Group.

Estimates of Groundwater Discharge to Lake St. Clair

Groundwater discharges to Lake St. Clair from three hydrogeologic units termed the shallow glacial (or shallow plus intermediate units), glacial-bedrock interface (or regional, freshwater aquifer), and bedrock units. The shallow glacial unit consists entirely of Pleistocene Age glacial deposits. In southeastern Michigan these are mostly silty-clay till and glaciolacustrine deposits that contain discontinuous stringers of sand and gravel. Base flow of perennial streams largely represents groundwater discharge from this unit.

The glacial-bedrock interface unit occurs between the shallow glacial unit and the bedrock. In general, the glacial-bedrock interface unit discharges less water to the Connecting Channels than does the shallow glacial unit. Environmental concerns, however, are that high head pressures from deep waste injection practices could cause waste fluids to migrate through fractures or more permeable horizons in the rock. The glacial-bedrock interface unit could thus be one pathway by which waste fluids could reach the channels or contaminate adjacent groundwater. No evidence exists at present that this has occurred in Michigan.

The bedrock unit is defined as the first bedrock aquifer lying directly beneath the Connecting Channels. In the Lake St. Clair study area, the bedrock unit includes all carbonate rocks of the Traverse Formation which lie at depths of 30 to 91 m beneath the Antrim shale.

Total discharge from the three units to the Lake St. Clair study area was estimated to be 1,315 L/s.

More direct measurement of groundwater flow to Lake St Clair was also undertaken. Recognizing that all flow entering the lake from groundwater must pass through its bed, the flow was calculated using the lakebed area, hydraulic gradients, and hydraulic conductivities established by an electrical survey of the lake sediments. The advantage of the electrical survey approach to calculating groundwater flux is that it produces continuous measurements of the hydraulic conductivity, as long as sediment is present over the bedrock, allowing both detailed resolution of the locations of groundwater inflow and an alternative method to calculate the quantity. Summations of groundwater fluxes for the entire lakeshore show a total groundwater discharge of 886 L/s.

This estimate agrees well with that from above, estimated from fluxes within geologic units.

Groundwater Contamination

In order to determine the concentration of contaminants in groundwater in the Lake St. Clair area, and subsequently to calculate loads from groundwater to the lake, eight monitoring wells were installed in four groundwater discharge areas on the Michigan shore of Lake St. Clair. Analyses of water from the wells were made for volatile, base neutral, acid extractable and chlorinated neutral extractable hydrocarbons, trace metals, and other chemical substances.

Volatile hydrocarbons, if present, were consistently less than the detection limit of 3.0 ug/L. Benzene was detected in water from one well near Mt. Clemens at a concentration of 3.1 ug/L. Concentrations of base neutral and acid extractable compounds, and 13 chlorinated pesticides, were also generally below the analytical detection limits of 0.1 to 30 ug/L and 0.01 ug/L respectively. Phthalates were found in the water from all but one well, with concentrations up to 170 ug/L (for bis (2-ethyl hexyl) phthalate).

Some pesticides were found in four wells at levels exceeding U.S.EPA Ambient Water Quality Criteria for Chronic Effects and the GLWQA Specific Objectives. Lindane and total DDT were found down-gradient from the Clay Township Landfill near the St. Clair River delta. DDT was found also in wells near New Baltimore and St. Clair Shores. Heptachlor was found in a well near the Selfridge Air National Guard Base (ANGB).

Most wells exceeded the GLWQA Specific Objectives, the Ontario (Provincial) Water Quality Objectives or the U.S.EPA Drinking Water Primary or Secondary Maximum Contaminant Levels for total phenols, phosphorus, pH and some heavy metals. The elevated metals concentrations may have been due to the inclusion of fine particulate matter in the samples, and if so, the concentrations of metals dissolved in the groundwater may be much lower than those reported. The well near the Selfridge ANGB contained the highest levels of phosphorus, phenols, dissolved solids and specific conductance.

A computation of the loading of chemical substances transported by groundwater to Lake St. Clair does not seem feasible based upon the data currently available. Concentrations of organic compounds were generally less than their respective limits of analytical detection, and concentrations of trace metals were reported higher than they would have been had the finely divided particulate matter been excluded from the analyses.

7. Spills

Spills reports from Michigan and Ontario information systems were reviewed and indicate that a limited number of spills to surface water occurred in 1986. However, in many cases the volume of the amount spilled was not known and it is not possible to compare point source effluent loadings with the loadings due to spills.

8. Contaminated Sediments

Identification

i) Organics

Depth-integrated samples (interval composites) were prepared from sediment cores collected in 1985 (Figure VIII-5) and analyzed for organics in order to estimate the mass of contaminants stored in the sediments. Horizontal distributions in total storage have patterns which are essentially congruent with the thickness of recent sediments and form the basis for estimating total storage in the lake by contour integration. For the sandy nonaccumulating area, where cores were not collected, a value of 5 ng/cm^2 was used for PCBs and HCB, and a value of 0.5 ng/cm^2 was used for OCS. These approximations were not critical since the sandy areas contributed less than 5% of the contaminant mass for these chemicals. Lake St. Clair sediments presently contain about 960 kg of HCB, 870 kg of PCBs and 210 kg of OCS.

These values are much higher than the contaminant masses found by Oliver and Pugsley (40) for the St. Clair River sediments (3 kg HCB, 20 kg OCS) indicating that Lake St. Clair is a more significant repository for chemicals than the river itself, in part due to the much greater mass of sediments in the lake. Recent loading estimates for HCB and OCS in the combined dissolved and particulate fraction at Port Lambton in the St. Clair River were 180 kg/yr for HCB and 11 kg/yr of OCS. At these rates, Lake St. Clair sediments contain the equivalent of 5 years loading of HCB and 20 years loading of OCS. Thus, the sediments retain significant fractions of these chemicals and, given the uncertainties in the calculation, accumulation is consistent with sediment reservoir residence times derived from historical studies of metal and organic chemicals in the system and from the response of sediments to particle-associated radionuclides.

ii) Metals

In order to estimate the total mass and anthropogenic mass of each metal stored in Lake St. Clair sediments, the sediment cores collected at each station in 1985 were designated to be representative of a region of the lake. The anthropogenic mass of each metal stored in each sediment type was calculated by subtracting background metal concentrations from all concentrations in post-settlement sediments. In general, metal concentrations increased above the glacial deposits.

Within the lake and its marshes, 30 to 64% of the mass of metals stored in post-settlement sediments is anthropogenic. Storage of anthropogenic metals is highest in the silts and clays (48-70%), second highest in the sands (32-35%), and lowest in the marshes (5-29%). An exception to these general statements is the high fraction of anthropogenic lead stored in the marshes (29%), based on the one core used to represent the marshes.

Lake St. Clair appears to be a temporary trap for some metals (Table VIII-9). Thus, sediments and their associated contaminants, appear to be transient and will eventually be transported down the Detroit River to Lake Erie.

Classification

Using the OMOE and U.S.EPA pollution guidelines, the sediments underlying the open water of Lake St. Clair can be classified as only lightly polluted. Sediments at the mouths of some tributaries are more contaminated.

9. Navigation

As a result of the Rivers and Harbors Flood Control Act of 1970, which authorized the U.S. Army Corps of Engineers to construct facilities for containment of polluted dredge spoil from the Great lakes harbors and waterways, two diked facilities were constructed on Dickinson Island adjacent to North Channel in the St. Clair delta. Both sites were located on the high pre-modern delta deposit and did not infringe on the wetlands. These disposal sites were designed to accommodate dredgings produced during a 10 year period, and they presently receive the materials dredged from the St. Clair system. Navigation-related dredging, which removes contaminated sediments and deposits them in confined disposal facilities could be considered beneficial in that the total contaminant load within the system is reduced. Impacts of the dredging due to resuspension of contaminated sediments during the dredging operations, and the subsequent temporary increase in bioavailability of the contaminants, have not been documented.

Commercial vessel operations through the shipping channel are also believed to cause some local sediment resuspension. The extent of influence and effects of the contaminants associated with the resuspended particles have not been documented.

D. DATA LIMITATIONS

A detailed discussion of data quality management for the UGLCC Study can be found in Chapter IV. The information presented below reflects concern for some data quality pertaining specifically to Lake St. Clair.

1. Sediment Surveys

References in the text to a "1983 sediment survey" in Lake St. Clair refer to a study conducted by the OMOE. The data have not yet been published, nor have the methods, results or any interpretation of the data been peer reviewed. Discussions with the principal investigators, however, indicate that the samples were obtained by bottom grab sampler, and the top 3 cm of each of 3 grabs were composited. The samples were then sent to a laboratory for analysis by "standard techniques". This study has the appearance of being a valuable contribution to the knowledge of the distribution of contaminants in Lake St. Clair sediments. However, the data must be considered "preliminary" at this time, and used only to support the findings of other documented surveys, particularly the 1985 surveys conducted by Environment Canada and by U.S. Fish and Wildlife Service.

2. Tributary Loadings

Accuracy of estimates of tributary loadings of chemical parameters is dependent on the responsiveness of the stream to storm events and on the frequency of sampling. Data from a program employing infrequent sampling will generally be biased low for substances which increase in concentration with increasing stream flow, such as nutrients from agricultural runoff (41). Of various sampling strategies, flow-stratified sampling, i.e., emphasizing storm events, and calculations provide the most accurate results. Loading data for phosphorus, nitrogen, chlorides, lead and cadmium from the Clinton, Thames and Sydenham Rivers were based on a combination of monthly and storm-event sampling and included from 15 to 72 samples per year. Data for the Ruscom, Puce and Belle Rivers were based on only 14 or fewer samples per year, and may therefore be subject to considerable error.

A recent analysis of the flow responsiveness of Great Lakes tributaries, i.e., their potential for change in rate of flow in relation to storm events, indicated that the Clinton River was "stable", the Sydenham River was "event responsive", and the Thames was intermediate between the other two (42) Estimates of loads of phosphorus, Cd and Pb for the Thames River, with the greatest number of annual samples, and the Clinton River, with the most stable flow, may be expected to have about the same accuracy, although confidence intervals were not reported. The estimate for the Sydenham, with the about the same or fewer samples and more variable flow response, may under represent the true load by some unknown amount.

The difficulty in calculating loads from small data sets created the need to make loading calculations using several methods. For Canadian tributaries, the Beale Ratio Estimator was used to arrive at loads for P, Cd, Pb, and Cl. Loading calculations for these parameters plus NO_3 were also made from the same data set by plotting P concentration vs flow. A "best line fit" was then drawn, and concentrations were then read off the graph for days on which no samples were taken. Phosphorus loads on the remaining Canadian tributaries were calculated using a two-strata method. A "cut-off" line was determined by doubling the annual mean flow. An average concentration was found for days when flow exceeded the cutoff, and another was found for days with flow below that value. Loads for unsampled days were calculated by multiplying the average concentration by the flow for that day. The values presented in this report represent an arithmetic average of results obtained by the two methods.

Concentrations of lead, cadmium, chloride and nitrogen in Canadian streams did not exhibit a variation with respect to flow. Therefore, loads were calculated by averaging all samples and multiplying by the flow.

For the Clinton River, loads were calculated using the Stratified Ratio Estimator (43). This method is essentially a modification of the Beale Ratio Estimator.

The average annual loads for Canadian tributaries as displayed in Table VIII-1 represents a mixture of included data. For P, the average unit area load is based only on data from the Sydenham and Thames Rivers, which comprise 57% of the Lake St. Clair watershed. Were an arithmetic average of all estimates of loadings from all Canadian tributaries to be used, the unit area loading would have been reported as 3.18 kg/ha instead of 2.26 kg/ha.

For NO_3 and Cl, the loadings include an average unit area loading from the Ruscom River, which was approximately 10 times that of the other rivers in 1985. The average unit area loading for the Sydenham and Thames Rivers combined for NO_3 and Cl was 20.5 kg/ha and 160 kg/ha, respectively, instead of the reported 40 kg/ha and 287 kg/ha. The cause for the Ruscom River concentrations and loads may need investigation, but the data should not be considered typical of the unit area loads for the Lake St. Clair watershed.

3. Point Sources

The point source monitoring data in general were developed with a rigorously defined quality assurance program. Due to constraints on the sampling frequency and quantity, however, a number of shortcomings in the point source survey data limit the inferences that can be drawn from the results of the study. Most facilities in the Lake St. Clair basin were not sampled. The major facilities closest to the lake itself, as opposed to those furthest upstream, were surveyed, however.

One deficiency, that of a small data base consisting of one day sampling by the U.S. and 3 to 6 day surveys by Canada, prevents precise determination of annual loadings. The timing of the surveys reduced the comparability of the data. The U.S. surveys were carried out during May and August of 1986, while the Canadian data was collected on October 1985 and March and November of 1986. The sampling methods were also different. The U.S. composited four grabs (one per six hours) for each facility. Canadian samples were collected by automatic composite samplers (one portion per 15 min.). Differences in the analytical methods and the method detection limits used by the U.S. and Canada for several parameters also reduced data compatibility. This deficiency was particularly pronounced for PCB analyses.

Despite these limitations, the data were considered adequate for identifying major sources of contaminants, and were used to make conclusions and recommendations concerning specific point sources.

4. Fish Consumption Advisories

The data upon which the fish consumption advisories for Lake St. Clair are based were derived primarily from Canadian analyses of samples of the edible portions of fish. This method generally returns concentrations of contaminants less than those found in larger skin-on fillets that the U.S. uses for its analyses of contaminants in fish. One implication, therefore, is that if the U.S. method for assessing contaminants in fish were used, the fish consumption advisories may become more restrictive. Although the impacts to humans of contaminants other than mercury in fish flesh for commercially marketed fish are not quantified, the advisories remain useful as a general guide for use by the public who consume fish from Lake St. Clair.

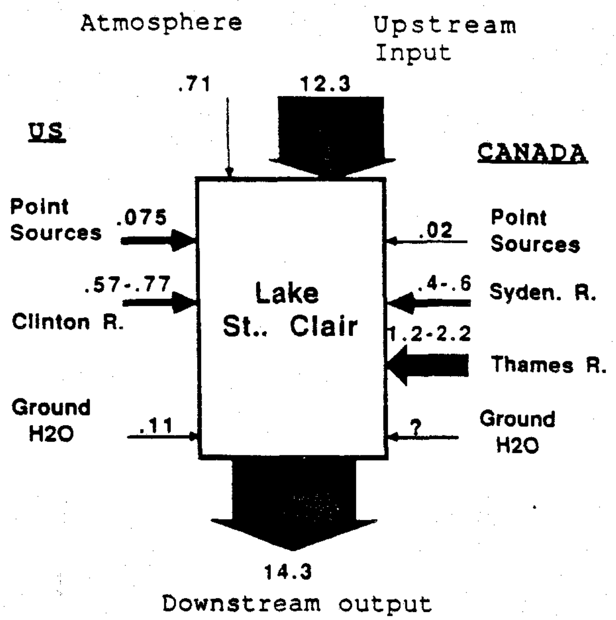
E. MODELING AND MASS BALANCE CONSIDERATIONS

1. Mass Balance Models

Four days prior to the onset of the System Mass Balance measurements in the Detroit River, measurements of contaminants entering Lake St. Clair from the St. Clair River were initiated. The intent of starting four days before making measurements on the Detroit River was to allow for passage of most of the St. Clair River water through the lake. By doing so, upstream and downstream contaminant fluxes could be compared and conclusions could possibly be drawn concerning whether Lake St. Clair is a source or a sink of contaminants. It must be emphasized that the validity of comparing upstream and downstream measurements in this mass balance calculation depends on how well the same parcel of water was sampled at the head and mouth of Lake St. Clair. Given winds that existed during the sampling time, and output from a particle transport model (developed at the National Oceanic and Atmospheric Administration - NOAA) discussed below, we estimate that 60-80% of the water that entered the lake, exited it on day four. Therefore, downstream contaminant fluxes that are 20-40% different from upstream fluxes cannot be argued to be significant. On the mass balance diagrams that follow (Figures VIII-6 through VIII-13), best estimates of point and nonpoint source inputs have also been noted. If estimates were not available, they are indicated with a "?" on a diagram. Loading information was compiled with data provided by the Point and Nonpoint Source Workgroups. Groundwater loading estimates are extremely preliminary and should be treated as such. These diagrams should therefore be used only to suggest possible issues that may require further investigation. This is because of uncertainty about time lags between the head and mouth of the Lake, and the "long term average" character of some of loading information.

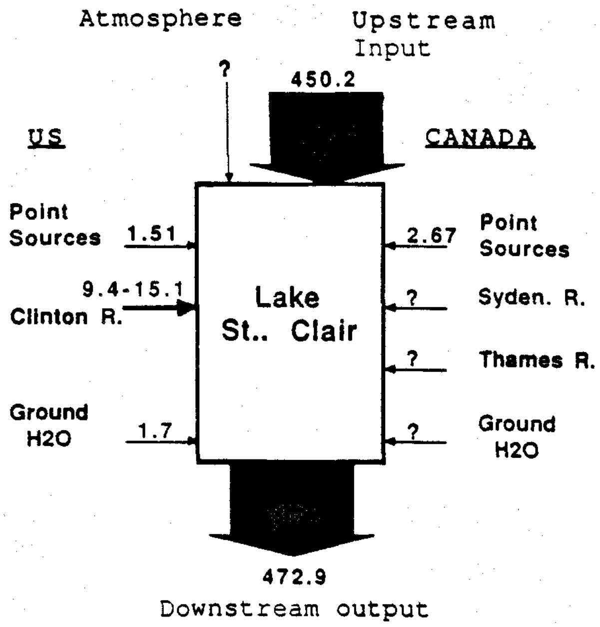
In most cases, the downstream contaminant fluxes do not differ widely from the contaminant flux entering the lake via the St. Clair River. In the cases of cadmium and particularly lead, it appears that a significant portion of the lake's total load could be coming from its tributaries. If the Thames River lead loads are reasonably accurate, then a regulatory problem may exist. Sediment records that indicate a net storage of lead over the years would corroborate these observations.

A total phosphorus budget was developed for Lake St. Clair for 1975-1980 (Figure VIII-13). Phosphorus load estimates were made for point sources and hydrological areas (Figure VIII-14). During this period Lake Huron accounted for 52% of the total annual load, while hydrologic area loads accounted for 43% (13). The remaining load came from the atmosphere, shoreline erosion and direct point sources. The Thames hydrologic area contributed 58% of the total hydrological area load, followed by the Sydenham (17%), the Clinton (9%), the Ruscom (7%), and the Black (6%).



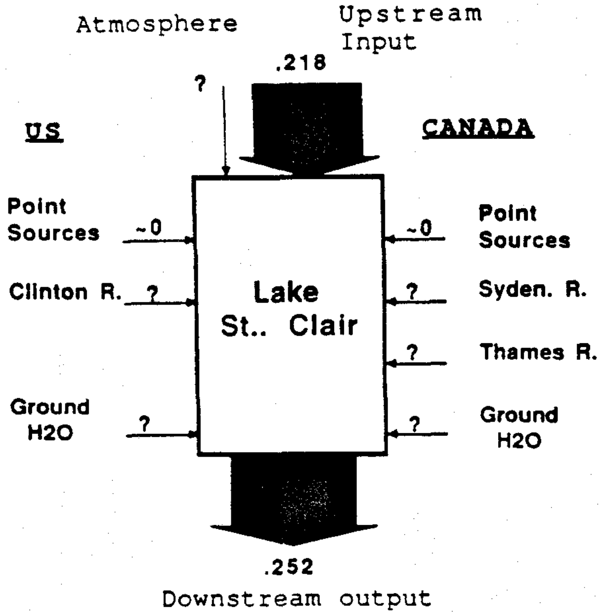
In=15.4-16.8
out=14.3
sink=1.1 - 2.5?

FIGURE VIII-6. Lake St. Clair total cadmium (kg/d).



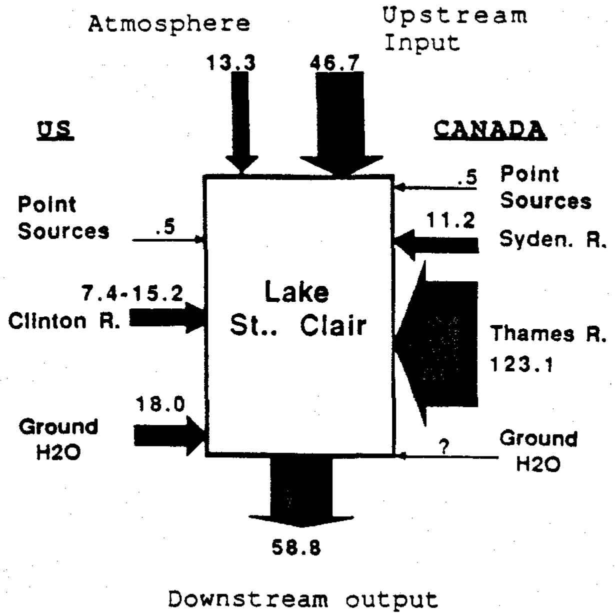
In=465.5-471.2
out=472.9
source=7.4-1.7?

FIGURE VIII-7. Lake St. Clair total copper (kg/d).



In=.218
out=.252
source=.034?

FIGURE VIII-8. Lake St. Clair HCB (kg/d).



In=220.7-228.5
out=55.8
store=161.9-169.7?

FIGURE VIII-9. Lake St. Clair total lead (kg/d).

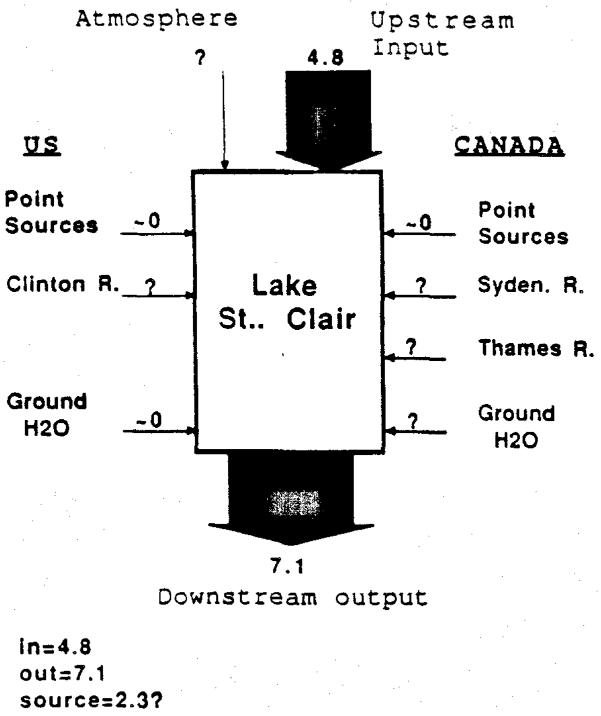


FIGURE VIII-10. Lake St. Clair total mercury (kg/d).

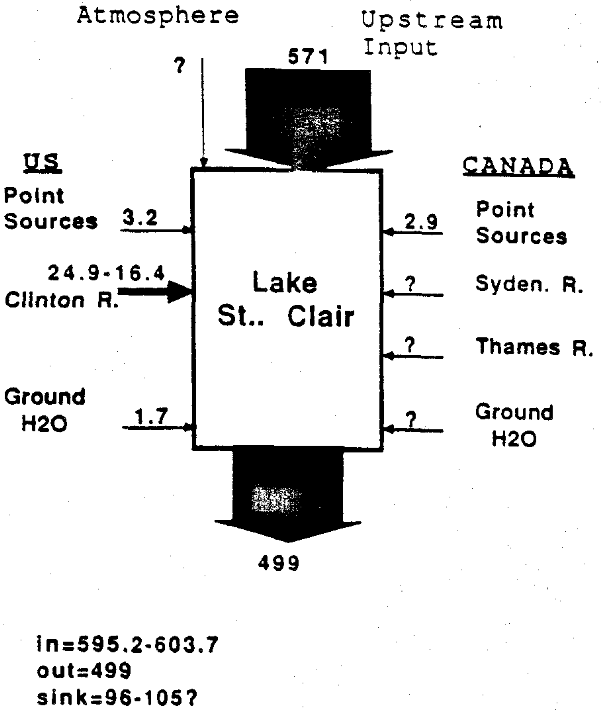


FIGURE VIII-11. Lake St. Clair total nickel (kg/d).

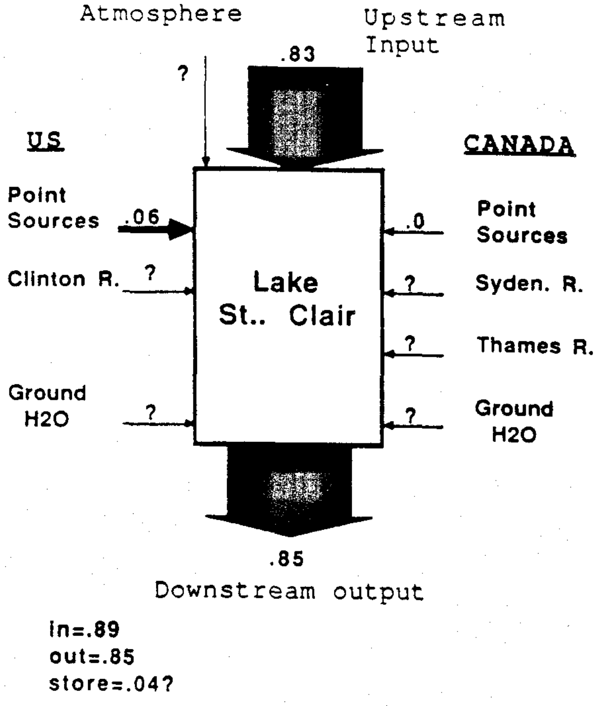


FIGURE VIII-12. Lake St. Clair total PCB (kg/d).

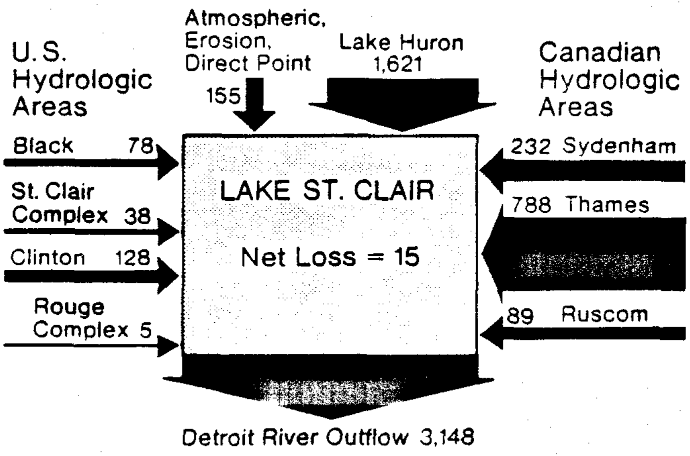


FIGURE VIII-13. Lake St. Clair average phosphorus loads and losses during 1975-80 (mt/yr).

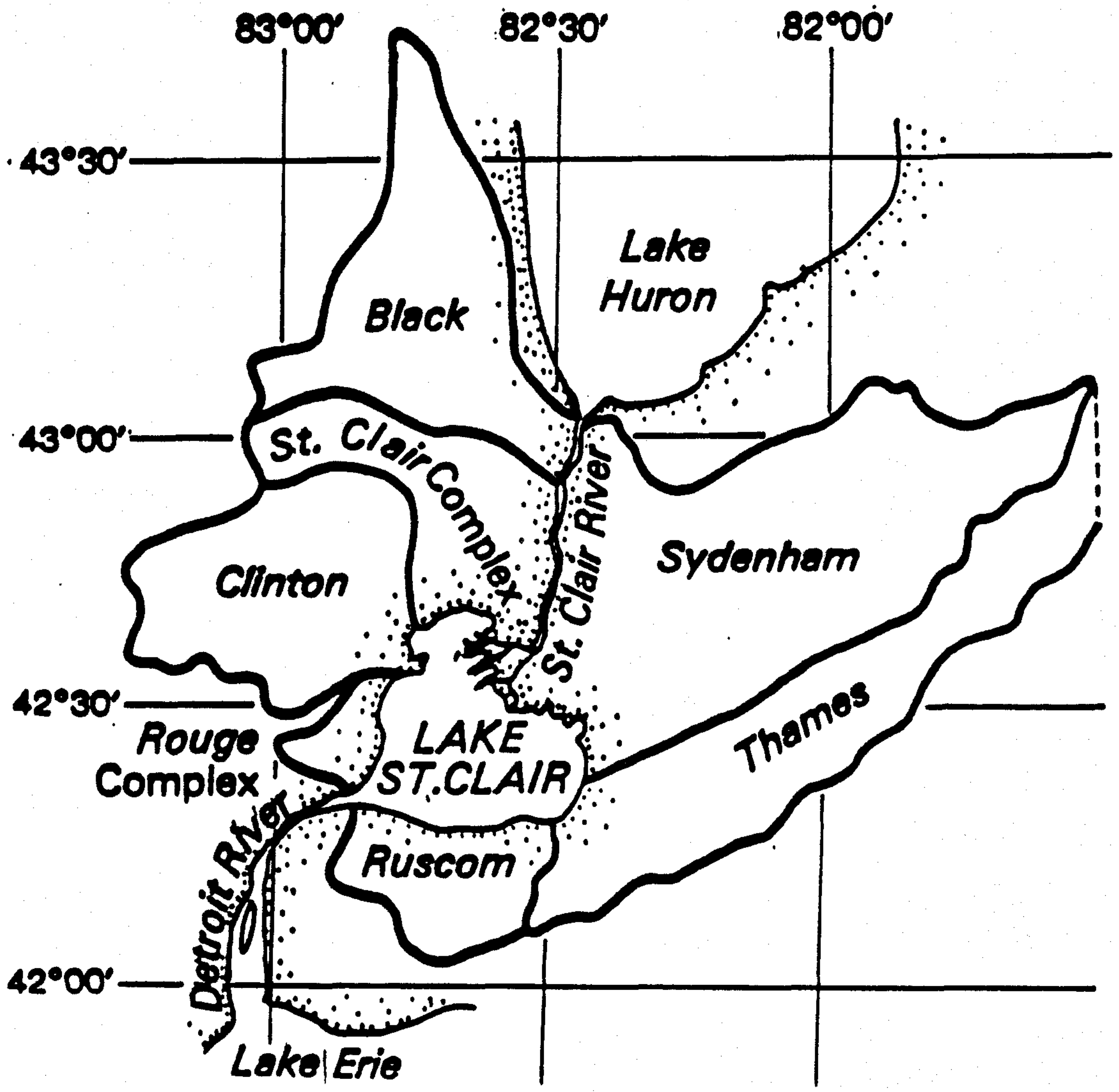


FIGURE VIII-14. Hydrological areas used in determining mass balances.

Over the six year period examined, the lake's total input and output of phosphorus were nearly equal. Therefore, there was no significant net source or sink of phosphorus in the lake during that period.

2. Process-Oriented Models

Changes of water level caused by wind are most pronounced in shallow lakes such as Lake St. Clair. The ability to predict wind-induced water level changes would therefore be useful, since these changes can affect shorelines and contingent properties. A hydrodynamic model was developed to investigate the effects of bottom drag and wind stress on computed lake setup, and to determine the efficacy of hydro-dynamic or purely empirical approaches to predicting water measurements. Empirical approaches by-pass many of the calculations that are used in the hydrodynamic approach. No essential difference between the two approaches was found, but for an empirical model to be developed, an adequate historical data base for the site of interest must exist. The strength of the hydrodynamic approach is that it is transferable among lake systems.

To predict the fate and transport of contaminants in any body of water, the movement of that water, as affected by winds or tributaries, must be known or predictable. Because of this need, several models were developed by Canadian and U.S. scientists to predict and understand currents in Lake St. Clair. In addition, models were developed for predicting and understanding wave dynamics in Lake St. Clair since waves can resuspend sediments and associated contaminants.

Simons and Schertzer, (Environment Canada - EC) developed a model that predicts mean daily currents in Lake St. Clair. They found that an important consideration in developing the model was accounting for the effects of a shallow bottom on currents. Lack of information regarding these effects has been a major impediment to the application of hydrodynamic models to shallow lakes. They were able to develop a tentative relationship between eddy viscosity and wind stress that aided in shallow water model development.

Schwab and Clites (NOAA) developed a particle transport model for Lake St. Clair to answer the following questions: 1) What path does water entering Lake St. Clair from one of the tributaries follow through the lake before leaving the Detroit River? 2) How long does it take? 3) How is the particle path changed by wind-induced circulation in the lake? 4) For the meteorological conditions during the summer and fall of 1985, what are the typical statistical distributions of these pathways? The model they developed calculates currents on a 1.2 km grid and yields results that are similar to those of Simons and Schertzer above. Their model can be used to make preliminary estimates of the spatial distribution, transport and residence times of conservative, hazardous spills in Lake St. Clair. This model, however, only tracks conservative, nondispersive tracers from the mouths of the tributaries through the lake under various wind conditions.

Even though the average hydraulic residence time for Lake St. Clair is about nine days, the residence time for conservative particles entering the lake from the individual tributaries ranges from 4.1 days for the Middle Channel to over 30 days for water from the Thames River, depending on the wind conditions. If significant contaminant loads were to enter the lake from tributaries that have long residence times, the impact of these contaminants might be greater than if they entered the lake from other tributaries.

Most of the water from the St. Clair River enters the lake through the North Channel (35%). According to the calculations, this water tends to flow down the western shore of the lake and never gets into the central or eastern parts of the basin. Water from the Middle Channel tends to remain in the western third of the lake, almost never entering the eastern half. Water from St. Clair Flats and the St. Clair Cutoff can be dispersed almost anywhere in the lake to the south of the shipping channel which connects the St. Clair Cutoff with the Detroit River. A small amount of the St. Clair inflow (5%) enters through Bassett Channel. This water can pass through any part of the eastern half of the lake depending on the wind conditions. The Thames inflow tends to be confined to the eastern and southern shores before reaching the Detroit River and it can take a very long time to get there. Water from the Clinton River and the Clinton Cutoff is most likely to follow the western shore of the lake southward with the most probable paths within 3 km of the western shore.

Water quality measurements made in Lake St. Clair by Leach (44, 45) showed two distinctly different areas in the lake. In the southeastern part of the lake, the water quality was dominated by the Thames inflow, which is a major source of phosphate and other dissolved and suspended material. The central and western parts of the lake possessed water quality similar to Lake Huron than to the southeastern part of the lake. The pattern of water mass distribution (45) is very close to the combined patterns of the four main St. Clair River inflows and the Thames inflow. Bricker et al. (46) examined the distribution of zooplankton in the western half of the lake. They distinguished an area of biological and physiochemical similarity along the western shore of the lake that appeared to be influenced more by the Clinton River than the St. Clair River. The shape of this area matches quite well with the modelled distribution pattern for water from the Clinton River.

To verify the circulation model and lend credulity to currents calculated by Schwab and Clites, their model was tested by comparing model output to actual current data measured in Lake. St. Clair in 1985. Two separate current data bases were gathered. One involved the use of 5 drifting buoys which were repeatedly launched and tracked in the lake. The other was the result of several synoptic current surveys utilizing electromagnetic current meters. Currents predicted by the circulation model were used to simulate 16 drifter tracks. Most of the tracks were about 2 days in length from various portions of the lake. In most cases, the model simulated the tracks extremely well as did a similar study by Hamblin et al., (26). For the entire data set, the mean root mean square (rms) of the drifter was 25% greater than that of the calculated current track. The directions compared favorably except for a few tracks near the mouth of the Bassett Channel, where the model prediction was over 90 degrees different in direction when compared with the observed track. The comparisons between current meter measurements and model-predicted currents were even better. In nearly 100 comparisons, 60% of the variance is explained by the model prediction. The model again seems to under-predict the current speeds, here by about 30%.

Contaminant transport depends in large part on the movement of suspended particles. Therefore, accurate computation of horizontal sediment transport should rely upon the accurate simulation of the vertical structure of the horizontal flow field. Hamblin et al., (26) developed such a three dimensional finite element model for Lake St, Clair. Model agreement with observations was good near the lake bottom but poorer near the surface and suggested that a more elaborate model would be needed to accurately model vertical velocity profiles. The more elaborate model would include the effect of surface waves.

An empirical model was developed to describe and understand the relationship between waves and sediment settling and resuspension (25). The importance of these relationships to our ability to predict and understand the transport of contaminants is evident. Statistical relationship between suspended matter and concentration and wave orbital velocity was computed. Integration of computed resuspension rates provided an estimate of sedimentation in sediment traps. The model-generated sedimentation rates compared rather well with the sediment trap data.

Present Status of Physical-Chemical-Biological Models

To predict the fate and behaviour of contaminants, models that integrate physical, chemical, and biological processes are often needed. Two such synthesis models were developed for predicting contaminant fate in Lake St. Clair. Halfon (EC) utilized TOXFATE and Lang, Fontaine and Hull (NOAA) utilized the U.S.EPA TOXIWASP model. TOXFATE was used to predict the spatial distribution of seven halocarbons in Lake St. Clair, and the fate of perchloroethylene in the St. Clair - Detroit River system. The TOXIWASP model was used to predict and understand the fate of the contaminant surrogate Cs-137, as well as PCBs and OCS. Neither of these models could be fully tested for Lake St. Clair applications due to a limited test data set. However, these models are based on well documented cause and effect relationships, and as such, could be used to forecast the fate and behaviour of contaminants introduced to the lake in the future. Representative results of Halfon's Lake St. Clair TOXFATE model is demonstrated in Figure VIII-15.

Lang and Fontaine (NOAA) developed a multi-segment, generic contaminant fate and transport model for Lake St. Clair. The TOXIWASP code upon which it was based was streamlined to make it more specific to Lake St. Clair. Because evidence of biological mixing in Lake St. Clair was extensive, this capability was added to Lake St. Clair version of TOXIWASP. An extremely fast version was created that calculates steady state contaminant concentrations in seconds rather than hours. Numerous programming errors in the original code were found, corrected and passed on to the U.S.EPA-Athens modeling group.

Lang and Fontaine (NOAA) calibrated the transport mechanisms of TOXIWASP using chloride and meteorological data that were collected during a series of cruises in Lake St. Clair during 1974. After obtaining reasonable agreement with the conservative chloride ion, calibrations of contaminant dynamics was carried out using Cesium-137. Cesium-137 was used to calibrate the model's contaminant dynamics since Cesium-137 adsorbs to particles in a manner similar to that of many hydrophobic, organic contaminants. Most importantly, the source function of Cesium-137 to the lake is well known (Figure VIII-16). This information, coupled with knowledge of the spatial and depth distributions of Cesium-137 in the sediments of the lake, provided an excellent calibration and verification data set. Verification results are acceptable (Figure VIII-17).

Having calibrated the TOXIWASP model for Lake St. Clair, it was used to hindcast possible loadings of octachlorostyrene and PCBs to Lake St. Clair. The model predicted that about 3.9 MT of OCS had to have been loaded to the lake over a period of 12 years to produce measured sediment concentrations (Figure VIII-18). This finding implies that OCS was first loaded in the latter part of 1970 and is consistent with speculation to that fact. The model also estimated that 3,400 kg of PCBs had to have been loaded to produce measured PCB sediment concentrations (Figure VIII-19). The model tended to under-predict the PCB values along the eastern and western segments of the main lake, which may indicate additional or increased PCB sources in these areas.

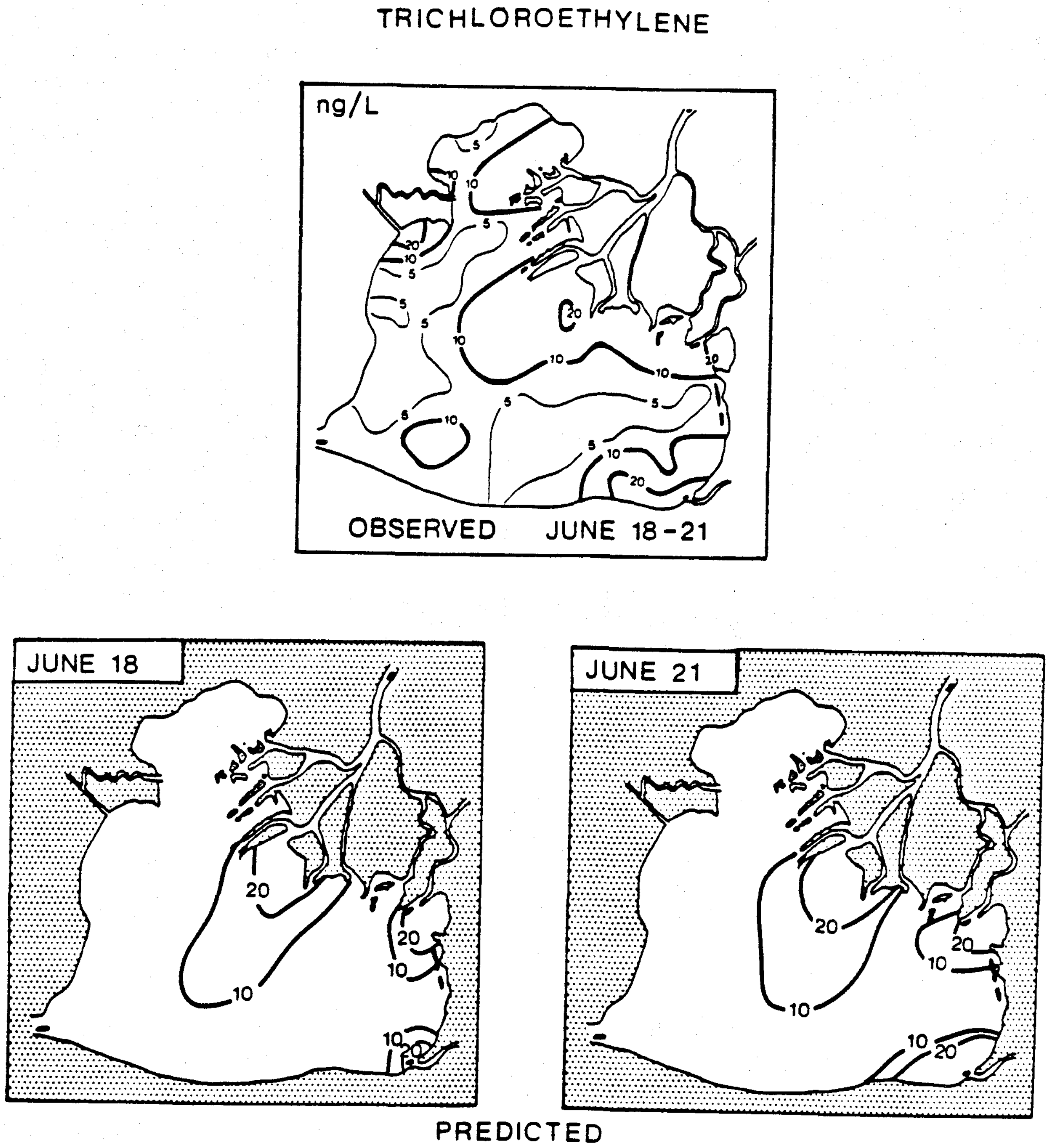


FIGURE VIII-15. Modelled and observed distributions of trichloroethylene 1984.

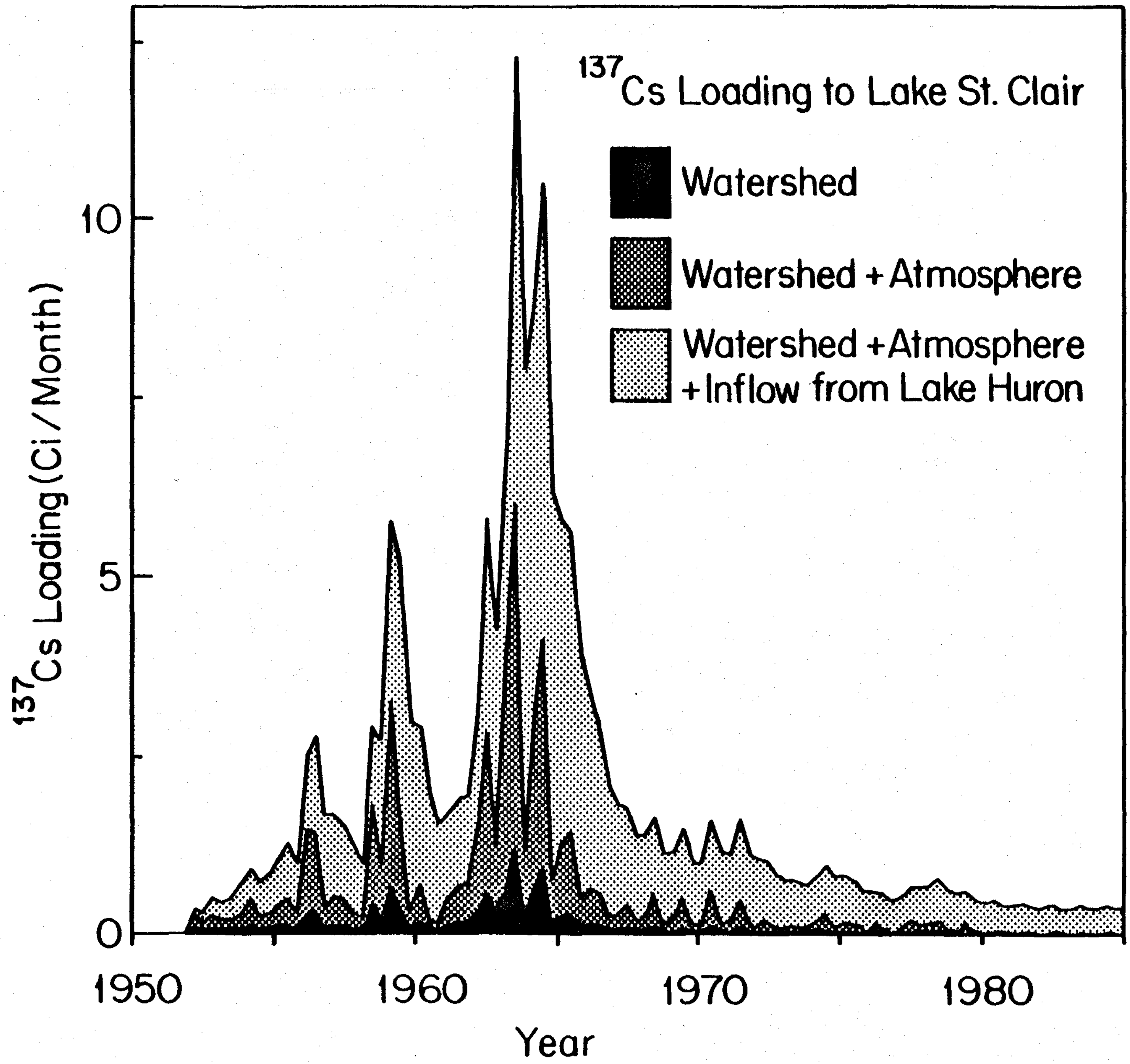


FIGURE VIII-16. ^{137}Cs loadings to Lake St. Clair.

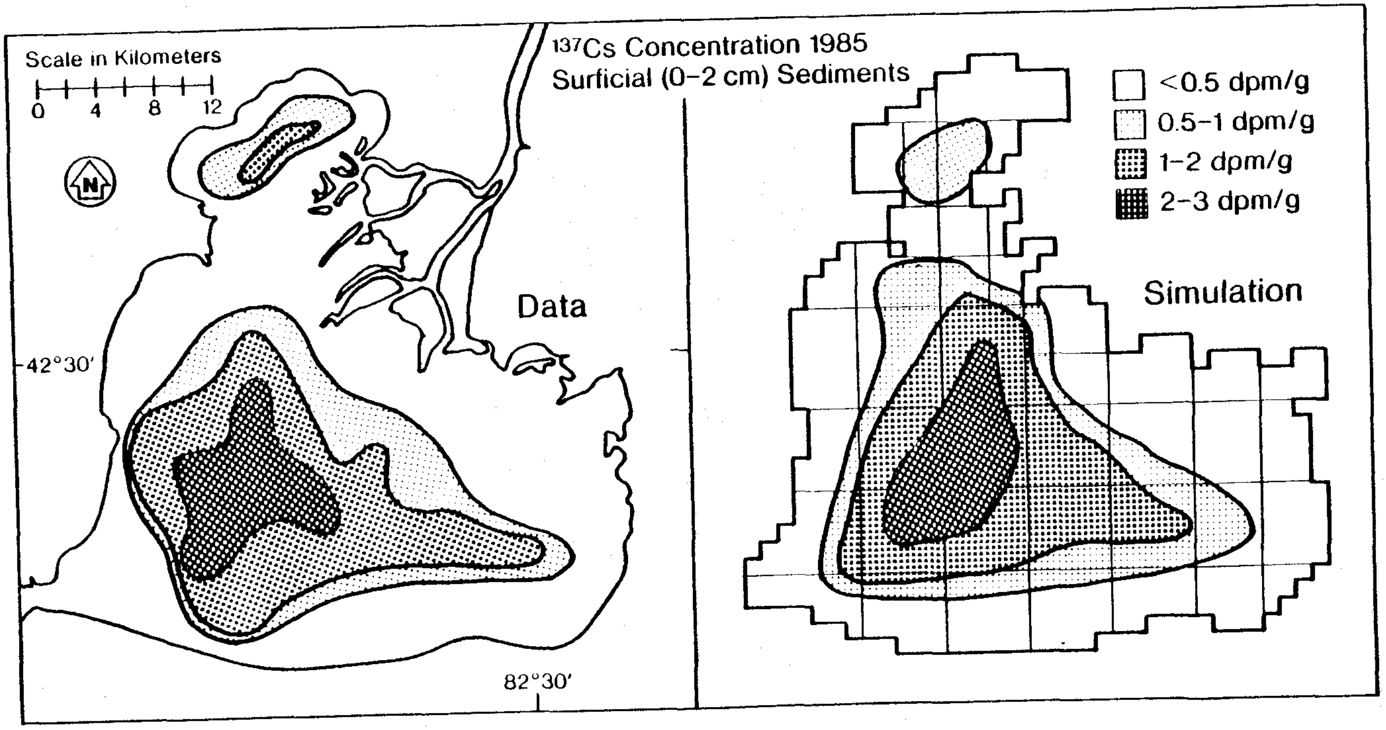


FIGURE VIII-17. ^{137}Cs concentration 1985 surficial (0-2cm) sediments.

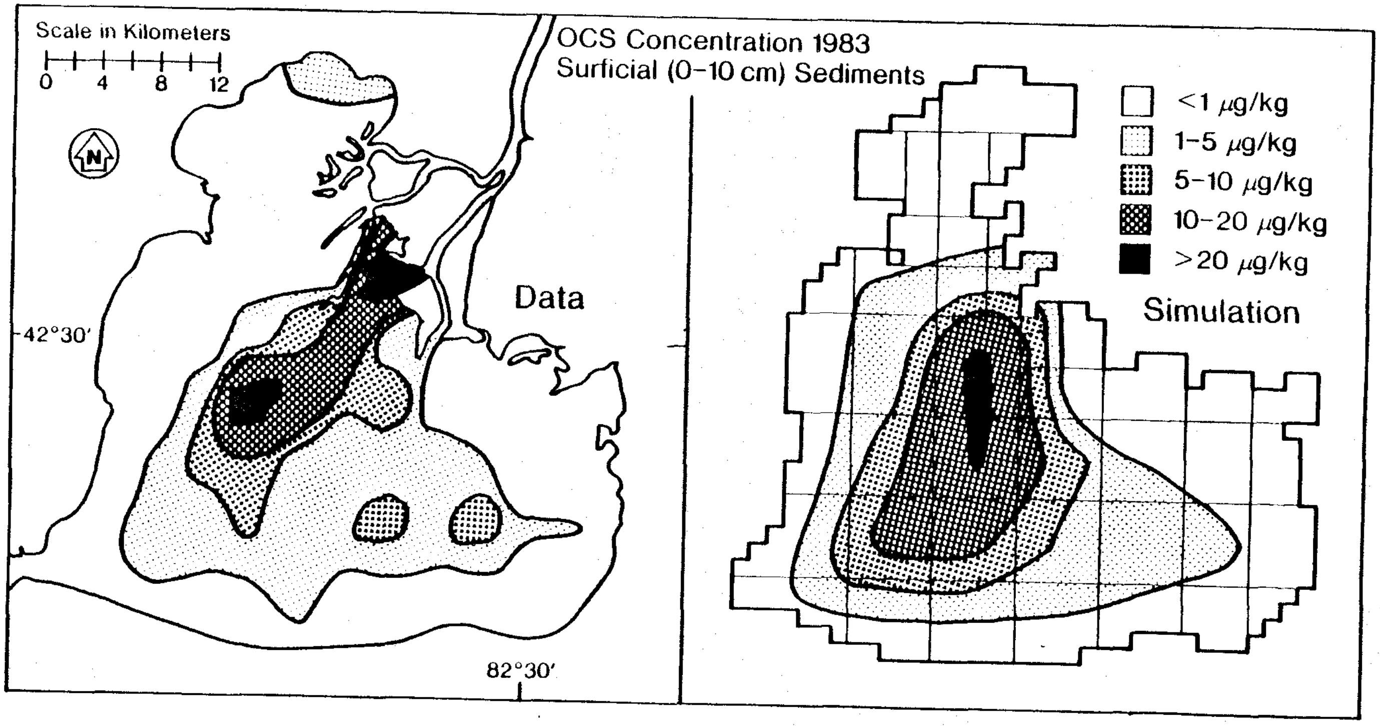


FIGURE VIII-18. OCS concentrations 1983 surficial (0-10cm) sediments.

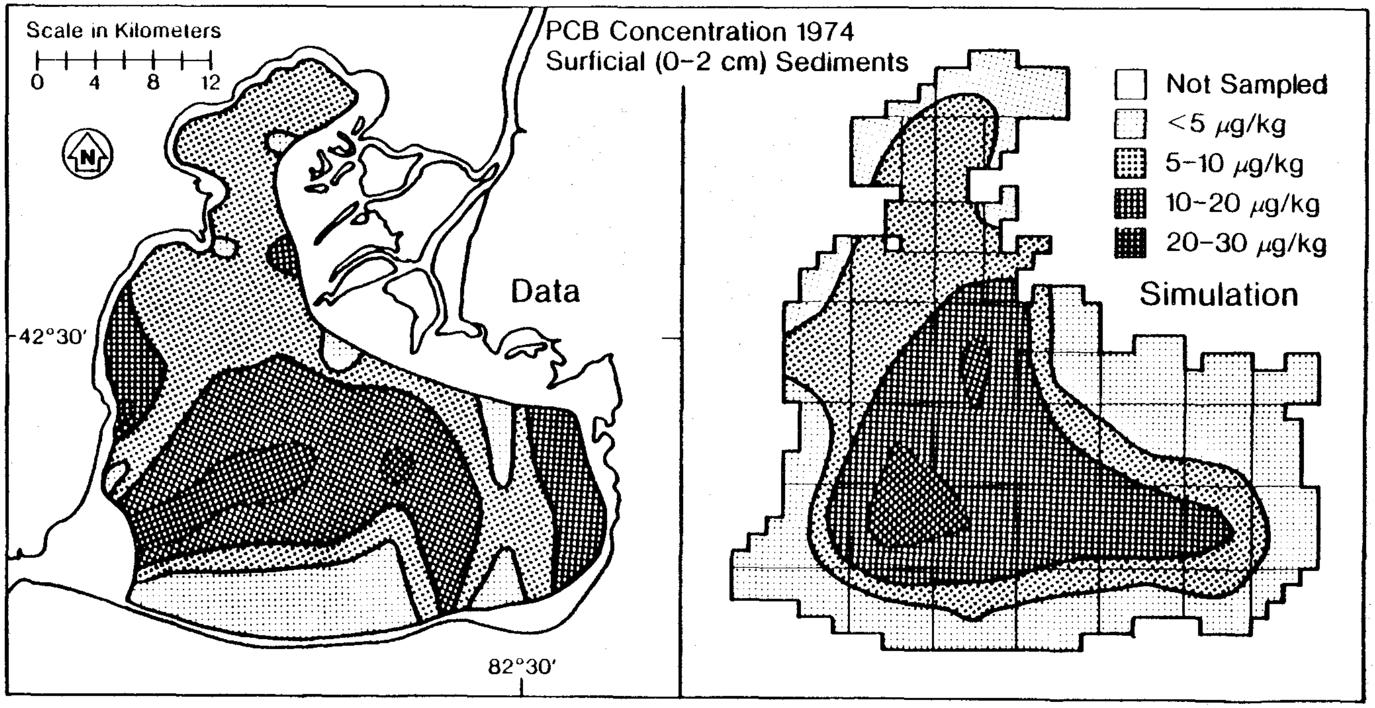


FIGURE VIII-19. PCB concentration 1974 surficial (0-2cm) sediments.

TOXIWASP assumes a local equilibrium between the dissolved, particle-adsorbed and bio-adsorbed chemical. Hull, Lang and Fontaine (NOAA) modified the TOXIWASP model so that kinetic, instead of equilibrium, reactions were simulated. This was done to determine whether the equilibrium approach was valid in all circumstances. Equilibrium models assume implicitly that incoming contaminant loads are at local equilibrium between dissolved, adsorbed, and bioaccumulated phases. When the same load conditions were assumed for the kinetic model, greatest deviations between the two models occurred when predicting the fate of highly hydrophobic contaminants ($K_{OW}>10^6$). The kinetic model not only required a longer time to reach steady state contaminant concentrations, but also required a longer time to flush out the resident contaminant mass after the input load was shut off. Generally, one would expect problems with an equilibrium approach when the time to equilibrium is longer than the residence time of the water body in question.

Halfon (EC) used TOXFATE to predict the fate of perchloroethylene (PERC) in the St. Clair - Detroit River system. The model suggested that about 82% of the PERC would be volatilized, and the remainder, less 1% that would remain in sediments, would enter Lake Erie. Comparison of simulated and measured PERC concentrations show reasonable agreement. Since so much of the PERC is volatilized before it reaches the open lake, Halfon's model does not realistically demonstrate what may happen to a nonvolatile spill entering the lake.

In the case of a nonvolatile spill travelling the lake from the St. Clair River to the Detroit River outflow, the dilution of the concentration would be determined mainly by the strength of horizontal turbulent mixing. There were no direct measurements of horizontal diffusion in Lake St. Clair reported by any of the UGLCCS activities. However, two investigations (17,53) have employed a vertically integrated model of transport and diffusion of a conservative substance, chloride, to infer an effective horizontal diffusion coefficient of 10^{+5} cm^2/s. Because this quantity has been deduced from vertically averaged concentration in the possible presence of current shear over the water column, these authors have termed the diffusion coefficient as a dispersion coefficient.

The particle trajectory measurements and models reported for August 12, 1985 by Hamblin (47) and by the Modeling Workgroup Report (53) for September 1985 demonstrated that particles would take about four days to cross the lake. If a slug of contaminated river water had dispersed longitudinally to a length of 5 km in the St. Clair River, then in the four day transit to the outflow region it would have grown by about 7 km to a characteristic patch size of 12 km under the assumptions of average meteorological conditions and horizontal Gaussian diffusion. In turn, this patch would take about two days to pass across the water intakes near the outflow. Finally, the average concentration would be about 20% of the original concentration entering the lake.

3. Summary

The modeling work on Lake St. Clair has made much progress during the study period from the water level fluctuation models (storm surge) to the coupled contaminant-circulation models. However, more work is required before the models could be used as effective water management tools. Testing of the models with parameters additional to PCB and OCS, more realistic treatment of sediment water interaction, and linkage of the models to lake biota are seen as necessary steps before the models can reliably assess the ecological responses to reductions in loadings to the lake. Although not developed for operational purposes, the models TOXFATE and TOXIWASP, with modest additional effort, could be used to predict the trajectories and dilutions of spills of either volatile or nonvolatile substances occurring on the lake or entering from the rivers.

F. OBJECTIVES AND GOALS FOR REMEDIAL PROGRAMS

The following objectives and goals are grouped according to media. However, remedial actions are likely to have multimedia effects. For example, elimination of point and nonpoint sources of contaminants can be expected to reduce concentrations in water, sediments and biota, even though direct remediation of contaminated sediments or biota may be infeasible. Some objectives may be reached, therefore, upon attainment of one or more others.

1. Water Quality

Since the water quality of Lake St. Clair is dominated by that of the St. Clair River, remedial programs directed towards the St. Clair River will also improve water quality in Lake St. Clair.

Objective 1. **Full implementation of recommendations for the St. Clair River presented in Chapter VII of this report for the elimination of industrial, municipal and nonpoint sources of contaminants to the St. Clair River, particularly HCB, HCBD, OCS, Hg, and Pb.**

Excluding input from the St. Clair River, phosphorus loadings to Lake St. Clair are dominated by nonpoint sources. For example, in the Thames River 93% of the loading was of the nonpoint source type. In water samples from Lake St. Clair tributaries, nearly all contained phosphorus in excess of the PWQO of 30 ug/L. Improved agricultural practices such as conservation tillage, elimination of over-fertilization and control of feedlot effluents are identified as actions relevant to reduction of nonpoint source loadings.

Objective 2. **Reduction of phosphorus loadings from point and nonpoint sources in Michigan and Ontario to assist in meeting target load reductions for Lake Erie.**

The Mt. Clemens WWTP was identified as having average phosphorus concentrations in its effluent exceeding the GLWQA objective of 1.0 mg/L for municipal water treatment facilities. Municipal treatment plants discharging to the Thames River in excess of this guideline in 1986 were Chatham, Ingersoll (new), City of London (Adelaide, Greenway, Oxford, Pottersburg and Vauxhall) and the Strathroy Town Plant.

Objective 3. **Necessary and sufficient technology and operation procedures at all wastewater treatment facilities to meet the target concentration of phosphorus in the effluent of no more than 1.0 mg/L.**

Excessive unit area loading of pesticides from agricultural lands into tributaries of Lake St. Clair was identified. Some areas were identified to be of particular concern.

Objective 4. **Reduction in the loadings of pesticides from all tributaries.**

Objective 5. **Identification and elimination of the source of DDT and metabolites to the Milk River.**

Water quality in several tributaries was reduced by the presence of heavy metals. Cadmium concentrations generally exceeded the GLWQA specific objective and PWQO of 0.2 ug/L, and some were greater than the chronic AWQC of 1.1 ug/L in the Belle, Sydenham, Thames and Clinton Rivers. Also, some lead concentrations were in excess of the chronic AWQC of 3.2 ug/L in the Belle and Sydenham Rivers, and in the Thames River some exceeded the acute AWQC of 82 ug/L.

Objective 6. **Identification and elimination of all point sources of Hg, Pb and Cd in the watersheds of the Clinton, Thames and Sydenham Rivers.**

Objective 7. **Elimination of combined storm sewer overflows which will reduce contributions of P, Pb, Cd, Hg and PCBs to Lake St. Clair tributaries.**

2. Sediment Quality

Reductions in industrial loadings of mercury in the St. Clair River have resulted in dramatic improvements since 1970 in the bottom sediments. However, surface concentrations in bottom sediments still exceed the IJC and OMOE guidelines of 0.3 ppm and contain values classified as "polluted" by the U.S.EPA Classification Guidelines. Since recent mercury concentrations of bottom sediment samples do not appear to be reducing as quickly as in the earlier studies there is some concern that unknown tributary sources exist. The mass balance studies of Section E indicate a net outflow of mercury from Lake St. Clair. Since the tributary loadings are not known, it is impossible to determine the source of the mercury.

Objective 8. **Identification and elimination of continuing sources of Hg to the St. Clair River.**

Objective 9. **Identification and elimination of point and non-point sources of Hg to Lake St. Clair tributaries.**

Of the other metals, only zinc and copper exceed the OMOE guidelines in the sediments of the open lake and would result in a classification of sediments as moderately polluted.

Objective 10. **Reduction in heavy metals concentrations in surficial sediments of Lake St. Clair to levels supporting a classification of "not polluted" by OMOE, U.S.EPA and IJC Guidelines.**

The sediment surveys revealed that PCBs did not exceed the guidelines in the open lake. However, guideline concentrations were exceeded in some of the tributary sediments including the Cottrell Drain, the mouth of the cutoff channel of the Clinton River and the Sydenham River. Other organic contaminants with specific guidelines such as HCD, OCS and pesticides were identified in sediments from the open lake and tributaries. In general, the sampling of all tributary sediments was incomplete, so there could be cases of excesses of certain compounds not reported or cases of compounds that were sampled which have no guidelines.

Objective 11. **Elimination of DDT in sediments at the mouth of the Milk River.**

Objective 12. **Identification and elimination of sources of PAHs in sediments from the Milk River, Cottrel Drain, Clinton River and Frog Creek.**

Objective 13. **Reduction in PCB concentrations at the mouths of Lake St. Clair tributaries such that the sediments would be classified as "not polluted" by OMOE, U.S.EPA and IJC Guidelines.**

3. Biota and Habitat

The most significant impaired use of Lake St. Clair waters is the restriction in the consumption of sports fish. A joint fish consumption advisory between Ontario and Michigan remains in effect for the larger specimens of 18 species of sports fish (33). Levels of mercury in excess of Canadian governmental guidelines have been identified as the main contaminant responsible for restricted fish consumption. Because the concentrations of mercury in the tissues of sports fish have declined dramatically since 1970, programs to control the major historical sources of mercury appear to be satisfactory. However, since tributaries were not monitored, smaller, uncontrolled sources could be contributing to the loading.

Objective 14. **Reduction in mercury concentration in Lake St. Clair fish to less than 0.5 mg/kg, and subsequent elimination of the fish consumption advisory based on mercury contamination.**

Objective 15. **Continued reduction in PCB concentrations in fish to meet the GLWQA specific objective of 0.1 mg/kg for protection of birds and animals which consume fish.**

In addition to being an important sports fishery, Lake St. Clair is a major duck hunting area. The habitat necessary for wildfowl resting, feeding and breeding is provided by the extensive wetlands around Lake St. Clair particularly in the Lake St. Clair Delta. More than 9,000 km of wetlands were lost to shoreline development in Lake St. Clair between 1873 and 1968. Losses are most evident in the Clinton River, the St. Clair River Delta and the eastern shore of the lake. In 1979 the state of Michigan prohibited the modification of a wetland over 5 acres in size to restrain encroachment into the wetland areas. In Ontario, subsidies for engineering projects still encourage drainage of wetlands and their conversion to agricultural use. However, tax relief that favors retention of the wetlands has recently (1987) been granted to wetland owners. Although diked Ontario wetlands are effectively managed for waterfowl hunting, there is a loss of other wetland functions, particularly those related to fish production.

Objective 16. **Preservation of remaining wetlands surrounding Lake St. Clair, and protection of them from further diking, filling or other forms of destruction.**

4. Management Issues

In the Clinton River, the concentration and impact of contaminants are sufficiently severe for the area to be recognized as an IJC "Area of Concern". A Remedial Action Plan is in the process of being developed by the State of Michigan for restoring beneficial uses of the area. This plan will contain details of the problems, their extent and causes, and a schedule for remedial actions to be implemented. Plans for further monitoring for results of the actions will also be included.

Objective 17. **Full implementation of the Remedial Action Plan by Michigan and other responsible agencies for cleanup and restoration of uses in the Clinton River.**

Although the Thames River is not presently one the IJC Areas of Concern, many agricultural and industrial contaminants have been identified in the water and sediments, and impaired uses were identified that are similar to those for the Clinton River. The absence of the Thames River on the AoC list should not imply that the area is contaminant-free.

Objective 18. **Preparation and implementation by Ontario of a** Plan for the restoration of impaired uses in the Thames River. The Plan should address issues of agricultural runoff of nutrients and pesticides, CSOs in the watershed, and sources of heavy metals in the tributary.

G. ADEQUACY OF EXISTING PROGRAMS AND REMEDIAL OPTIONS

1. Projection of Ecosystem Quality Based on Present Control Programs

In general, the ecosystem quality in Lake St. Clair is adequate for the maintenance of a desirable biological community that includes the production of sport fish. Impairment of the biological communities due to contaminants appears to exist only in localized areas around the mouth of some tributaries (although some contaminant levels in fish are sufficient to force the issuance of a fish consumption advisory by Michigan and Ontario), and the loadings of agricultural nutrients have not caused severe eutrophication problems. Loss of habitat due to wetlands destruction, however, has been extensively documented.

The specific concerns addressed in Section B, above, relate mostly to contaminants in the Lake St. Clair basin, and can be grouped into three major categories: nonpoint source loading of contaminants and nutrients, contaminants in tributary water and sediments, and contaminants in fish. Of these categories, insufficient data exist to determine trends in the loading of contaminants from nonpoint sources, including tributaries. However, the concentration of mercury in the edible portions of northern pike, white bass and yellow perch from Lake St. Clair, and of PCBs in walleye from 1970 through 1984 have been declining at a geometric rate (7), indicating that control programs for these two contaminants have been at least partially effective. Evidence for continuing loadings of nutrients, pesticides, PCBs, and heavy metals implies that the rate of decline in contaminant burdens in fish could be greater were no additional contaminants entering the system.

Although the impact of the loading of the UGLCCS parameters to Lake St. Clair directly may appear to be minimal, consideration must be given to the ultimate impact on Lake Erie populations. Lake St. Clair may be storing HCB and HCBD, but it is a source for PCBs and total phosphorus. These contaminants are then transported through the Detroit River and should be accounted as loadings to Lake Erie.

2. Assessment of Technical Adequacy of Control Programs

Present Technology

In 1985, inputs of nine of the UGLCCS parameters were determined to be significant, resulting in impacts to either water, sediment or biota quality. These were cadmium, copper, cyanide, lead, mercury, nickel, PCBs, phosphorus and zinc. In general, discharge of these parameters from point sources was not controlled by limitations or objectives. All of the surveyed point sources were municipal facilities, and all were subject to discharge limitations mainly for conventional parameters. However, for many of the parameters, point sources were not the most significant contributors. Rather, the largest loading was obtained from unidentified sources discharging through tributaries.

The control of phosphorus has been the main approach of the U.S. and Canada to remediating the eutrophication of the Great Lakes. All municipal plants surveyed in the Lake St. Clair basin had average concentrations less than 1 mg/L, except the Mt. Clemens WWTP. The GLWQA Objective, the Canadian Municipal effluent Objective, and the standard Michigan permit limit for phosphorus is 1.0 mg/L monthly average in sewage plant effluent. The Mt. Clemens WWTP exceeded the 1 mg/L average frequently in 1986 according to self-monitoring data. An expansion and improvement of the facility is underway (1987) which will enable the plant to meet the limitation.

Excluding input from the St. Clair River, the Thames River provided the largest loading of phosphorus to Lake St. Clair, exceeding the contributions made by the point sources by a factor of about 16. Similarly, the Sydenham and Clinton Rivers exceeded the point source loadings by factors of 7 and 3 respectively. Atmospheric loading to the lake was less than 5% that from the Clinton River. This indicates that these rivers were receiving substantial inputs of phosphorus from other sources, and that controls were not adequate or effective. The most probable route is drainage of phosphorus from agricultural uses and livestock operations. The application rates in Michigan and Ontario were found to be 2 and 3 times the recommended rates, respectively, and the use of conservation tillage techniques were not widespread.

Likewise, excluding input from the St. Clair River, the Thames River provided the largest loading of cadmium to Lake St. Clair, almost twenty times greater than all point sources combined. Of the three point sources that were found to discharge cadmium, none did so to the Thames River. The loading from the Sydenham River was 34 times greater than accounted for by the Wallaceburg WWTP, and the loading from the Clinton River was 11 times that of the two WWTPs that discharged Cd. None of the facilities had site-specific permit limits or objectives for Cd. However, the evidence indicates that all three rivers were receiving significant inputs of cadmium from other sources, perhaps from air deposition or use of cadmium-contaminated phosphate fertilizer (48). Estimated loading of Cd to Lake St. Clair from the atmosphere was approximately the same at that from each of the Sydenham and Clinton Rivers.

The Thames River also provided over 100 times the loading of Pb than all the surveyed point sources combined, and three times the loading from the St. Clair River. The Clinton and Sydenham

Rivers each contributed more than 10 times the quantity of lead than did the point sources, and the atmospheric loading was estimated to be similar to that of the Clinton and Sydenham Rivers. Clearly the loading of lead to Lake St. Clair from unidentified sources in the tributary basins was more significant than from the point sources, which did not have effluent limitations or objectives for lead.

Mercury contamination in Lake St. Clair has resulted largely from historical inputs through the St. Clair River. However, inputs may still be occurring, as evidenced by sediment surveys and by the mass balance calculations presented in Section E, above. Although none of the point sources surveyed had effluent limitations or objectives for the discharge of mercury, point source loadings accounted for only 0.0157 kg/d of an estimated 2.3 kg/d source in the Lake St. Clair basin. The source could include the contaminated sediments themselves. Loading estimates from the tributaries and atmosphere were not available for this study.

The Clinton River also contributed significant loads of PCBs to Lake St. Clair. Both the Warren WWTP and Mt. Clemens WWTP serve large communities with substantial industrial bases, and both had industrial pretreatment programs in place. Neither reported specific sources of PCB in their service areas, and neither had permit limits for PCB at the time of the survey. PCBs were not found in three Ontario WWTPs. Although the Canadian MDL was 1,000 times greater than that in the U.S., the PCB concentrations in the U.S. sources were much higher than the Canadian MDL.

Michigan and Ontario both recommend zero discharge of PCB. Michigan is now using a water quality based effluent limit of 1.2 X 10^{-5} ug/L in some NPDES permits, the allowable effluent guideline calculated using the State's Rule 57(2). The level is below any current MDL, so the permits also contain an interim limit of detection at 0.2 ug/L, the MDL commonly achieved with routine monitoring methods. The permittee is further required to develop a plan to meet the water quality based limit.

The Warren WWTP, Mt. Clemens WWTP, Rochester WWTP and Pontiac WWTP all operate an industrial pretreatment program, receiving waste water from industries in their area. Due to the quantities of contaminants coming from these facilities, however, the pretreatment requirements of these facilities and/or the compliance by the contributing industries with the requirements may be suspect.

Similarly, the Chatham WWTP receives industrial waste water, and it provided the largest loading of oil and grease and the third largest loading of nickel to the Lake St. Clair Basin. The quality of the waste water it receives may also be suspect and not in compliance with the Ontario By-Law to control the receipt of contaminants from industrial sources.

Best Available Technology

Discussions concerning the adequacy of "best available technology" (BAT) for reducing or eliminating loadings of contaminants to Lake St. clair are premature until specific sources of the loadings are defined. No direct industrial discharges occur to Lake St. Clair, but elevated levels of contaminants were found in the water and sediments of many tributaries, implying that sources may exist upstream. Should specific sources of contaminants be identified, then an assessment of the impact of BAT may be made for that industry on the receiving stream and on Lake St. Clair.

Because phosphorus is found to be coming from agricultural practices, the implementation of conservation tillage and reduced fertilizer application rates should greatly reduce the magnitude of the loadings of P to the system. Likewise, reductions in phosphorus loadings from municipal and industrial effluent, if needed, can be achieved with improved facility design and operations. Urban nonpoint source runoff, however, may be more difficult to control.

Additional efforts are needed to identify the sources of mercury loadings to Lake St. Clair. If internal loadings from the contaminated sediments are found to be significant, active control technology might be infeasible. Techniques for dealing with in-place polluted sediments is a topic for current research, and demonstration projects are expected to be established within the next several years by U.S.EPA. However, technology for treating contaminated sediments is expected to be applicable to localized areas, including harbors and restricted tributary mouths, but not appropriate for a whole lake basin. Given the rather short residence time of sediments in Lake St. Clair, in the order of 10 years, the problem of contaminated sediments could be resolved for Lake St. Clair through natural processes. However, continued problems would be expected in the western basin of Lake Erie.

3. Regulatory Control Programs Applicable to Lake St. Clair

A detailed discussion of regulatory programs in the UGLCCS regions may be found in chapter III. The following programs have particular impact on Lake St. Clair. The Clinton River is one of the Areas of Concern as designated by the International Joint Commission. As part of the effort to develop and implement a Remedial Action Plan (RAP) for the river basin, the State of Michigan has begun intensive remedial activities in the area (49). All major NPDES permits in the Clinton River basin were reviewed and new water quality based or technology based effluent limits (whichever was more restrictive) were developed in 1985. Metals, organics and conventional pollutants were included. A pretreatment program for process industrial wastewater was implemented throughout the Clinton River basin as of 1987, and upgrades to four WWTPs were completed in 1986 and 1987. Full details of the remedial programs and schedule for implementation will be included in the RAP, which is expected to be submitted to the IJC in 1988.

Where stormwater is determined to impact water quality in Michigan, the stormwater provisions (section 405) of the U.S. Water Quality Act of 1987 will be implemented to correct the problem. The State 305 (b) report will be reviewed in 1988 to determine if any of the Upper Great Lakes Connecting Channels areas are impacted by stormwater runoff.

Some technical and educational programs for farmers are in existence. For example, a Canadian Federal and Provincial effort called the Soil and Water Environmental Enhancement Program (SWEEP) encompasses all aspects of soil and water conservation. Within the SWEEP program, a provincial program called the Ontario Soil Conservation Environmental Protection Assistance Program exists which will financially assist the farmer in implementing soil and water conservation practices with up to 67% funding. A Land Stewardship Program has also recently been announced to assist farmers in the implementation of conservation techniques. All of these programs should assist in achieving reduced phosphorus and pesticide contamination in streams.

The preservation of wetlands in Lake St. Clair has been assisted by three relatively recent laws enacted by the State of Michigan: 1) The Great Lakes Submerged Lands Act (1955) which prohibits constructing or dredging any artificial body of water that would ultimately connect with a Great Lake, and which requires a permit from MDNR to fill any submerged lands, including Lake St. Clair; 2) Shorelands Protection and Management Act (1970) which designates wetlands adjacent to a Great Lake as environmental areas necessary to preserve fish and wildlife; and 3) The Goemaere-Anderson Wetland Protection Act (1979) which regulates wetlands through several laws relating to shorelands and submerged lands (36).

H. RECOMMENDATIONS

A. Industrial and Municipal Point Source Remedial Recommendations

1. Ontario and Michigan should incorporate the Great Lakes Water Quality Agreement's goal of the virtual elimination of all persistent toxic substances into their respective regulatory programs.

2. The City of Mt. Clemens should determine the source of PCBs, total phenols and mercury in the WWTP effluent and, through pretreatment or in-plant controls, reduce the concentrations of these pollutants to acceptable levels. Effluent limitations for these parameters should be considered. Phosphorus concentrations in the effluent should be lowered to meet the 1 mg/L Great Lakes Water Quality Agreement objective.

3. Site specific effluent limitations for total cadmium, total copper, total chromium and total nickel to protect the water quality for the Sydenham River and Lake St. Clair should be developed for the Wallaceburg WWTP. The operation of the plant should be optimised to meet the Ontario industrial effluent objective of 10 mg/L for ammonia.

4. The Warren WWTP should determine the source of PCBs in its effluent and take the necessary steps to reduce the concentration to acceptable levels.

B. Nonpoint Source Remedial Recommendations

5. Agricultural areas with high rates of wind erosion need to be targeted for assistance due to the characteristics of wind transported soil (fine textured, high enrichment ratio, and high organic matter content) and its ability to transport nutrients and agrichemicals. The relatively low erosion rates and high percentage of wind erosion in combination make conservation tillage the most practical conservation practice to be recommended. The primary reasons for this are the effectiveness of residue cover in reducing wind erosion and the low cost of implementing the practice. Conservation tillage is recognized as being highly cost-effective and physically effective in areas of sandy soils where wind erosion is a problem. If conservation tillage were applied to all cropland eroding over the soil tolerance level, with a resulting compliance with the tolerance level, a 32% reduction in phosphorus loading from cropland could be achieved.

6. Rural landowners need to implement, with the assistance of Federal, State and Provincial governments, a comprehensive

soil and water management system in order to control, at source, the contribution of conventional and organic pollutants including manure and pesticides to surface and groundwater. Specifically:

a. Agricultural and conservation agencies need to accelerate the implementation of control technologies through technical, financial and information/education programs. There is a need for extension, education and incentives to persuade farmers to implement conservation management systems including cropping, tillage and structural practices, nutrient and pesticide management technology, thereby reducing the movement of soil, conventional pollutants and contaminants off their land into the waterways.

b. Environmental and agricultural agencies should assess the adequacy of existing controls, regulations and permits for the use of fertilizer and pesticide products.

c. Specific programs, especially in Macomb County, MI, should be directed at reducing the excessive levels of phosphorus fertilization, improving the management of animal waste disposal and storage, and educating pesticide users with respect to handling, application and storage of pesticide products.

7. Future assessment and control of agricultural nonpoint sources of pollution would be facilitated by compatible Federal, State and Provincial monitoring data and more frequent flow-weighted tributary monitoring data. The small water quality monitoring data set available for tributaries indicated the need for increased sampling for all parameters, especially flow weighted data. The lack of samples in high flows created difficulty in calculating representative loads as well as understanding seasonal patterns of pollutant transport. More samples on high flow days would improve the basis for pollution control strategies.

8. Macomb and St. Clair Counties, Michigan, should be targeted for fertilizer management. U.S.EPA Region V has requested the USDA-SCS Michigan State Office to develop standards and specifications for a nutrient, best management practice that would protect ground and surface waters as well as sustain crop production. The Michigan Departments of Agriculture and Natural Resources are developing a joint action plan to manage livestock waste problems that includes best management practices for proper animal disposal that gives attention to air and water pollution from concentrated animal operations. This program may require a system of

permits for concentrated feeding operations.

9. The CSOs from municipal wastewater treatment plants should be intensively surveyed to determine their contribution of pollutant loadings to the surface waters. In the long term (due to enormous cost) combined sewers in all municipalities should be eliminated. In the interim, the municipalities should institute in-system controls to minimize the frequency and volume of overflows.

10. The Michigan Pollution Emergency Alerting System and the Ontario Spills Action Centre spills reports should be improved so that all information on recovery, volume (if known) and final resolution are fed back to the central reporting system to complete each report for inventory purposes.

11. The Superfund Site Investigations to be undertaken at Selfridge ANGB should focus on groundwater and surface water runoff impacts upon Lake St. Clair and the Clinton River. In the event that this site is not included on the U.S. National Priorities List, the State of Michigan should place high priority upon cleanup on this site.

12. Michigan should require groundwater monitoring as a permit condition for the Sugarbush solid waste landfill.

13. Michigan should include groundwater monitoring as part of the RCRA Generators permit for G and L Industries.

C. Surveys, Research and Development

14. Data interpretation would be facilitated by the development of more complete water quality objectives for the organic pollutants and pesticides that are used extensively by the agricultural industry. Currently, water quality objectives do not exist for many parameters that are measured. Although meeting water quality objectives does not guarantee "no impact" of a contaminant, the objectives do provide a point of reference for assessing the relative potential for negative impacts of various contaminants in the aquatic system.

15. The presence of organic contaminants (PCBs, HCBs and OCS) in the Canadian tributaries illustrates the need to locate the contaminant sources.

16. The cadmium content of the phosphate fertilizer that is being used on agricultural lands should be determined.

17. A study of atmospheric deposition of organic contaminants, particularly PCBs, to Lake St. Clair and to the tributary watersheds would provide quantitative information on loading of these contaminants to the lake. The loading estimates are important for mass balance calculations and the identification of unknown sources of the contaminants.

18. Urban runoff was identified as being a potentially major nonpoint source of many parameters,including PCBs, oil and grease, zinc, mercury, copper and nickel. The loadings from urban runoff, however, were based on contaminant concentrations from Canadian urban areas outside of the Lake St. Clair basin. Therefore, the loading information provide only a general potential for urban runoff to contribute contaminants to Lake St. Clair. A study should be performed to determine the contribution actually made by urban runoff on the Michigan shore where the shoreline is more urbanized than is that of Ontario.

19. The sediments near the mouth of the Clinton, Sydenham and Thames Rivers contain contaminants that may be impairing benthic communities. Studies are needed to document possible impairment of benthic communities of these sites. Appropriate actions to remedy any observed problems will need to be defined. Techniques and technologies for remediating in-place polluted sediments should be developed.

20. Recognizing that the biological effects of a substance are dependent in part on the chemical species of that substance, studies should be conducted to identify the chemical species and valances of the heavy metals in Lake St. Clair and its tributaries. For those forms which are present but for which toxicity information is lacking in the literature, toxicity and bioaccumulation experiments should be conducted on appropriate target organisms.

21. The evaluation of the point source data has been conducted on a parameter by parameter basis. In order to assess the quality of whole effluents, it is recommended that biomonitoring studies, both acute and chronic, be conducted at the major facilities (Wallaceburg WWTP, Chatham WWTP, Warren WWTP, and Mt. Clemens WWTP).

22. An inventory of all point sources, hazardous waste sites, urban and rural runoff, and spills discharging or potentially discharging to the Clinton River should be collected. These facilities, sites or incidents should then be examined for their potential to contribute chemicals to the Clinton River.

23. A more complete analysis of sediment, water and biota quality along the entire stretch of the Clinton River is

needed. Such information would establish the locations of sources of contaminants.

24. The Thames and the Sydenham Rivers were found to be major contributors of phosphorus, ammonia, lead and cadmium. An inventory of all point sources, hazardous waste sites, urban and rural runoff and spills discharging to these rivers should be collected. These facilities, sites or incidences should then be examined for their potential to contribute chemicals to the rivers.

I. LONG TERM MONITORING

1. Purposes for Monitoring and Relationships Between UGLCCS and Other Monitoring Programs

A presentation of the purposes for monitoring and surveillance activities is included under Annex 11 of the 1978 GLWQA, and a discussion of considerations for the design of a long term monitoring program can be found in Chapter 7 of the Report of the Niagara River Toxics Committee (50). Because the focus of the UGLCC Study was toward remedial actions to alleviate impaired uses of the Connecting Channels System, long term monitoring recommendations will likewise focus on the evaluation of trends in environmental quality in order to assess the effectiveness of remedial actions. In general, post-UGLCCS monitoring should be sufficient to 1) detect trends in system-wide conditions noted by the UGLCCS, and 2) detect changes in ambient conditions which have resulted from specific remedial actions. Monitoring programs should be designed to specifically detect the changes intended by the remedial actions so as to ensure relevance in both temporal and spatial scales.

Two major programs sponsored by the IJC also contain plans for long term monitoring: the Great Lakes International Surveillance Plan (GLISP) and the Areas of Concern Remedial Action Plans (AoC-RAPs). The GLISP for the Upper Great Lakes Connecting Channels is presently incomplete, pending results of the UGLCC Study, but it is expected to provide monitoring and surveillance guidance to U.S. and Canadian agencies responsible for implementing the provisions of the GLWQA that include general surveillance and research needs as well as monitoring for results of remedial actions.

Lake St. Clair is not one of the AoCs, although the Clinton River in Michigan is, and a RAP is being developed by Michigan for the Clinton River. The RAP will present details of uses impaired, sources of contaminants, specific remedial actions, schedules for implementation, resources committed by Michigan to the project, target clean-up levels, and monitoring requirements. Results and recommendations coming from the UGLCC Study will be incorporated extensively into the RAP, which will then be the document that influences Michigan programs in the Clinton River. The recommendations for long term monitoring that are presented below are intended for consideration and incorporation into either or both the GLISP for the Upper Great Lakes Connecting Channels, and the RAP for the Clinton River.

2. System Monitoring for Contaminants

Water

Knowledge of the concentrations of the principal contaminants in the water of Lake St. Clair should be used to indicate general exposure levels for the biota, to identify changes and trends over time in the concentration levels, and to be used for general assessment of contaminant impacts. The parameters to be monitored include phosphorus, PCBs, mercury, lead, and cadmium. Near tributary mouths, concentrations of ammonia, total phenols, pesticides, Cu, Ni and PAHs should also be determined. Monitoring stations should be located to coincide with identified water use areas, such as biota habitat, and with contaminant entry points to the lake. Suggested locations include the mouth of the St. Clair River at Port Lambton, around the St. Clair Delta, at the mouth of the Clinton, Sydenham, and Thames Rivers, and at the head of the Detroit River. Sampling frequency should be influenced by the variability in contaminant sources. Spring high flow conditions and late summer low flow conditions would be expected to bracket the normal seasonal variability in flow that could influence measured contaminant concentrations.

A mass balance approach to contaminant monitoring will help to identify any changes in the contaminant mass over time, and it will provide the basis for targeting future remedial actions by providing a comparison of the magnitude of the sources. A mass balance analysis should be conducted approximately once every five years, assuming that some effective remedial action has been implemented against one or more sources such that the total loadings of contaminants, or the relative contribution of the sources to the loading, has changed. The sources to be measured should include:

1) Head and mouth transects. The number and location of stations should relate to measured and predicted plume distributions. Suggested locations include the mouth of the St. Clair River at Port Lambton and the head of the Detroit River. Dispersion modeling and past sampling results should be used to predict contaminant concentrations and therefore to establish appropriate collection and analytical methodology. Both dissolved and particulate fractions should be analyzed. The quantity of suspended sediment flux should also be measured.

2) Municipal and industrial point sources. No direct industrial sources are considered to be major contributors of contaminants to Lake St. Clair. The principal municipal sources all discharge to tributaries. Thus, special monitoring consideration should be given to the Sydenham, Thames and Clinton Rivers to fully address municipal loadings of the contaminants.

3) Tributaries. Efforts should be focused on seasonal and storm event loadings of contaminants to Lake St. Clair from the Clinton, Sydenham and Thames Rivers. Tributary mouth stations should be sampled and analyzed for both dissolved and sediment-associated contaminant loadings.

4) CSOs and Urban Runoff. To provide an estimate of contaminant mass loadings expected during storm events, occasional studies on selected urban drainage areas should be conducted, particularly for the Michigan shoreline.

5) Groundwater inflow. The quantity and quality of potential contaminant releases from waste disposal sites adjacent to Lake St. Clair or its tributaries should be determined.

6) Sediment transport. Efforts to measure and model sediment transport to, within and from Lake St. Clair should be continued. The quantity of contaminants being desorbed from the sediments should be determined in order to assess loadings from these in-place polluted sediments.

7) Atmospheric deposition. Monitoring of wet and dry atmospheric deposition to Lake St. Clair should continue, and should be expanded to include organic contaminants. Volatilization losses of organics should also be quantified.

Sediments

Monitoring of sediments for concentrations of contaminants should be conducted periodically throughout Lake St. Clair in order to assess both the trends in surficial contaminant concentrations and the movement of sediment-associated contaminants within the Lake. The grid used by the U.S. Fish and Wildlife Service during the 1985 survey would be appropriate for consistency in sampling sites and sediment composition. An analysis of sediment chemistry including bulk chemistry, organic and inorganic contaminants, and particle size distribution should be conducted every five years, in conjunction with a biota survey (see "habitat monitoring" below).

In Lake St. Clair, particular attention should be given to sediment concentrations of PCBs and mercury. Additional stations should also be established at the mouth of the Clinton, Sydenham and Thames Rivers and at Chenal Ecarte to track effects of remedial actions in the tributary watersheds to reduce loadings of these materials.

Because the grid stations are distributed throughout the river reach and are associated with appropriate habitat for a sensitive benthic invertebrate (Hexagenia), the periodic survey will allow assessment of 1) contaminant concentrations in the river sediments throughout the river reach, 2) relative movement of the contaminants within the river sediments between surveys, and 3) correlation of contaminant concentrations with benthic biotic communities.

The sediments at any stations established at the mouths of tributaries to Lake St Clair should be monitored for organic and inorganic contaminants on an annual or biannual basis when significant remedial actions are implemented within the watershed of the tributary. In order to trigger the more frequent sediment monitoring program, the remedial actions should be expected to measurably reduce loadings of one or more particular contaminants via the tributary.

Biota

Long term monitoring of concentrations of contaminants in biota will provide a time series useful to track the bioavailability of contaminants to selected representative organisms. Three long term monitoring programs are already in place and should be continued:

i) Annual or Bi-Annual Monitoring of Sport Fish.

This program should focus especially on PCBs, mercury and/or other contaminants (e.g. dioxins and dibenzofurans) that are considered to be known or suspected health hazards. The monitoring should be continued regardless of the differences that may be observed between acceptable concentrations or action levels that may be established by governmental agencies and the measured contaminant concentrations in the fish flesh. As a link between human health concerns and integrated results of remedial programs to reduce contaminants in the UGLCCS system, this program is critically important.

ii) Spottail Shiner Monitoring Program.

This program is designed to identify source areas for bioavailable contaminants. In locations where spottail shiners contain elevated levels of contaminants, additional studies should be conducted to identify the sources of the contaminants. Some upstream studies in tributaries may be required. Spottails should also be employed to confirm that remedial actions upstream to a previous survey have been effective in removing or reducing the loading of one or more contaminants.

iii) Caged Clams Contaminants Monitoring.

Caged clams should continue to be used at regular time intervals, perhaps in conjunction with spottail shiners, to monitor integrated results of remedial actions to reduce contaminant loadings to the water. Clams may be located at tributary mouths and downstream of suspected source areas. Repeated assays from the same locations should confirm results of remedial actions.

3. Sources Monitoring for Results of Specific Remedial Actions

Remedial actions intended to reduce concentrations and/or loadings of contaminants from specific point sources generally require monitoring for compliance with the imposed criteria or standards for permitted contaminants. The monitoring may be conducted by the facility or by the regulating agency, whichever is applicable, but attention must be given to the sampling schedule and analytical methodology such that mass loadings of the contaminants can be estimated, as well as concentrations in the sampled medium. Monitoring of the "nearfield" environment, i.e., close downstream in the effluent mixing zone, should be conducted regularly to document reductions in contaminant levels in the appropriate media and to document the recovery of impaired ecosystem processes and biotic communities. Such monitoring may be required for a "long time", but over a restricted areal extent, depending on the severity of the impact and the degree of reduction of contaminant loading that is achieved.

For Lake St. Clair, seven actions were recommended that would affect specific sources of contaminants, and that would require site-specific monitoring for compliance or other effects of the action at the following locations: Macomb and St. Clair Counties, Michigan (fertilizer management); Mt. Clemens WWTP (PCBs, phenols, mercury, phosphorus); Wallaceburg WWTP (Cd, Cu, Cr, Ni, ammonia); Warren WWTP (PCBs); Selfridge Air National Guard Base (several contaminants); Sugarbush landfill, Michigan (groundwater monitoring); and G and L Industries, Michigan (groundwater monitoring).

Other recommendations for specific contaminant sources involve an assessment of the present conditions or a study to quantify concentrations or loadings: quantify CSOs from municipal waste water treatment plants, identify sources of organic contaminants in tributaries; determine Cd content of phosphate fertilizer, measure atmospheric deposition of organic contaminants; measure loadings of contaminants from urban runoff; conduct biomonitoring studies at WWTP's; inventory point sources and waste sites discharging to the Clinton River; analyze sediment, water and biota quality along the Clinton River; and inventory point sources and waste sites discharging to the Sydenham and Thames Rivers. Each of these items requires a specific program of data collection and analysis. Additional needs for longer term monitoring may be identified as a result of these studies.

4. Habitat Monitoring

Habitat monitoring should be conducted to detect and describe changes in the ecological characteristics of Lake St. Clair through periodic analysis of key ecosystem elements. The following items are recommended:

a) The abundance and distribution of the mayfly _Hexagenia_ should be determined every five years. The grid used by the U.S. Fish and Wildlife Service during the 1985 survey would be appropriate for consistency in sampling sites each survey. An analysis of sediment chemistry, including bulk chemistry, organic and inorganic contaminants, and particle-size distribution, should be conducted for samples taken concurrently with the _Hexagenia_ survey. These data will provide information on the quality of the benthic habitat for a common pollution sensitive organism that would serve as an indicator species of environmental quality.

b) Quantification of the extent of wetlands along Lake St. Clair should be conducted every five years, in conjunction with the _Hexagenia_ survey. Aerial photography or other remote sensing means would be appropriate to discern both emergent and submergent macrophyte beds that are important as nursery areas for larval fish and other wildlife. Verification of areal data should be conducted by inspection of selected transects for plant species identification and abundances. Changes in wetland areas should be correlated with fluctuating water levels and other natural documented influences so that long term alterations in wetlands can be tracked and causes identified.

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CHAPTER IX

THE DETROIT RIVER

A. STATUS OF THE ECOSYSTEM

1. Ecological Profile

Watershed Characteristics

The Detroit River makes up the lower 51 km of the connecting channels between Lakes Huron and Erie. An international boundary divides the Detroit River about equally into United States (Michigan) and Canadian (Ontario) waters (Figures II-5 and IX-1).

The Detroit River is a hydrologically and ecologically distinct ecosystem compared to Lake St. Clair and the St. Clair River (1). It is limnologically mesotrophic and supports cold water fish from September to June. The Detroit River provides important habitat for fish, birds and the bottom dwelling life on which they feed. It is also an important source of potable water, with drinking water intakes near Belle Isle, Windsor, Amherstburg and Wyandotte (2). Water is also used to supply a major industrial complex consisting of automobile, steel and chemical companies.

The St. Lawrence Seaway utilizes the Detroit River for commercial shipping. This portion of the Seaway is presently the busiest in the upper Great Lakes, involving shipments of iron ore, coal, limestone, gypsum, oil, and wheat.

The topography of the Detroit River basin is flat, broken only by the valleys of the Rouge River and a few lesser tributaries. Low moraine deposits and beach ridges of ancestral Lake Erie provide slight relief. Land elevations range from 214 m above sea level near the tributary head waters to approximately 174 m along the Detroit River. The relative relief of the lake plain is 1 to 5 m/km^3, and most slopes are less than 3%.

The Detroit River courses through Pleistocene glacial drift

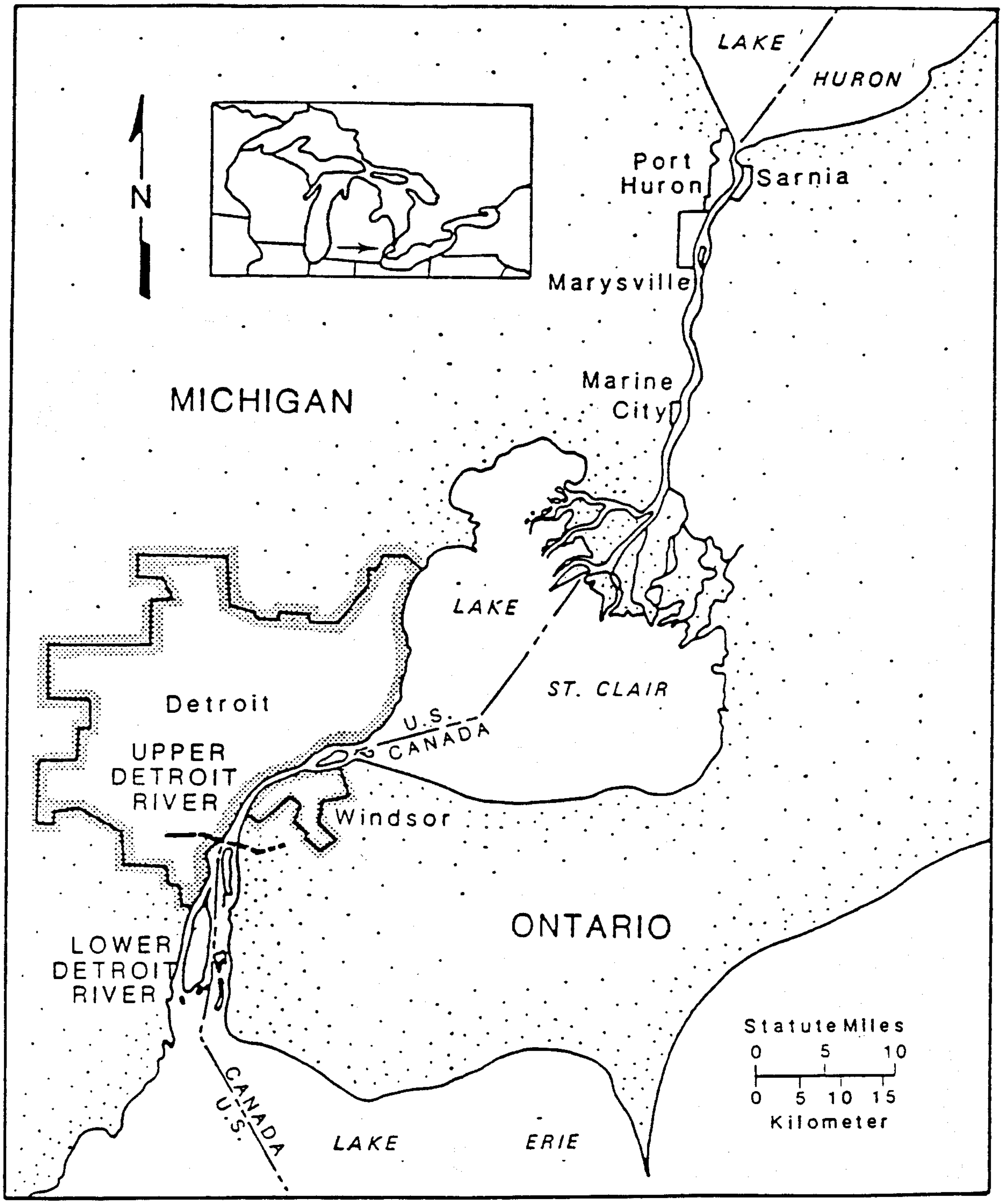


FIGURE IX-1. The Huron-Erie corridor.

underlain by Paleozoic sedimentary rock. The sedimentary rock beneath the river is the Detroit River Formation (primarily dolomite) which outcrops intermittently in the navigation channels east of Grosse Ile. On top of the bedrock is a mantle of glacial drift 0 to 30 m thick.

Lake plain soils are poorly drained loam and clay loams, which developed on former lake bottoms or lacustrine clay sediments. Sandy ridges mark former shorelines, and on the Michigan side, an isolated sand sheet marks remnants of the glaciofluvial delta of the post-glacial Huron River. When drained and tiled, the loamy lake plain soils are agriculturally productive. Many surface and subsurface soils are moderately permeable (0.25 and 1.27 cm/hour) with high surface runoff coefficients causing the local streams to be storm event responsive.

The Ontario shoreline, except for the City of Windsor and its docks, is less disturbed than the Michigan shoreline. North of the Canard River there are scattered marinas, canals, and private boat slips. In places, Ontario farmers have encroached upon the wetland margins of the Detroit River and its tributaries. Thus, a green buffer zone exists only intermittently between the farm fields and the riverine ecosystem. Access to the water for commercial navigation, business, pleasure boating, fishing and hunting is important locally on both sides of the river.

Hydrology

Nearly 98% of the Detroit River flow enters from Lake Huron via the St. Clair River and Lake St. Clair. The river discharge averages 5,300 m^3/sec and ranges from a low of 3,200 m^3/sec to a maximum discharge of 7,100 m^3/sec. The Fleming Channel in the upper Detroit River, north of Peach Island, accounts for 77% of total river flow. Flow distribution in the lower river is relatively complex downstream of Fighting Island, as several channels separate or combine the flow (2,3,4).

Flow velocities average 0.49-0.88 m/sec, but mid-surface velocities can be nearly twice that rate. Surface currents near the Ambassador Bridge and in the Amherstburg Channel reach 1.2 m/sec, while the Trenton Channel flow averages 0.6 m/sec.

Detroit River water depth and velocity are directly affected by water levels in Lakes St. Clair and Erie, which vary seasonally and annually. Lake Erie seiches and Lake St. Clair ice jams may also produce changes in Detroit River water levels and currents. The river slope is relatively uniform, and falls 0.9 m over its 51 km length. The average time of passage for water through the Detroit River is about 19 to 21 hours.

The Rouge River, the main tributary to the Detroit River, drains about 121,000 ha in Michigan, and consists of upper, main, middle and lower branches. The stream is very event-responsive and frequent flooding occurs along the middle Rouge. Its mean annual discharge is 26 m^3/sec, with over 75 percent of it draining through urban areas, collecting considerable stormwater runoff, overflow from combined sewers during wet weather, and over 500 million gallons per day (mgd) of waste water from municipal and industrial facilities. The lower Rouge is partially lined with concrete, so runoff rapidly reaches the Detroit River during storms.

Other tributaries include the Ecorse, Canard and Little rivers and Turkey Creek. The Ecorse River tributary drains 11,556 ha in Michigan, occupied by 2 communities with a total population of 198,000 in 1980. The Ecorse River has two open channel tributaries, the North Branch and the South Branch (or Sexton-Kilfoil Drain). These branches join approximately 1 km upstream from the confluence of the Ecorse and Detroit rivers near Mud Island. Ontario's Little River empties into the Detroit River at its mouth, by Peach Island. It drains approximately 5,750 ha of agricultural and industrial land. Turkey Creek enters the Detroit River just north of Fighting Island, draining 2,960 ha of primarily agricultural land in Ontario. The Canard River enters the Detroit River in Ontario, south of Windsor and east of Grosse Ile. It is a turbid, slow moving stream which discharges into diked wetlands just north of its mouth, and drains approximately 20,000 ha of primarily agricultural land (5). Other minor tributaries also exist, such as Monguagon Creek (in Michigan, by the northern end of Grosse Ile) and Conners Creek (in Michigan, by the eastern end of Belle Isle).

Effluent from the Detroit area wastewater treatment plants (WWTPs) discharge over 32 m^3/sec (1985), a volume equal to the combined tributaries flowing into the Detroit River. The Metropolitan Detroit WWTP alone discharges 30 m^3/sec near the mouth of the Rouge River (6).

Habitats and Biological Communities

The Detroit River ecosystem can be divided into an upper stretch (upstream of the Rouge River) and a lower river stretch. The Detroit River's biologic zones include deep channels, shallow water/nearshore zones, and terrestrial zones. Deep channel environments generally have water depths exceeding 7 m, relatively high flow velocities, and coarse sediments. Since the river channels are also used for shipping, the high sediment load and lack of anchorage prevent macrophyte growth. Macrophytes and associated periphyton and invertebrates are most abundant in the shallow water-nearshore zone, seldom occurring at depths greater than 4 m. The terrestrial biological zone includes undeveloped island habitat, coastal wetland and riparian environments along such less developed tributaries as the Canard River. The Wyandotte National Wildlife Refuge is located in the Detroit River, off the northern tip of Grosse Ile. This Refuge encourages shorebirds and waterfowl feeding, nursery and nesting activities. Stony, Celeron, Grassy and Mud Islands provide shorebird habitat.

The coastal wetlands and large, emergent and submersed macrophyte beds along the Detroit River were nearly continuous in colonial times. They now exist only in 31 small isolated remnants covering 1,382 ha (7). Most of the remaining vegetation along the river consists of submersed macrophytes because the land formerly occupied by the swamp-scrub-meadow communities along the terrestrial river margin has largely been converted to other uses. Fifty-four percent (748 ha) of the remaining wetlands are in Ontario. The single largest wetland, immediately north of the Canard River, is functional only along its outer, undiked margins. Functional wetlands also exist along the open water margins of a few islands.

A number of biological surveys have documented the biotic communities in the river (7,8,9,10,11,12,13,14,15,16). Although it is not well understood how the various trophic levels relate to one another, enough information exists to describe species composition, standing crop and biomass for a variety of primary and secondary producers.

i) Macrophytes

At least 21 submersed macrophyte taxa occur in the river, dominated by *Vallisnera*, *Chara*, *Potamogeton*, *Myriophyllum* and *Heteranthia*. Stands are typically composed of 2 or 3 species but as many as eleven have been recorded in a single stand. *Chara* is the only taxon consistently occurring in monotypic stands. The lower depth limit for plant colonization is not established, but most stands occur in water less than 3.7 m deep. In the Detroit River, the area of the river bed between shoreline and the 3.7 m depth contour is about 99 km^2, 72% of which is occupied by submersed plants. The wetlands and submersed macrophyte beds constitute the most critical areas for primary and secondary production for plants, fish and birds, and are the most stable habitat in the ecosystem (17). Their invertebrate populations include clams, snails, midges, caddisflies, mayflies, amphipods, springtails, and worms. Juvenile yellow perch and adult northern pike have been observed feeding along the wetland shoreline among the submersed macrophytes. These areas are also heavily used for spawning by numerous fish species. No detailed studies of species composition, distribution, and relative abundance of emergent macrophytes have been completed, although wetland communities have been mapped by remote sensing. Over 95% of the emergent beds occur in the lower river.

The St. Clair-Detroit River system produces about 264,000 tons of plant biomass each year, of which 19% originates in the Detroit River. Most of the plant biomass in the Detroit River is produced by submersed macrophytes.

ii) Phytoplankton

Phytoplankton standing crop and production values is assumed to have phytoplankton biomass and daily production similar to Lake St. Clair. Eighty two phytoplankton species are present in the river at low density (about 500 cells/ml), and are dominated by diatoms that are common in Lake Huron in July and August. Blue-green algae that are common in Lake St. Clair at that time dominate the Detroit River phytoplankton. No periphyton studies have been conducted to date, but a recent study in a wave exposed breakwater in western Lake Erie indicates that diatoms, green algae and red algae may be common over-wintering taxa in the Detroit River. Filamentous green algae can be expected to dominate during summer months.

Current information is inadequate to determine how much of the planktonic production of the river is used by river biota. If only moderate amounts of this biomass is retained, then the littoral plant complex of emergent and submersed macrophytes and macrozoobenthos are the main standing stock in the river. From calculations of drifting macrophytic plants, it appears that the Detroit River is a large source of detrital organic matter that supports productivity in western Lake Erie.

iii) Zooplankton

Detroit River zooplankton studies are not yet completed, but zooplankton composition and abundance seem to resemble those found in Lake St. Clair. Cladocera and several species of Cyclops and Diaptomus dominate the zooplankton in Lake St. Clair. Difflugia is the most common protozoan, and Conochilus, Keratella, Polyarthra, Synchaeta, and Brachionus are the most common rotifers. Maximum numbers of zooplankton may be expected between June and September. A study of foods eaten by larval yellow perch during passage through the Detroit River revealed that zooplankton, including copepod nauplii, older cyclopoids and copepods, cladocera and rotifers were eaten. Hence, zooplankton are likely the critical food resource for larval fish.

iv) Macroinvertebrates

The Detroit River benthic macroinvertebrate community includes over 300 species. Oligochaetes, chironomidae, gastropoda, ephemeroptera, trichoptera and amphipoda dominate the biomass. Chironomidae are common throughout the system while oligochaetes are dominant in the lower river. Hydropsychid caddisflies are the dominant trichoptera and Hyalella is the most common amphipoda.

Hexagenia is the most common mayfly, but density is lower in the Detroit River ($88/m^2$) than the St. Clair or the St. Marys Rivers ($95/m^2$ and $199/m^2$), respectively. Detroit River benthic production (5.4 g ash-free dry weight/m^3/yr) is lower than the St. Clair River and Lake St. Clair (7.0 and 6.8 g ash-free dry weight/m^3/yr) with the annual production (440 metric tons ash-free dry weight/yr) equal to about 2% of the combined annual Detroit River phytoplankton, periphyton, macrophyte and zooplankton production (7,14,16).

v) Fish

The present Detroit River fish populations are a mixture of natural and introduced (exotic) species. Among the exotic fish is the common carp, which was introduced in 1883 in western Lake Erie. From there, it spread through the Detroit River to the upper Great Lakes, destroying beds of wild celery and wild rice, the preferred food of native waterfowl. Large carp populations continue to inhabit the Detroit River. Rainbow smelt and alewife, introduced in 1932, spread through the Detroit River and upper lakes. Alewives now comprise the bulk of forage fish in all the Great Lakes. The sea lamprey spread through the Detroit River to the upper Great Lakes in the 1940s, greatly reducing populations of desirable fish, such as the lake trout. The most recent exotic Detroit River fish, the white perch, was introduced into Lake Erie in 1953 and now hybridizes with native white bass. The Detroit River fish community presently has approximately 60 resident or migrant species, 32 of which use mainly the lower river along the islands and the mainland shoreline for spawning (18,19,20,21,22).

The Detroit River and its tributaries are important spawning, feeding and nursery areas for many species that support major fisheries in the river and Lakes Huron and Erie. There are 60 recorded resident or migrant fish species in the Detroit River, 32 of which spawn in the river. Townet catches of larval fish in the Detroit River in 1977-1978, 1983-1984 and 1986 show that the river is a nursery ground for at least 25 species of fish. Most abundant were alewife, rainbow smelt, and gizzard shad. Other species were much less abundant.

The river is part of a complex migration route for walleye and yellow perch, important recreational fish species, which move between Lake St. Clair and Lake Erie. Large walleye spawning runs once occurred in the lower river, the reduction of which is attributed to pollution and sedimentation. In the 1970s, spawning was again documented, and walleye larvae were collected in several locations in the lower 16 km of the Trenton Channel and the main river. Recently, yellow perch spawning has been observed in the Trenton Channel and near the mouth of the Detroit River in some areas previously used by walleye.

The Detroit river once supported a large commercial fishery for lake whitefish, lake herring, walleye, lake sturgeon, black bass, northern pike, muskellunge and carp. Overfishing, pollution and dredging contributed to the Detroit River commercial fishery decline (23,24,25).

Sport fishing is still an important activity in the Detroit River. In 1985, an estimated 1.4 million hours were spent harvesting approximately 1.4 million fish (22). The lower river harvest was 980,200 while the upper river was 440,600 annually. Dominant species were white bass (63%), walleye (12%), yellow perch (10%), and freshwater drum (7%).

A larval fish passage study from Lake St. Clair to Lake Erie was conducted along the Detroit River at 17 transects, 2.5 km apart (Figure IX-2)(22). Thirteen larval fish taxa were observed. Larval fish densities of walleye, yellow perch and white bass/white perch greatly increased in the mid-Trenton Channel (transect 12-13), suggesting spawning and rearing activities in the vicinity. Yellow perch showed a strong lateral distribution with greatest densities along the western near-shore, decreasing toward the main channel with lowest densities along the eastern shore. Surprisingly, the area containing the highest density of larval yellow perch coincides with the highest concentration of environmental contaminants in water or sediments. White bass/white perch and rainbow smelt did not exhibit significant east-west density gradations. Longitudinal distribution patterns were evident for larval bloaters, burbot and deep water sculpin. Deep water densities of these species were greatest in the upper Detroit River, but were present throughout, probably being transported from Lake Huron and Lake St. Clair. Walleye and white bass/perch were not found, and yellow perch and rainbow smelt exhibited relatively low abundances in the upper river. Yellow perch, white bass/white perch, rainbow smelt and walleye larval densities were greatest in the lower river.

vi) Waterfowl

At least 3 million waterfowl migrate annually through the Great Lakes region, which is situated at the intersection of the Atlantic and Mississippi flyways. An estimated 700,000 diving ducks, 500,000 dabbling ducks, and 250,000 Canadian geese migrate across Michigan each fall (1).

Important species of nesting ducks in the Detroit River wetlands include mallards, blue-winged teal, black ducks and, if nesting boxes are provided, wood ducks. In the past, 24 species of ducks regularly fed in the river. Each year, thousands of waterfowl, including scaup, goldeneyes, canvasbacks, black ducks, redheads, and mergansers congregate on the river to forage sediments. Major concentrations of feeding ducks are often found in littoral waters around Belle Isle, Grosse Ile and Mud, Fighting, Sugar and

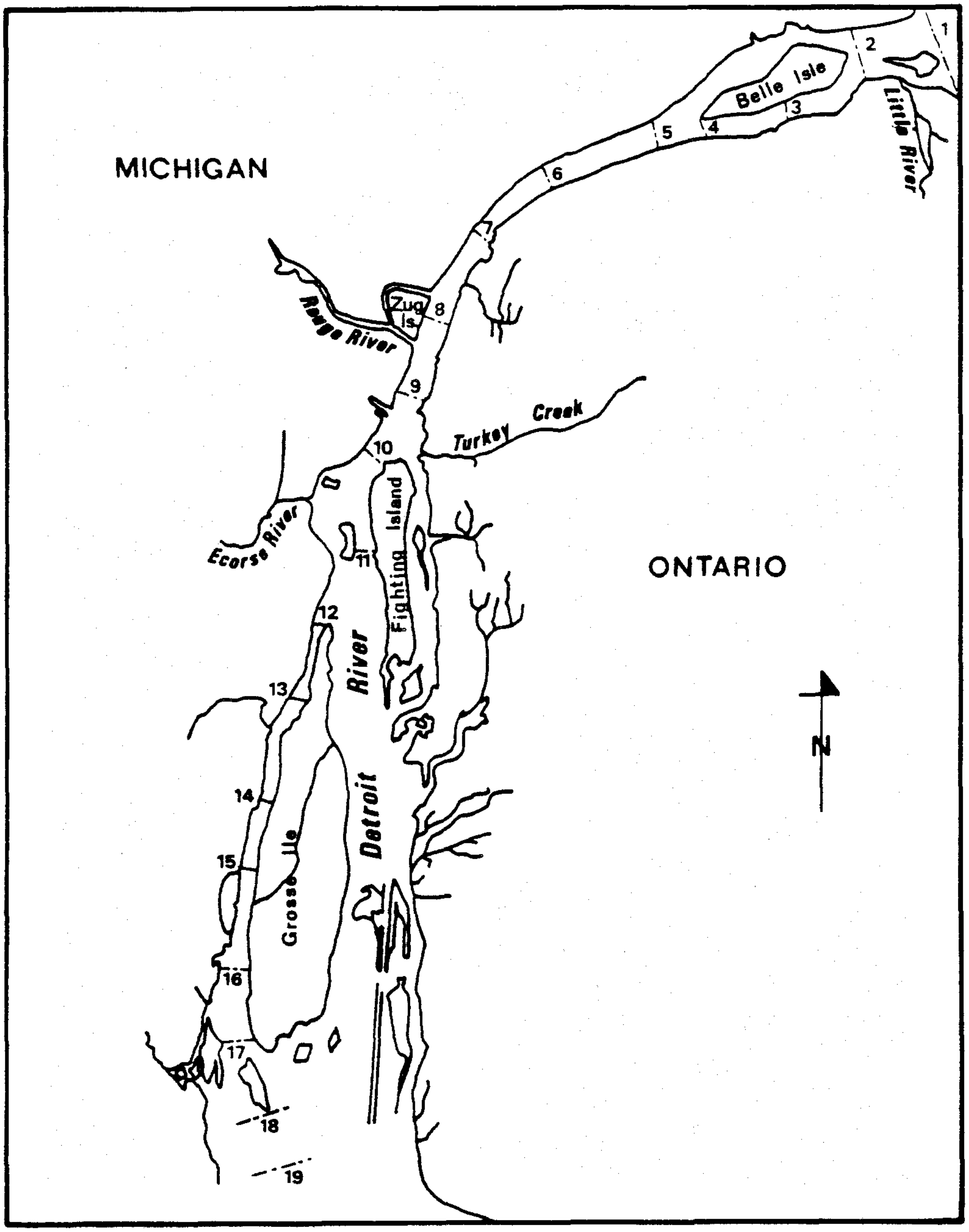


FIGURE IX-2. Detroit River water sampling transects and 24-hour sampling locations.

Celeron islands. Preferred foods vary among species. Mergansers feed primarily on fish, whereas American goldeneyes prefer crayfish, clams, and other invertebrates. Many diving ducks feed on submersed aquatic plants and their associated communities.

A recent survey of eelgrass tubers, a preferred food of many waterfowl, indicated that over the past 35 years, tuber densities have decreased substantially, resulting in a net loss of 4.6 x 10^9 tubers in the lower river. This large loss of eelgrass tubers in the Detroit River explains in part why fewer waterfowl now use the Michigan migration corridor.

Climate

The Detroit River area enjoys a mid-continental climate, with cold winters and relatively short hot summers, moderated somewhat by the Great Lakes. The average first frost is on October 21 and the average last freezing temperature is on April 23, with an annual growing season of 180 days. Precipitation averages about 76 cm per year, including 40 cm of snow. Prevailing winds are from the southwest, and average 16 km/hour.

During late autumn and early winter, water from Lake Huron cools rapidly as it flows through shallow Lake St. Clair. As a result, ice often enters the Detroit River from Lake St. Clair before it begins to form in the Detroit River itself. Before the 1930s, most of the Detroit River was ice covered in winter, but now large volumes of heated effluents entering the river usually prevent the upper river from freezing over, except between Belle Isle and the Michigan mainland. Extensive slush ice still develops in the lower river, especially in the broad shallow expanses adjacent to the islands. In general, ice may now be found in the river from early December to mid-March, but main navigation channels remain ice-free. Minor ice jams occur in the Detroit River with the breakup ice moving south from Lakes Huron and St. Clair from late March to early May. Easterly winds can also cause Lake Erie ice to reverse into the lower Detroit River. Monthly water temperature data show that the highest water temperatures occur in August, with an average of 22.2°C. In the shallow nearshore areas of the lower river, water temperatures may attain 25.2°C. Lowest temperatures occur in January-February, sometimes reaching 0°C.

2. Environmental Conditions

Water Quality

The Detroit River area is heavily industrialized and densely populated. Industrial and municipal raw water is taken from the river then returned after use. Due to its varying channel width and depth, berms and islands, the Detroit River is hydrologically complex, a fact which influences water quality and modifies the human impact on the Detroit River system.

Information on water quality was obtained as part of this study (26). To obtain a reliable data set which could provide a meaningful interpretation while minimizing the need for analyses, water sampling transects across the river were used. Figure IX-3 shows the location of the upper (DT 30.8W and DT 30.7E) and lower (DT 8.7W and DT 9.3E) transects and the major tributaries. The upper transects are at Peach Island near Lake St. Clair, upstream of Detroit and Windsor. The lower transects are near Grosse Ile, upstream of the Livingston Channel and Stoney Island in the east, and near the lower end of the Trenton Channel on the west. The lower transect was designed to avoid the influence of Lake Erie, and in the process was located upstream of two industrial facilities, General Chemical at Amherstburg and McLouth Steel, Gibraltar. Therefore, water quality data for the lower transect does not reflect these facilities. In addition, loadings from Frank and Poet Drain, which serves several permitted Michigan industrial discharges, were also excluded (26). Figure IX-4 describes the flow distribution in the channels of the Detroit River, and shows that approximately 21% of the total Detroit River flow passes through the Trenton Channel and approximately 26% and 47% through the Livingston and Amherstburg channels, respectively (27).

Three additional, partial river width water quality monitoring transects were established in the Trenton Channel between Grosse Ile and the Michigan shore at Point Hennepin (A), just south and parallel to the Grosse Ile toll bridge (C), just south and parallel to the Grosse Ile Parkway Bridge off the Monsanto Breakwall (D). Michigan's monthly Detroit River water sampling transect at the mouth of Detroit River between Bar Point and Maple Beach (DT 3.9) is also shown (Figure IX-3).

i) Cross-Channel Variations in Water Quality

Cross-channel variation of water quality occurs where large volumes of low concentrations or smaller volumes of higher concentrations of substances are discharged to the river. Cross-channel variations were demonstrated by dye studies below the Detroit WWTP outfall (Figure IX-5) (28). The upper Detroit River between Belle Isle and Fighting Island has a relatively constant channel width and depth where little or no cross-channel mixing occurs. In contrast, the lower river section is broken up into three major channels and several shallow embayments. There, and downstream of these islands and structures, increased cross-channel mixing may occur due to the generally lower current velocities, eddies below these structures, and wind driven currents cross and counter to the normal current direction.

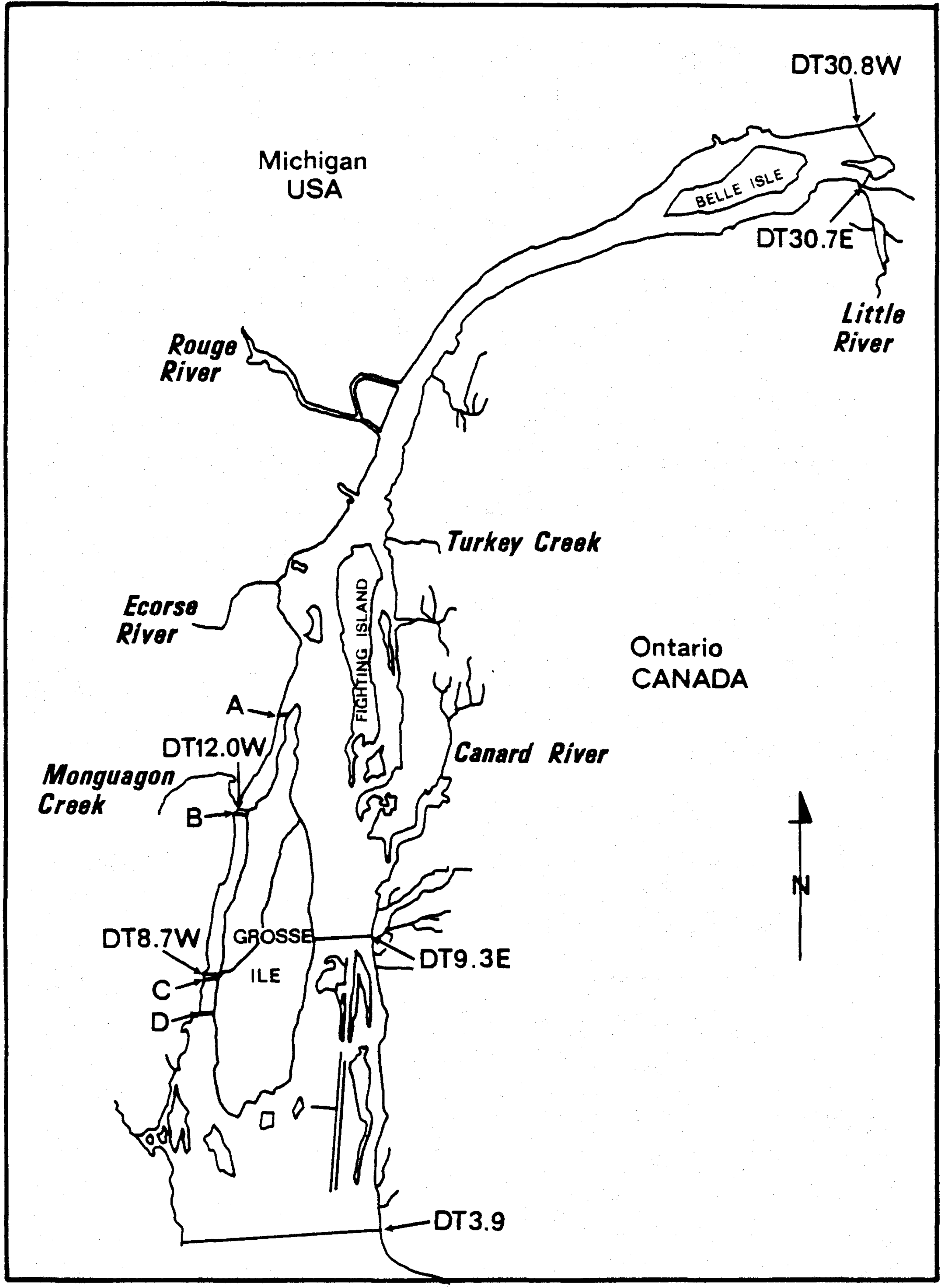


FIGURE IX-3. Detroit River mass balance sampling transects.

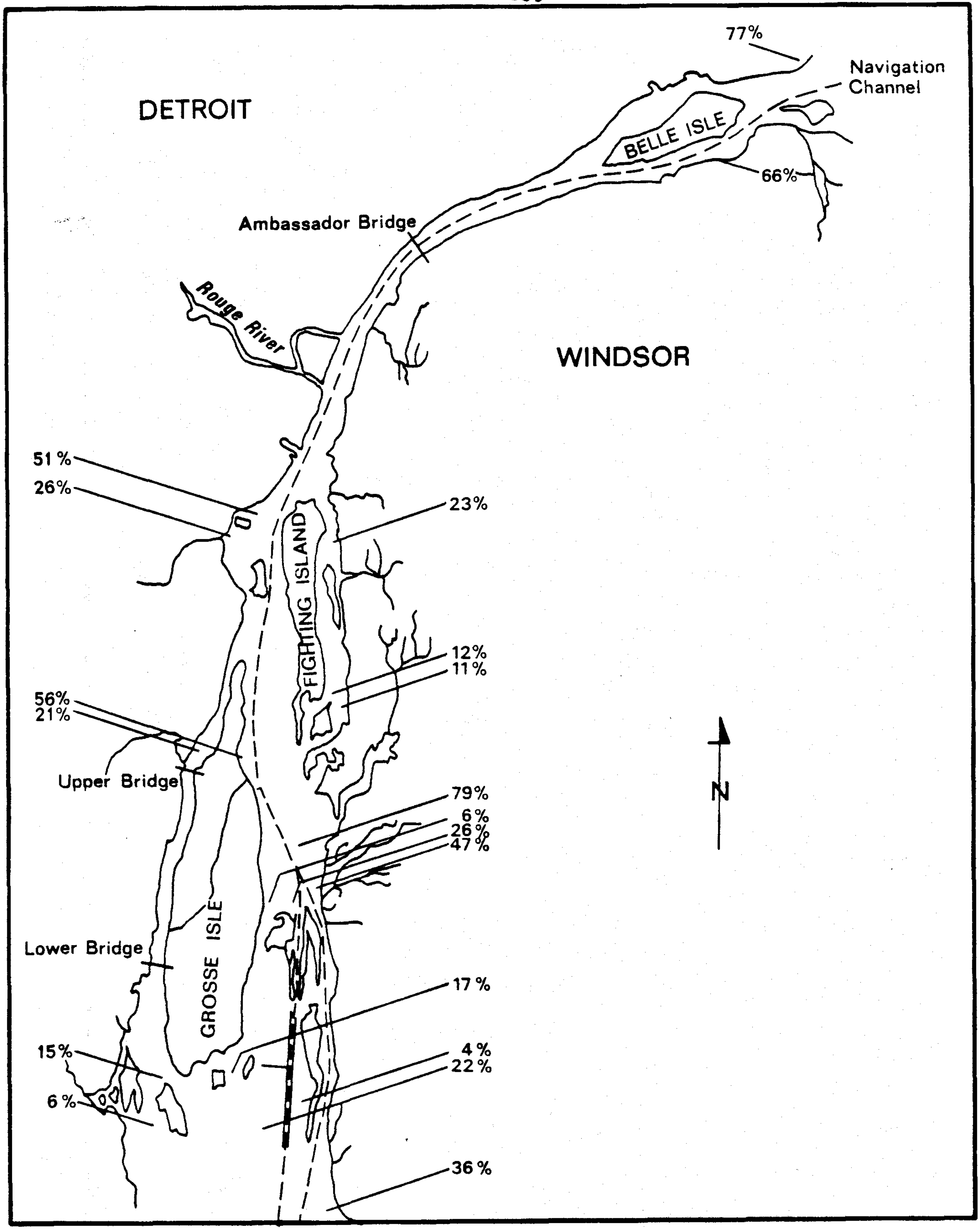


FIGURE IX-4. Flow distribution in the Detroit River (27).

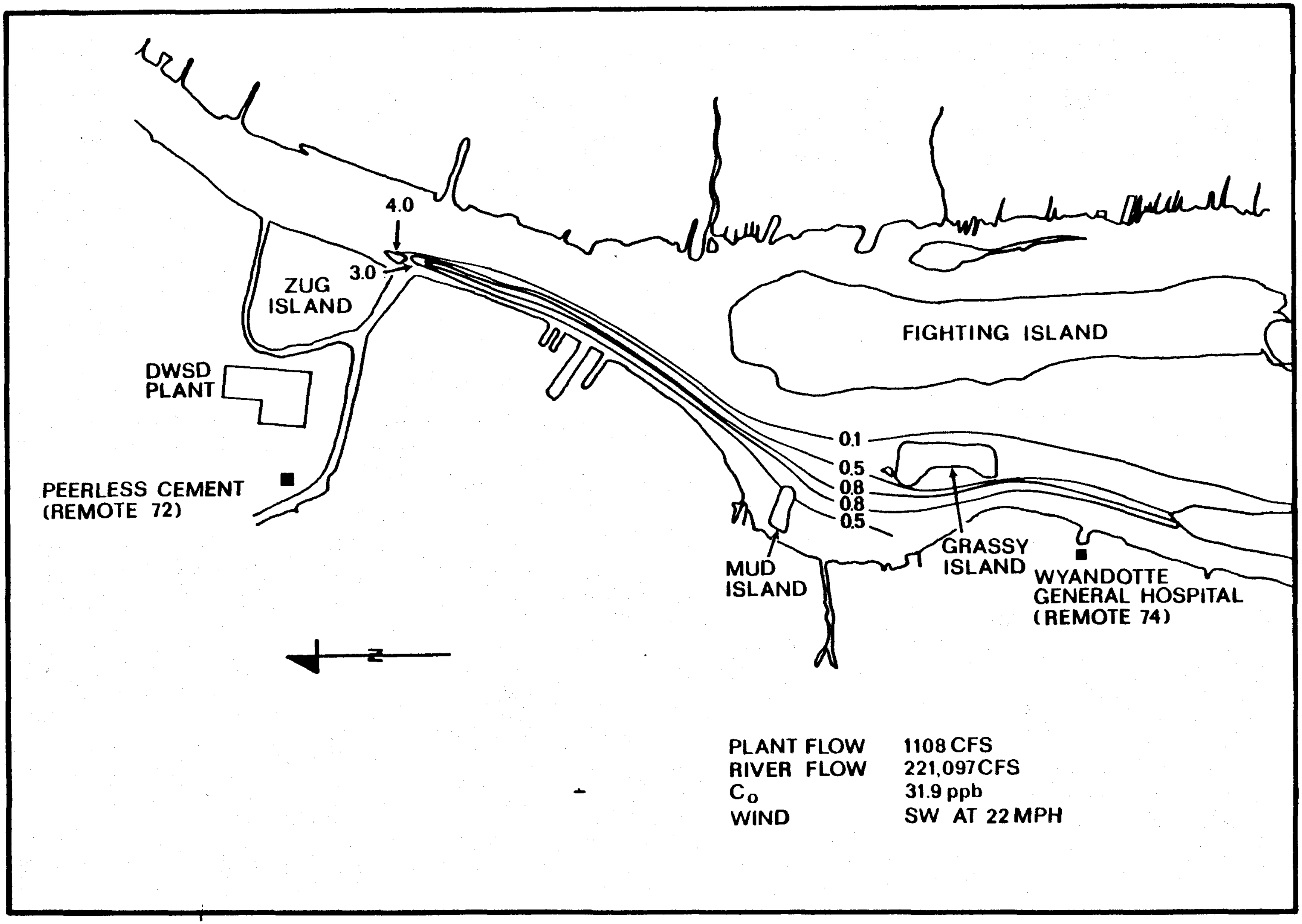


FIGURE IX-5. Plume from the City of Detroit WWTP, March 1985 (28).

Cross-channel variation in concentrations of some organochlorine contaminants (for example PCBs and chlorobenzenes) between water in the upper Detroit River and the Detroit River mouth has been shown (Figure IX-6). Organochlorine concentrations are similar at the head of the river along both the Michigan and Ontario shores (about 0.5 ng/L at stations 399 and 379, respectively) (29). Proceeding downstream, higher levels are found along the Michigan shore, with levels up to 209 ng/L (station 346), compared with 0.5 ng/L across the river. Station 269 (17 ng/L), on the Canadian side, may be influenced by U.S. sources as this station is well within the 50% flow panel of the Detroit River.

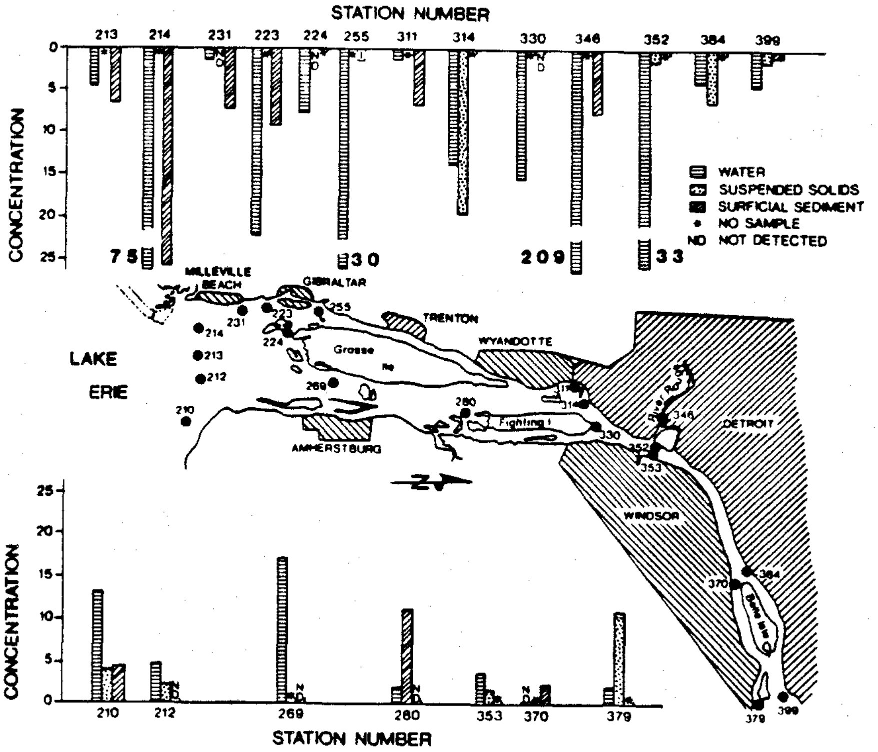
ii) Longitudinal Variations in Water Quality

The flow of the Detroit River ranges from 3,200 m^3/sec to 7,100 m^3/sec, constituting a large water mass. To detect statistically significant changes in water quality between the river head and mouth, inputs or sinks of such substances must be substantial. Due to natural fluctuations between seasons, shipping and dredging activities and both natural and man-induced fluctuations of in-coming water quality, any quantitative and even qualitative interpretation of data is difficult. Only a statistical evaluation of many samples will allow definite conclusions. That sampling intensity was not achieved in this study for most data, and comparisons made are primarily relative comparisons. Evaluation of relative changes in water quality parameters does not require absolute values, but compares the relative abundance or absence of materials, and may indicate temporal or spatial differences.

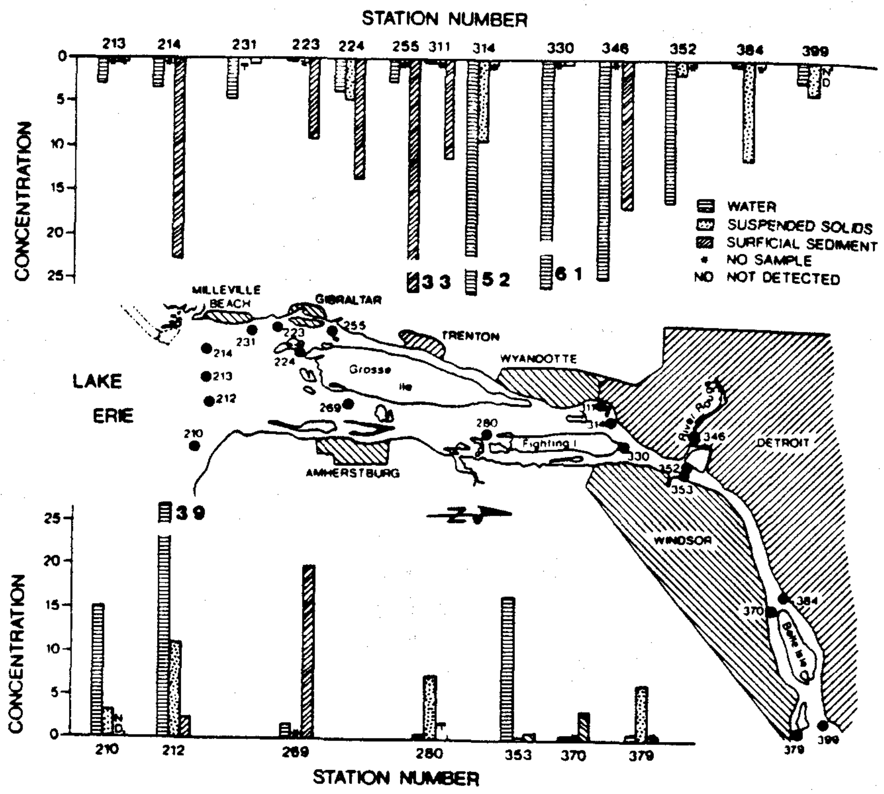
Polychlorinated Biphenyls (PCBs):

Qualitatively, the composition of PCBs in Detroit River water changes from the upper to the lower Detroit River transects (Figure IX-7). For nine commonly observed PCB homolog series (comprising approximately 100 of the theoretically possible 210 PCB isomers), a decrease of the lower chlorinated homologs (with one to four chlorines per biphenyl molecule) and an increase of the higher chlorinated homologs (6 to 10 chlorines per molecule) is observed as one moves downstream. Considering the stability of PCBs, it can be concluded that the observed change in PCB homolog distribution is due to inputs of higher chlorinated PCBs along the river stretch (26).

The observed qualitative changes in PCB composition are also supported by quantitative observations. PCB concentrations in water averaged approximately 0.6 ng/L at four stations above and below Belle Isle on both sides of the river from a 1985 survey (26). Downstream, at several locations along the Ontario side, PCB concentrations increased to approximately 1.0 ng/L, while PCB concentrations on the Michigan side in and downstream of the Trenton Channel increased to levels as high as 3.4 ng/L. In the

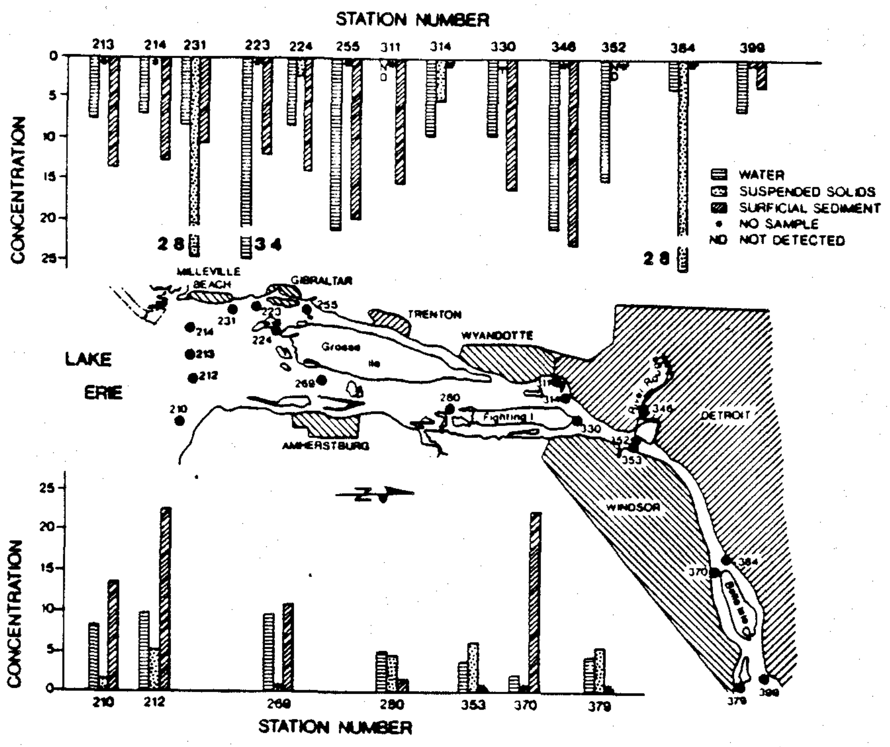


Organochlorine contaminants (OCs) in water, suspended solids, and surficial sediments of the Detroit River. Concentrations in 10^4 ng kg^{-1} (sediments, suspended solids) and 10^{-1} ng L^{-1} (water), respectively.

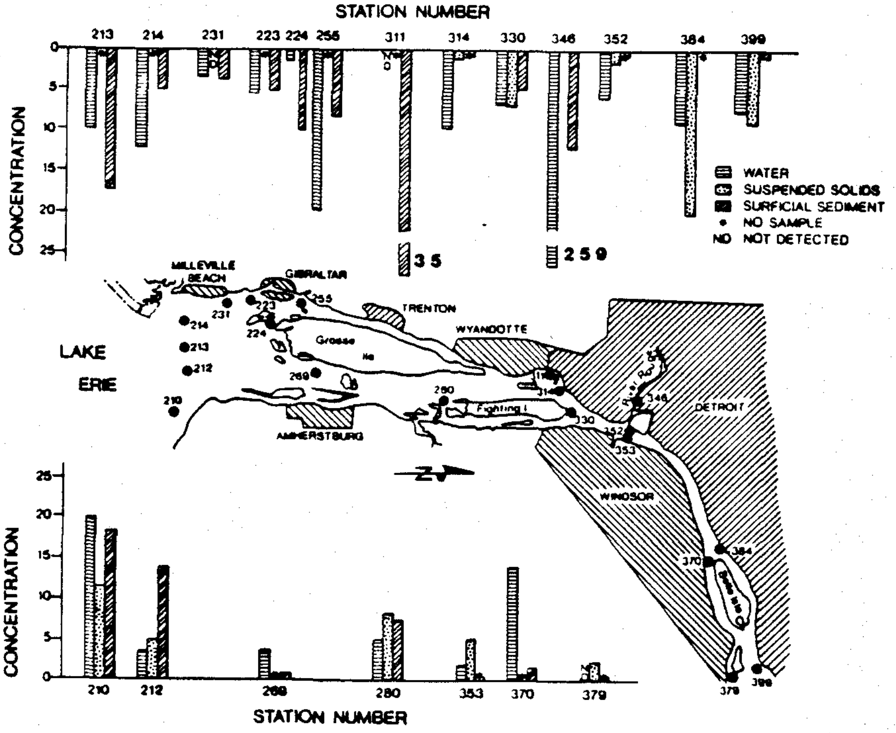


Polynuclear aromatic hydrocarbons (PNAs) in water, suspended solids, and surficial sediments of the Detroit River. Concentrations in 10^3 ng kg^{-1} (sediments), 10^4 ng kg^{-1} (suspended solids), and 10^2 ng L^{-1} (water), respectively.

FIGURE IX-6. PCBs, CBs, PAHs and OCS in Detroit River water, suspended solids and surficial sediments (29).



Polychlorinated biphenyls (PCBs) in water, suspended solids, and surficial sediments of the Detroit River. Concentrations in 10^4 ng kg^{-1} (sediments, suspended solids) and 10^{-1} ng L^{-1} (water), respectively.



Chlorobenzenes (CBs) in water, suspended solids, and surficial sediments of the Detroit River. Concentrations in 10^3 ng kg^{-1} (sediments, suspended solids) and 10^{-1} ng L^{-1} (water), respectively.

FIGURE IX-6. (Cont'd.) PCBs, CBs, PAHs and OCS in Detroit River water, suspended solids and surficial sediments (29).

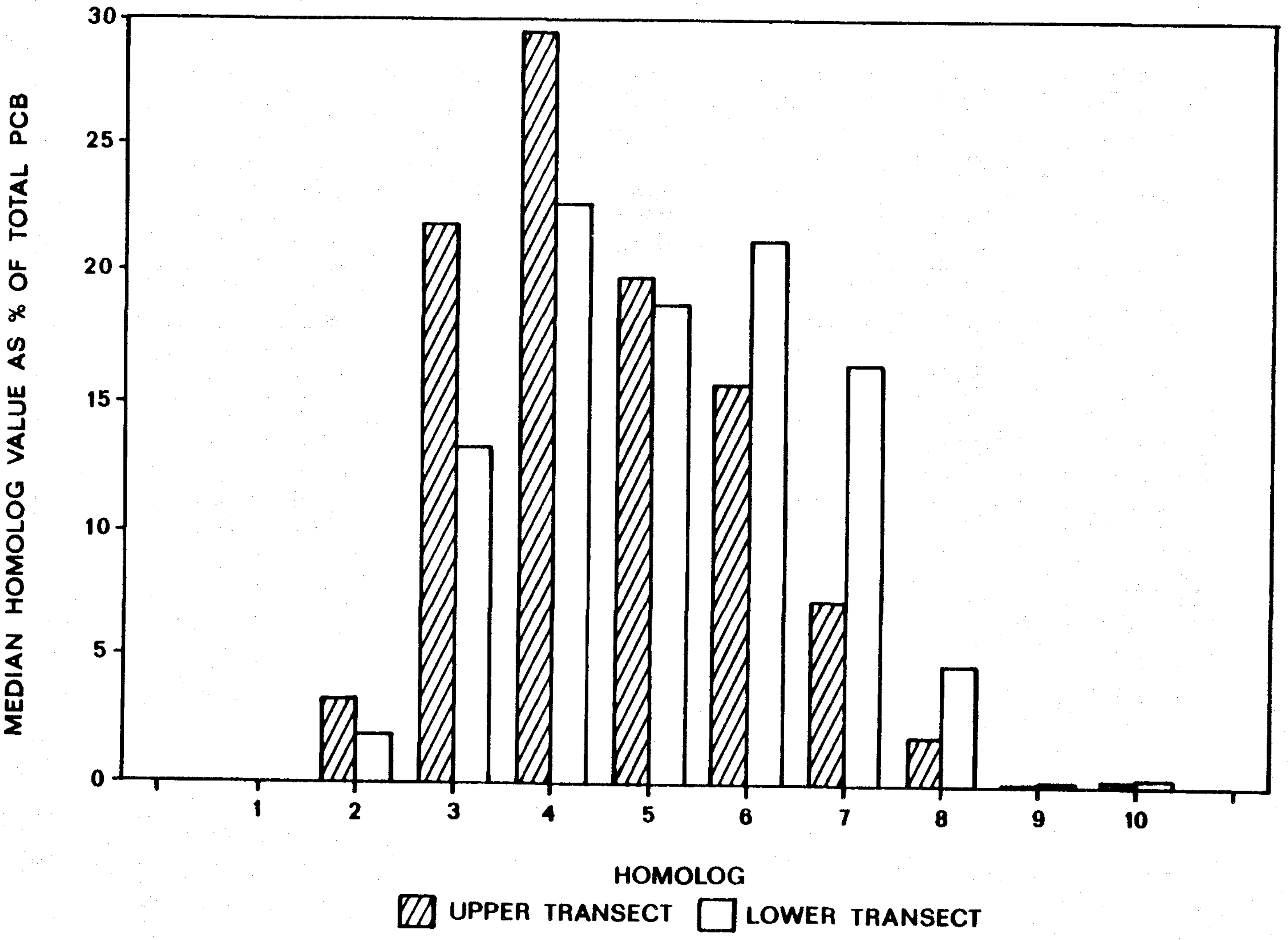


FIGURE IX-7. PCBs in Detroit River water.

Detroit River System Mass Balance Study (30), total PCB concentrations averaged 1.4 ng/L (plus or minus 0.6 ng/L) at the head of the river and 3.3 ng/L (plus or minus 1.3 ng/L) at the mouth, based on composite samples across the entire river at each respective transect. Total PCB concentrations in whole water samples from tributaries averaged 45.4 ng/L in the Rouge River, 47.9 ng/L in Turkey Creek, 33.3 ng/L in the Ecorse River and 7.6 ng/L in the Little River (Table IX-1). In the Trenton Channel Mass Balance Study (31), total PCBs in whole river water ranged from 1 ng/L to 385 ng/L. The highest concentrations were found along the western shore of the Trenton Channel, with daily variations ranging from 6.8 ng/L to 15.7 ng/L.

PCB concentrations throughout the Detroit River exceeded Michigan's Rule 57(2) allowable level of 0.02 ng/L, the Ontario Provincial Water Quality Objective (PWQO) of 1 ng/L and the U.S.EPA Ambient Water Quality Criteria (AWQC) for Human Health (based on fish and water consumption) of 0.079 ng/L, and some locations (e.g., Trenton Channel) exceeded the U.S.EPA chronic AWQC of 14 ng/L.

In suspended solids, PCB levels were at or below 50 ng/g at most locations on both sides of the river, except at two stations on the Michigan side, below Belle Isle and at the lower end of the Trenton Channel, where they reached 280 ng/g. Concentrations measured on suspended solids at the head of the Detroit River averaged 428 ng/g, largely due to one elevated measurement. A single suspended sediment sample collected in 1985 from the Canard River had a very high PCB concentration of 11,760 ng/g, but other data suggest that the Canard River is only an intermittent PCB source (32).

Chlorobenzenes:

Several of the 5 possible chlorobenzene homologs are commonly found in aquatic systems, of which hexachlorobenzene (HCB) is probably the most widely distributed congener. In Detroit River water, chlorobenzenes ranged from 0.3 to 1.0 ng/L at stations above Belle Isle and at all but two Ontario stations (maximum approximately 2 ng/L, Figure IX-6). On the Michigan side, chlorobenzene levels were somewhat higher, particularly at the mouth of the Rouge River, where chlorobenzene levels reached 25.9 ng/L (Figure IX-6). However, HCB concentrations were only 0.28 ng/L, indicating other chlorobenzenes are present. In a later study, concentrations of HCB remained virtually the same from the head (0.31 ng/L) to the mouth (0.33 ng/L) of the Detroit River (Table IX-1). In another survey, HCB in water and/or suspended particulates showed essentially the same HCB concentrations on both shores and at upstream and downstream transects. These results indicate small or intermittent sources of HCB along the Michigan side of the Detroit River, perhaps from the Rouge River, with important background concentrations of HCB entering the Detroit

TABLE IX-1

Mean concentrations of polychlorinated biphenyl, hexachlorobenzene, major trace metals, phosphorus and choride at the Detroit River head and mouth, and major tributary mouths (1984-1986)[1].

LOCATION	TOTAL CADMIUM (ug/L)	TOTAL COPPER (ug/L)	TOTAL MERCURY (ug/L)	TOTAL NICKEL (ug/L)	TOTAL ZINC (ug/L)	CHLORIDE (mg/L)	TOTAL PHOSPHORUS (ug/L)	TOTAL LEAD (ug/L)	TOTAL PCBs (ng/L)	HCB (ng/L)
Detroit-Head	0.023	1.29	0.008	0.97	1.22	6.7	8.6	-	1.4[4]	0.31[4]
Detroit-Mouth	0.035	1.64	0.008	1.15	3.30	8.4	15.7	-	3.3[4]	0.33[4]
Ecorse River	0.084	2.83	0.002	2.62	14.2	37.7	88.0	-	33.3[4]	0.39[4]
Rouge River	2.061	7.09	0.017	3.30	167.3	69.2	102.0	-	45.4[4]	0.28[4]
Turkey Creek	0.196 (0.2-3)[2]	4.38	0.016	8.76	21.2	105.6 (51-880)[2]	351.0 (47-7000)[2]	3-33[2]	47.9[4]	0.24[4]
Little River	0.058 (0.2-0.4)[2]	5.14	0.016	ND[3]	73.7	93.8 (16-215)[2]	473.0 (52-2400)[2]	3-13[2]	7.5	1.01
Canard River	0.2-0.4[2]	-	-	-	-	27-125[2]	57-550[2]	3-30[2]	-	-

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[1] From U.S.EPA as reported in the Water Quality Workgroup Report (26), except as noted. Values are rounded. See Water Quality Workgroup report for reported values, sampling methodology and statistical information.

[2] Upper and lower values reported by Wall _et al_. (5). No average value reported.

[3] ND = not detected.

[4] Average of two surveys (26).

River from upstream. Data from a 1984 study, however, indicated increased HCB concentrations on suspended sediments, from approximately 3.5 ng/g at the river head to approximately 15 ng/g at the Detroit River mouth.

Other Organochlorine Compounds:

A variety of additional organochlorine contaminants (OCs) are frequently observed in Detroit River water and seston samples. Among these are DDT and its environmental metabolites, commonly referred to as total DDT, hexachlorocyclohexane (three isomers), chlordane (two isomers), heptachlor epoxide, endosulfan (two isomers), dieldrin, endrin, methoxychlor, and octachlorostyrene (OCS). These compounds, collectively referred to as OCs, were found at concentrations of 0.3 to 0.5 ng/L in upper Detroit River water on both shores (Figure IX-6). Significantly higher OC concentrations were observed at many downstream stations on the Michigan side, with values as high as 20 ng/L at the mouth of the Rouge River. OCS levels, however, were virtually constant throughout the river at 0.005 to 0.008 ng/L in water and at 2.0 to 4.3 ng/g on particulate matter as found in another survey. These data indicate sources of OCS are primarily upstream of the Detroit River but important loadings of other OC compounds occur along the Michigan side of the Detroit River (26,32,33).

Polynuclear Aromatic Hydrocarbons:

Polynuclear aromatic hydrocarbons (PAHs) are byproducts of incomplete combustion of fossil energy resources. PAHs are also associated with petroleum refining and steel-making operations (coking, in particular). Consequently, their presence in air and water in urban and industrial areas is not surprising. At the head of the Detroit River, PAH concentrations of 100-200 ng/L were found in water. Higher concentrations were observed at several downstream stations along the Ontario, and particularly, the Michigan side of the river, with values as high as 6,100 ng/L (Figure IX-6). Based on the high concentrations of PAH that were found at the mouth of the Rouge River and sampling locations immediately downstream, large sources for PAHs appear to exist in the Rouge River area (26,30,31). Water samples from the Ontario tributaries (Turkey Creek, Little River and the Canard River) obtained during 1984 revealed no PAHs were present at the limit of detection used (34). There is no appropriate ambient water quality guideline with which to compare PAH concentrations in Detroit River water.

Total Trace Metals, Total Phosphorus and Filtered Chlorides:

A 1987 survey of selected trace metals (copper, cadmium, mercury, nickel, and zinc), phosphorus and chloride concentrations resulted in the following general conclusions (Table IX-1)(26,30).

Total cadmium concentrations increased from the head to the mouth of the Detroit River from a mean of 0.023 ug/L to a mean of 0.035 ug/L. In general, Detroit River water concentrations were below relevant ambient water quality guidelines. The Trenton Channel Mass Balance Study found total cadmium concentrations ranging from 0.7 ug/L to 0.77 ug/L (data not shown in Table IX-1) in the vicinity of the Grosse Ile free bridge along the western shore of the Trenton Channel, three of the four times it was sampled. These concentrations exceeded Michigan's Rule 57(2) allowable level of 0.4 ug/L (assuming a water hardness of 100 mg/L calcium carbonate). High cadmium concentrations were found in the Rouge River (2.06 ug/L), the Canard River (0.2-0.4 ug/L), Turkey Creek (0.196 ug/L in one study and up to 3 ug/L in another), the Ecorse River (0.084 ug/L) and the Little River (0.058 ug/L in one study, and up to 0.4 ug/L in another). Concentrations in the Rouge River, Turkey Creek and the Canard River exceeded the Great Lakes Water Quality Agreement (GLWQA) specific objective and the PWQO of 0.2 ug/L, and concentrations in the Rouge River and Turkey Creek exceeded Michigan's Rule 57(2) allowable level.

Total copper concentrations were slightly higher at the Detroit River mouth than at the river head (1.64 ug/L vs. 1.29 ug/L). Total copper concentrations in the tributaries were between two and six times higher than in the Detroit River, with the Rouge River levels highest at 7.1 ug/L. In general, both Detroit River and tributary copper concentrations were below relevant guidelines, with the exception of the Rouge and Little rivers, which slightly exceeded the GLWQA specific objective and the PWQO of 5 ug/L.

Total mercury concentrations in Detroit River water did not show any change between river head and mouth (both 0.008 ug/L). Total mercury concentrations in the Detroit River and in the Trenton Channel ranged from 0.024 ug/L to 0.449 ug/L. Tributary mercury concentrations were approximately double those in the Detroit River, except in the Ecorse River, where they were lower. These concentrations generally exceeded the U.S.EPA chronic AWQC of 0.012 ug/L.

Total nickel concentrations in the Detroit River showed little change between upper (0.97 ug/L) and lower (1.1 ug/L) Detroit River transects. Nickel concentrations in the Ecorse and Rouge rivers, and Turkey Creek were from two to eight times the Detroit River level, with the highest concentration in Turkey Creek (8.8 ug/L). Especially high concentrations of nickel were noted in the Little River (676.2 ug/L)(26). With the exception of the Little River, all Detroit River and tributary concentrations of nickel were below ambient water quality guidelines. Little River exceeded U.S.EPA chronic, Ontario and Michigan ambient water quality guidelines.

Total lead concentrations were all below the method detection limit (MDL) of <0.1 ug/L in the Detroit River head and mouth transects. Several locations in the Trenton Channel contained total lead concentrations ranging from 3.24 ug/L to 10.61 ug/L, which exceeded Michigan Rule 57(2) allowable levels (3.0 ug/L) and the U.S.EPA chronic AWQC (3.2 ug/L). The highest concentration was upstream of the Grosse Ile toll bridge along the western shore of the Trenton Channel (transect A, Figure IX-3). Transects C and D also have total lead concentrations exceeding guidelines along the western shore of the channel. Total lead concentrations in Ontario tributaries were determined for the Little River (3-13 ug/L), the Canard River (3-30 ug/L) and Turkey Creek (3-33 ug/L). These tributaries all contain total lead concentrations above guidelines (26,35). Concentrations of total lead in Michigan tributaries were not available for this report.

Total zinc concentrations increased between upper (1.2 ug/L) and lower (3.3 ug/L) Detroit River transects. Each of the tributaries also had high mean zinc concentrations, with the Ecorse River having the least (14 ug/L) and the Rouge River the highest (167 ug/L) total zinc concentrations. With the exception of the Rouge River and the Little River (74 ug/L), water concentrations were below ambient water quality guidelines. Little River concentrations of total zinc exceeded GLWQA specific objectives (30 ug/L). Rouge River total zinc concentrations exceeded this guideline and also the U.S.EPA chronic and acute AWQC.

Total phosphorus concentrations were nearly twice as high at the Detroit River mouth (15.7 ug/L) compared to the river head (8.6 ug/L). Total phosphorus concentrations in the major Detroit River tributaries were much higher than concentrations in the Detroit River.

Filtered chloride concentrations increased from 6.7 mg/L to 8.4 mg/L between upper and lower Detroit River transects. The lower Detroit River transect was located above General Chemical, a major chloride loading source discussed later, and therefore this loading was not reflected in the Detroit River mouth transect value shown in Table IX-1. The filtered chloride concentrations in the Detroit River tributaries were one to two orders of magnitude greater than the Detroit River head. Total chloride concentrations (not shown) did not increase between the head and the mouth. The drinking water guideline for chlorides (250 mg/L) was exceeded in Turkey Creek and North Drain.

Nutrients, Dissolved Gases and Microorganisms:

The basic plant nutrients in the Detroit River include phosphates, nitrates, and silicates. Dissolved oxygen and the metals iron, sodium, calcium, magnesium, manganese and aluminum are also present in sufficient quantities. The oversupply of phosphate, chloride and ammonia has decreased substantially over the past 20 years.

Dissolved organic carbon (DOC) and particulate organic carbon (POC) are often many times greater than the organic carbon found in living plankton, macrophytes, and fauna produced in streams. DOC measurements available from Lake Huron, the St. Clair and Detroit Rivers are in the range of 2-3 g/m^3. The POC entering the St. Clair-Detroit River system from Lake Huron is about 0.7 g/m^3. An average of 1.4 g/m^3 was measured at the mouth of the St. Clair River, and up to 2.0 g/m^3 were found in Lake St. Clair. A single POC sample from the mouth of the Detroit River was 3.8 g/m^3. Suspended solids increased by a factor of six between Lake Huron and Lake Erie, and bed load POC has not been studied, so 3.8 g/m^3 may underestimate POC in the Detroit River.

Although not measured during these studies, fecal coliform bacteria are of concern in the Detroit River because fecal coliform bacteria standards and criteria have been violated on both sides of the river. The Ontario objective is 100 counts/100 ml and the Michigan standard is 200/100 ml fecal coliform bacteria. Beaches have been closed or not developed because of this continuing problem.

Water Bioassays:

Seven day chronic bioassays measured the impacts of Detroit River near-bottom water on <u>Ceriodaphnia</u>. Reproductive success was significantly reduced (mean young produced/female) relative to Lake Michigan controls at all four test sites. Station 83 near-bottom water collected along the southwestern shore of Fighting Island produced the greatest reduction in the number of young produced/female (70 to 100% reduction) followed by stations 34 (along the west shore of the Trenton Channel), 53 (at the southern tip of Grosse Ile and 30CR (in Monguagon Creek). These reductions were most severe from July to September (36).

Considering both exceedences of water quality and impacts on biota, the pollutants of concern in water of the Detroit River, or that of its tributaries, include PCBs, chlorobenzenes, PAHs, total cadmium, total mercury, total lead, total zinc, and total phosphorus, in addition to fecal coliform bacteria.

<u>Biota</u>

i) Phytoplankton, Macrophytes and Zooplankton

Detroit River phytoplankton communities consist of low densities (500 cells per ml) of 82 species dominated by diatoms (8,10,37). Summer blue-greens contribute to phytoplankton community, but Detroit River picoplankton, a large component of the phytoplankton biomass, were not surveyed.

Activity causing habitat loss, such as filling or dredging, water or sediment contaminants or simply continuous elevated suspended solids that reduce macrophyte production, reduces desirable fish and wildlife production in the Detroit River and western Lake Erie. Macrophyte production was estimated at 16,410 metric tons of ash-free dry weight/yr (12). Only 25% is from emergents reflecting the limited habitat presently available.

Detroit River zooplankton populations (potential larval fish food) were 85% copepods with other zooplankton populations at very low relative abundances. Zooplankton densities were greater during the night than the day with typically patchy distribution with peak numbers between June and September (36,38). Zooplankton are a critical component in the diet of many larval and some juvenile fish. Poor diversity or depressed zooplankton production is likely to result in poor fish year classes during naturally occurring or contaminant related stressful conditions.

ii) Benthic Macroinvertebrates

Diversity and abundance of benthic macroinvertebrates are lower in the deep, fast flowing areas of the river because the substrate is either difficult to adhere to or burrow into. Shallower, uncontaminated zones containing macrophytes are likely to yield the greatest diversity. The greatest densities are reached in strongly enriched, unconsolidated sediments where oligochaetes are often monotypic.

The Detroit River benthic community upstream of Zug Island is diverse and dominated by pollution intolerant organisms with the exception of the Windsor shoreline. Adjacent to Zug Island, the community is severely impacted, and downstream, especially in the Trenton Channel, the community is dominated by pollution tolerant oligochaetes (13,15,39). The Ontario shoreline is considerably better as evidenced by the presence of pollution intolerant mayflies (11,15).

Schloesser, _et_ _al_. (40) demonstrated an inverse relationship between Hexagenia abundance and visible oil in sediments of the Connecting Channels. Edsall _et_ _al_. (41) found Hexagenia averaging 2,086 mg dry wt/m^3/yr at three locations where sediment contaminants did not exceed sediment guidelines, but only 364 mg dry wt/m^3/yr where as many as seven contaminants exceeded these guidelines.

Native Detroit River _Lampsilis_ _radiada_ _siliquoidea_, at 4 stations along the Ontario shore, contained lead and cadmium ranging from 3 to 9 and 3.5 to 6.2 mg/kg respectively (42). PCBs ranged from 73 to 196 ug/kg at these same locations. Octachlorostyrene (OCS) in clams ranged from 31 to 57 ug/kg, 70 to 285 times higher than sediment concentrations.

Caged Elliptio compalanta placed in the Detroit River for 18 months accumulated HCB and OCS and a variety of organochlorine pesticides (43). Highest levels were found along the western Detroit River shore near Conners Creek, the lower Trenton Channel and the Rouge River. PCBs were the major organochlorine clam contaminant, ranging from 20 to 293 ug/kg along the Michigan shore; clams from the Ontario shore had much lower concentrations (Figure IX-8).

Polynuclear aromatic hydrocarbons (PAHs) were also reported in caged clams at elevated levels along the Michigan shoreline and downstream in the Trenton Channel ranging from 136 to 772 ug/kg. Along the Ontario shoreline PAHs ranged from 52 to 274 ug/kg.

iii) Fish

Five fish species were collected from six sites in the lower Detroit River and examined for external lesions, necropsied for internal abnormalities and tissues removed for histological examination (Figure IX-9) (44). Several neoplasms and pre-neoplastic lesions were found in Detroit River brown bullhead, walleye, redhorse sucker, white sucker and bowfin. Bullhead and walleye were the only two species exhibiting dermal/oral neoplasms at 14.4 and 4.8 %, respectively. Other species exhibited liver neoplasms with highest incidence observed for bowfin at 15.4%. In bullhead, no relationships between dermal/oral and liver tumors were found. Tumor incidence was age/size related since tumors were present in bullheads over 25 centimeters and in walleye over 50 centimeters. Of the six sites examined, bullheads at Point Hennepin and Gibraltar Bay, exhibited the greatest tumor incidence at 36.4% and 33.3%, respectively. Bullheads near Mud Island north of the Trenton Channel and in the lower end of the Trenton Channel did not exhibit tumors.

In this study (44), bile was analyzed for benzo(a)pyrene (BaP) and its metabolites. All species had BaP or its metabolites in their bile. Walleye and redhorse sucker contained the greatest BaP concentrations, with concentrations in bullhead substantially lower. The greatest BaP concentrations were in bowfin and redhorse sucker from Point Hennepin and in brown bullhead, walleye, and white sucker from Mud Island.

Contaminants exceeding relevant guidelines were found in the flesh of fish in the Detroit River. PCBs were found in carp, with concentrations exceeding the Ontario Ministry of Environment (OMOE) and Ontario Ministry of Natural Resources fish consumption guidelines and the U.S. Food and Drug Administration action level of 2 ppm, as well as the GLWQA specific objective of 0.1 ppm (Figure IX-10). PCBs in young-of-the-year spottail shiners were found at significantly ($p<0.01$) higher concentrations along the Michigan shoreline than along the Ontario, suggesting Michigan inputs of PCBs (45). High concentrations of mercury were found

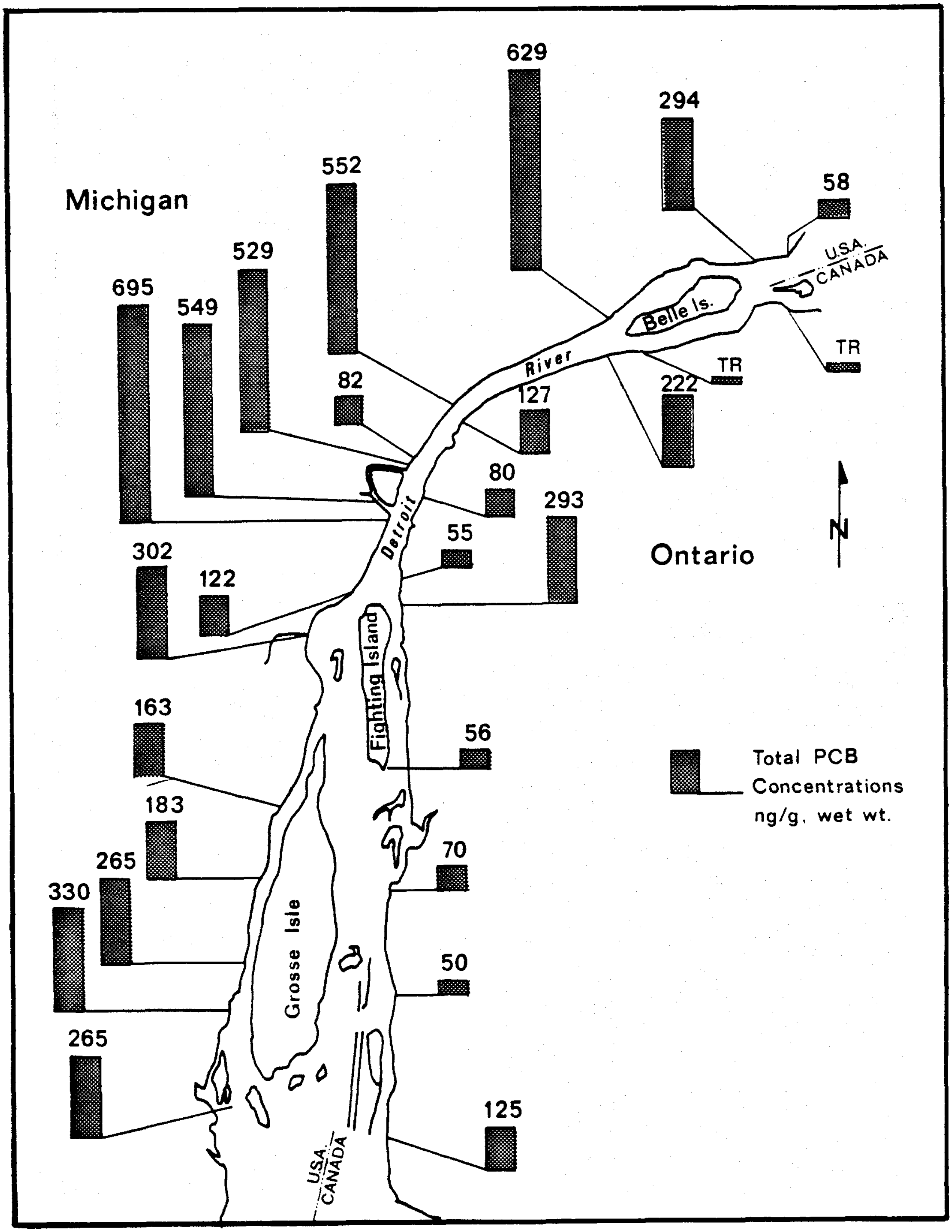

FIGURE IX-8. Total PCB concentrations in Detroit River caged clams.

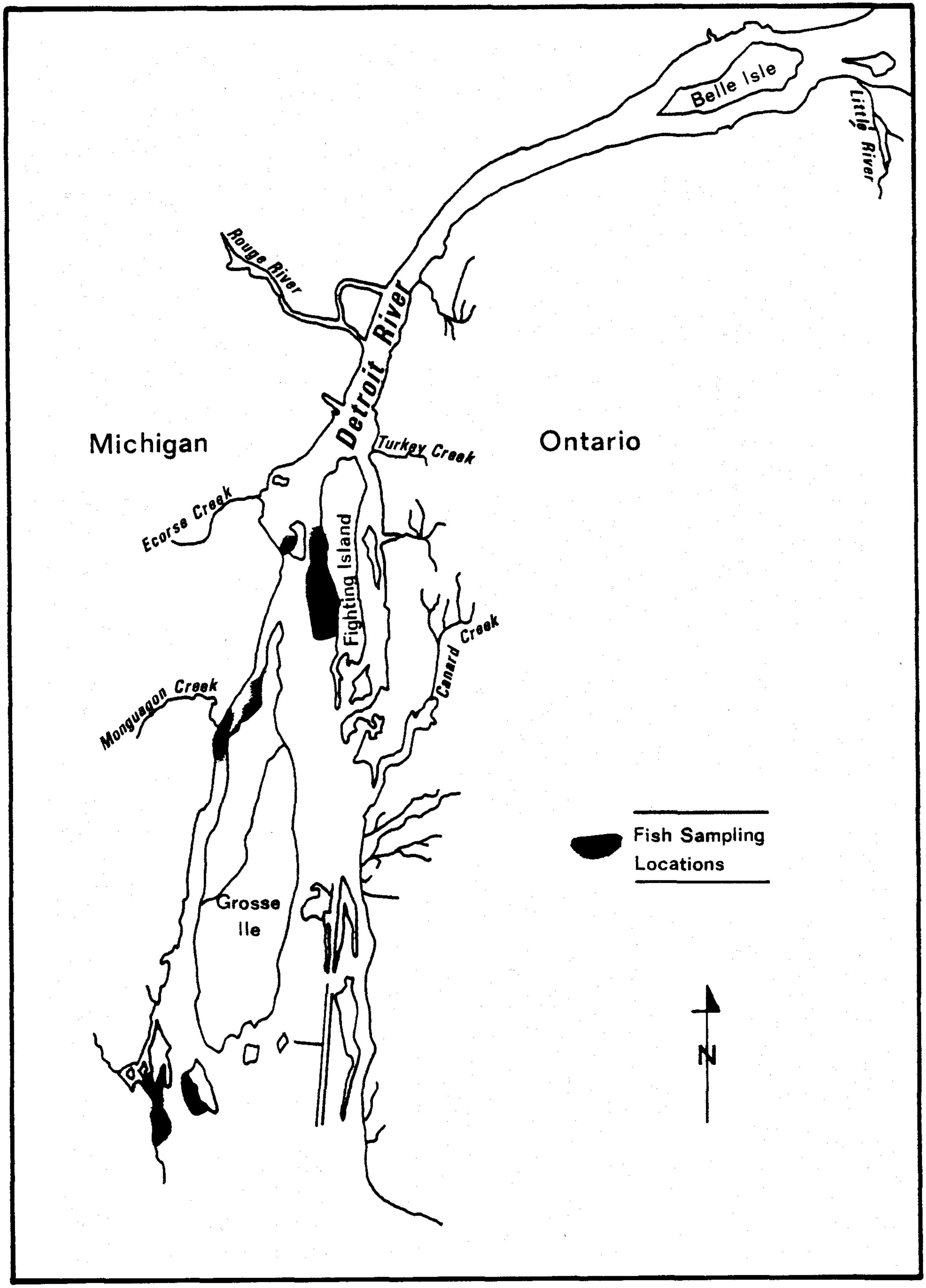

FIGURE IX-9. Fish sampling locations for tumor analysis.

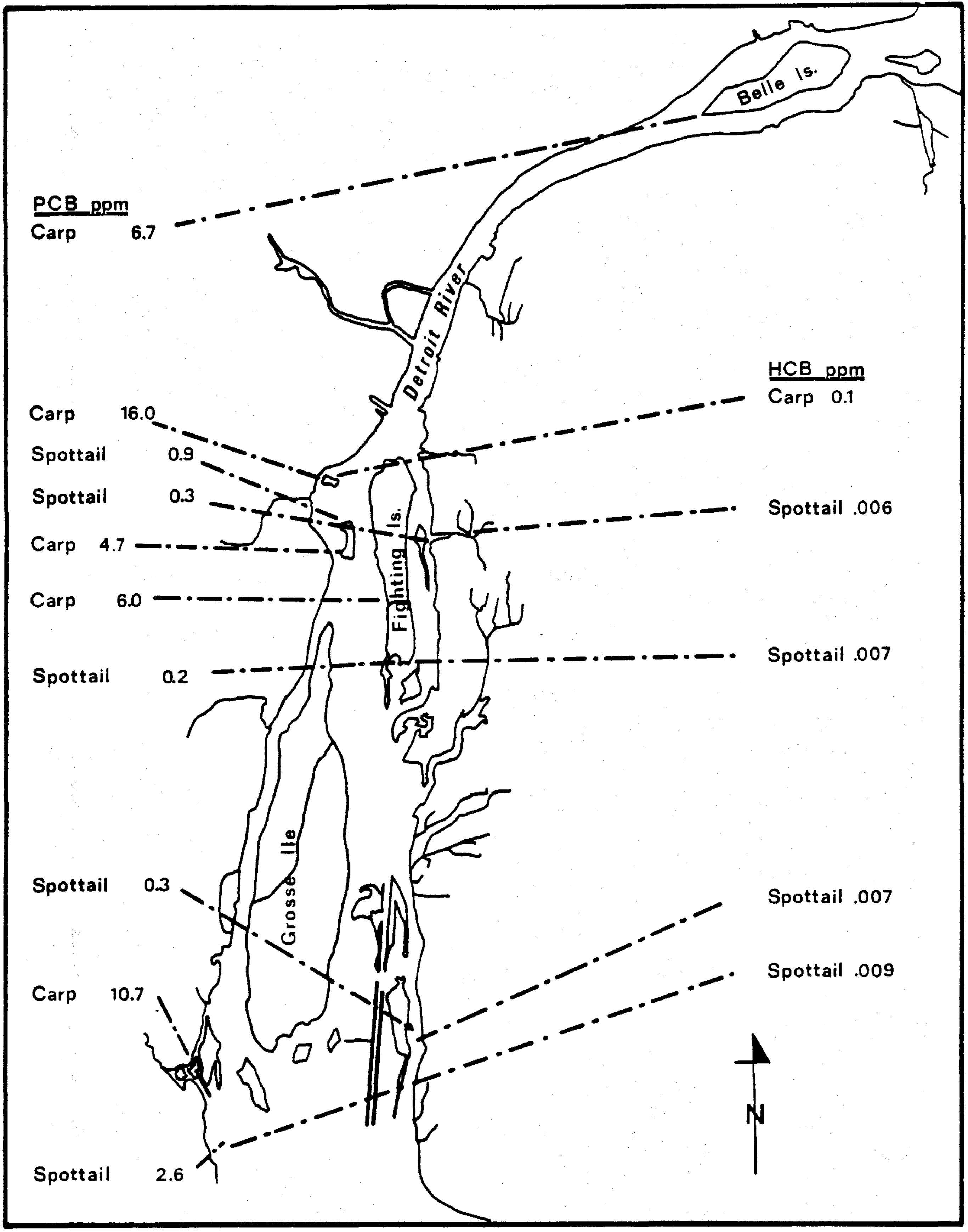

FIGURE IX-10. PCBs and HCB concentrations in Carp and Spottails shiners.

in the edible portion of several species of fish (rock bass, freshwater drum and walleye). Concentrations were above both the GLWQA specific objective and the Ontario fish consumption advisory of 0.5 ppm (46,47). Other chemicals, such as HCB, OCS, chlordane and DDT metabolites, were uniformly distributed in Detroit River spottail shiners, suggesting a diffuse source (45).

iv) Birds

Thirteen wintering lower Detroit River diving ducks (7 lesser and 3 greater scaups and three goldeneyes) were analyzed for organic chemical contaminants (48). Total PCBs ranged from 2 to 20 mg/kg, indicating significant bioaccumulation. Highest mean concentrations of other residues in ducks were 1.7 mg/kg hexachlorobenzene in goldeneyes, and trans-nonachlor (0.33 mg/kg) and 4,4' DDE (1.3 mg/kg) in greater scaups. Similar chemical residues were also found in some tern species. Concentrations of total PCBs in Detroit River seston (5.2 mg/kg) and oligochaete worms (0.44 mg/kg) mg/kg) were also noted.

Herring gull eggs from Fighting Island contained high PCB and HCB concentrations in 1985 and 1986 studies. Detroit River herring gull eggs contained the lowest concentrations of dieldrin, heptachlor epoxide, photomirex, oxychlordane and alpha hexachlorocyclohexane in the Great Lakes (49).

Detroit River waterfowl surveys completed in 1982 showed dramatic declines in merganser and black ducks, and dramatic increase in canvasbacks and redheads since 1974 (50). It was postulated that loss of emergent macrophytes caused by high Great Lakes water levels caused this reduction in dabbling ducks.

In summary, the pollutants of concern in Detroit River biota include PCBs, PAHs, HCB, OCS, mercury, lead, cadmium and oil and grease. Other biota concerns include habitat alteration and fish tumors.

Sediment Quality

i) Sediment Characteristics

Sediments in the Detroit River are generally sandy, consolidated clay or bedrock because of the relatively high flow velocities. Sediment particle size analysis conducted in 1980 revealed that surficial sediments were generally sand, but gravel dominated areas of high velocity along the Detroit waterfront, the entrance of the Trenton Channel and the upper Amherstburg Channel. Fine-grained samples were collected in slow waters near tributary mouths. Silts and clays were found downstream of Zug Island, in the Rouge River, the Trenton Channel near Trenton and the Detroit River mouth (51,52).

Detroit River sediment thickness over bedrock revealed a maximum sediment thickness of 33 m near Belle Isle, which declined steadily southward to nearly zero in the Trenton Channel and zero in the main channel (53). The outer and Amherstburg Channel silt layer averaged 0.45 to 0.50 m near Lake Erie and zero in the Amherstburg Channel at Bois Blanc Island and in the Ballard Reef Channel.

The Michigan Detroit River tributaries which were not sampled in 1982 were sampled in 1985, revealing fine-grained, anthropogenic sediments frequently of sludge-like consistency (54,55). Samples in Monguagon Creek and downstream of the Rouge River contained very fine sands, silt, and coarse sand and gravel. The upper Rouge River sediments were coarser than elsewhere, consisting of medium to fine sands with little very fine sand sediments. Conners Creek sediments also had only minor amounts of fine to very fine sands. Studies conducted in 1986 at 47 sites (56,57), generally confirmed the earlier findings.

ii) Sediment Transport

Detroit River average main channel velocities are 0.49 to 0.88 m/sec, but surface velocities may be nearly twice that rate in the main channels (0.9 to 1.2 m/sec)(58). Sand is transported in the main channels when the velocity exceeds 0.42 m/sec, while along the shore and in shallow water areas, where velocities may drop to 0.25 m/sec or less, sand deposition occurs. Navigation channel bottoms are scoured by currents leaving few sediments to resuspend, and no significant relationships between ship passage and turbidity has been found (59).

A field portable shaker device was used to measure sediment resuspendability at eight Trenton Channel locations from Monguagon Creek to Celeron Island. Lick et al. predicted that resuspension could occur regularly in the Trenton Channel (60). Direct instantaneous measurements of flow velocity, turbidity and sediment concentration at four locations in the Trenton Channel using instrumented towers assisted the above researchers (61).

iii) Navigation and Dredging

Until recently, the entire Detroit River commercial navigation system was dredged by the U.S. Army Corps of Engineers (USCOE) to a depth of 8.2 m below low water datum. At present, the Ontario portion of these channels are dredged by Public Works Canada under contract to Transport Canada. Before enactment of the Rivers and Harbors Act of 1970, nearly 3 million m^3 of dredged materials were disposed of in the open lake at two sites in Lake Erie south of the Detroit River mouth (62). In addition, an unknown amount of Detroit River dredged materials were placed in Lake St. Clair, near the head of the Detroit River. Since 1970, about 30,100 m^3 of polluted dredged materials were placed on

Grassy Island. From 1979 to 1984, 3.1 million m^3 of dredged material were deposited in the Pointe Mouillee confined disposal facility (CDF) near the Huron River mouth (58). In 1985, 814,000 m^3 of polluted Detroit River material was scheduled for disposal in the Point Mouillee CDF. Rouge River sediments, since 1950, have been placed on Grassy Island (62). Some polluted dredged materials were also disposed of along the lower Raisin River prior to 1979. Mud Island, a small containment site near Grassy Island, was also used for dredged material disposal.

iv) Sediment Contamination

Results of the six major surveys conducted since 1982 include contaminant chemistry at approximately 135 sites (51,54,55,63,64, 65,66,67,68,69,70,71,72,73). For ease of presentation, the Detroit River was divided up into seven subareas (Figure IX-11). Because the purposes for the survey, sampling gear, analytical methods, depth of sample collection, compositing techniques and sampling locations varied considerably between the studies, comparison of these data from year to year may not be entirely valid. However, an attempt was made to make some comparison.

Organics - Polychlorinated Biphenyls:

High total PCB concentrations were found by six surveys in all subareas except subarea 7 (Table IX-2, Figure IX-11). The highest mean sediment PCB concentrations were found in subarea 2, just below Belle Isle, where 5 of 10 samples exceeded 10,000 ug/kg in 1986. These were associated with sewer system outfalls, and indicate that combined sewer overflows have historically been, and may still be, an important source of PCBs (64).

The 1984 analyses of Oliver and Pugsley (74) noted localized areas of high concentrations of PCBs downstream of the Detroit WWTP and the Rouge River (in subarea 3), at concentrations higher than reported in 1980 (75), assuming the methodologies of the 1980 and 1984 studies were comparable. Comparison of 1982 and 1985 collections are supportive of the conclusion that subarea 2 sources were more significant than the Rouge River. Rouge River sediments collected at the mouth in 1986 revealed total PCBs up to 3,500 ug/kg (76). Samples collected downstream of the Detroit WWTP outfall and off the Rouge River mouth in 1985 and 1986 revealed PCBs up to 2,840 ug/kg near Zug Island (28). Concentrations up to 3,800 ug/kg were found in the Ecorse River (subarea 4). The highest concentrations in the navigation channel (subarea 4) was 140 ug/kg, between Grosse Ile and Fighting Island (77). Sediments analyzed from along the Windsor waterfront showed PCB concentrations ranging from less than 1 ug/kg to 370 ug/kg.

Sediment collections made in 1982 and 1985 also indicate PCB sources in subarea 6, the Trenton Channel. Highest levels were

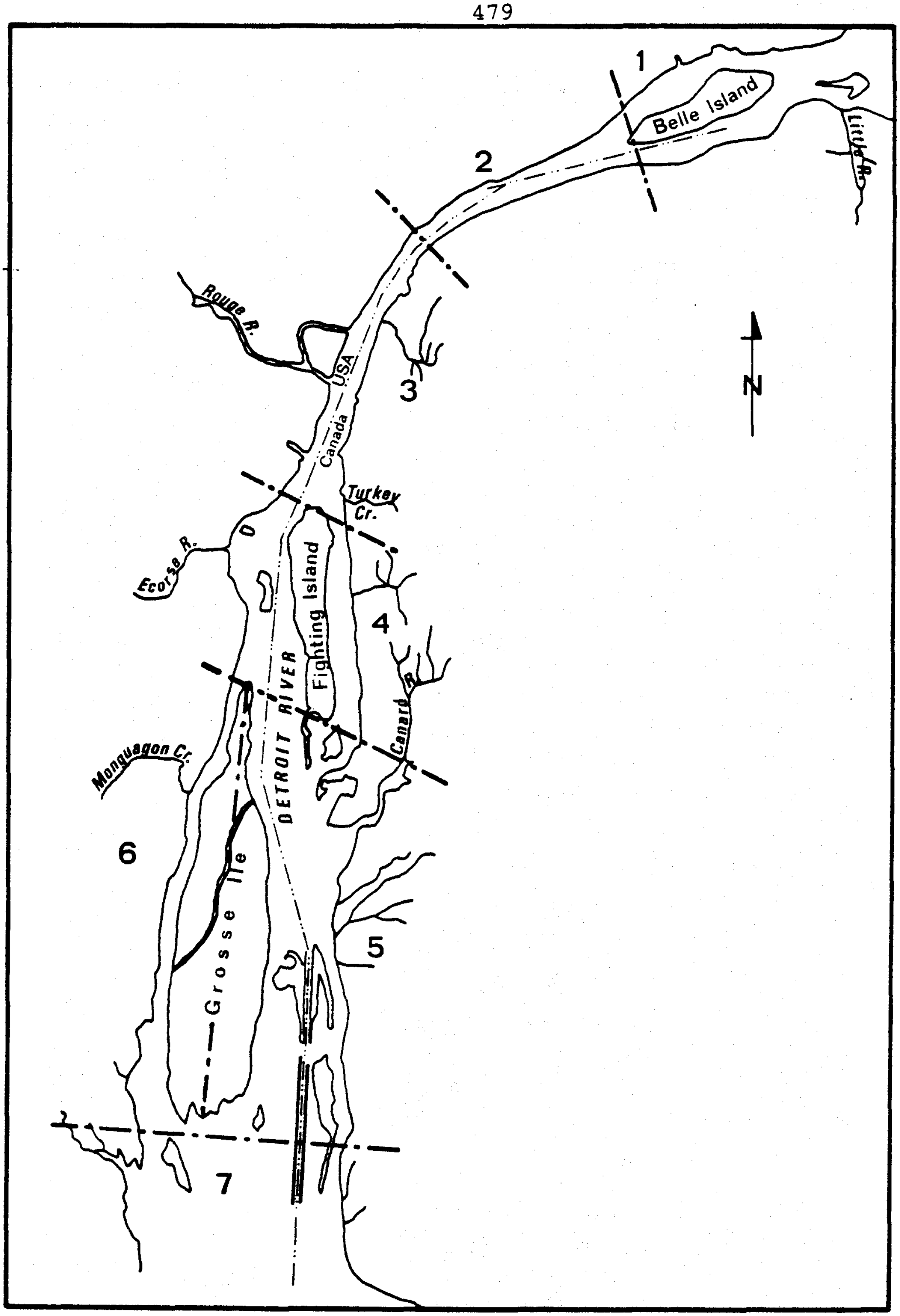

FIGURE IX-11. Detroit River sub-areas for sediment sampling.

TABLE IX-2

Polychlorinated biphenyl (PCB) concentrations in Detroit River sediments (ug/kg)[1,2].

SUB-AREA[3]		MDNR	OMOE	EPA82	EPA85	DOE	U.S.FWS
1	MAX	2900	420	9133	2020	470	358
	MIN	100	35	116	962	0	0
	MEAN	674	110	2351	1491	91	79
	n	9	7	7	2	6	8
	SD	608	524	2704	529	170	111
2	MAX	4000		12010		190	5410
	MIN	1910		6200		190	153
	MEAN	147		9636		190	1494
	n	10		3		1	4
	SD	10561		2705		0	2261
3	MAX	4800	1815	9647	2213	7900	4000
	MIN	970	25	1229	958	7	135
	MEAN	3007	551	3901	1538	1506	1166
	n	7	8	8	7	10	4
	SD	1357	524	2609	399	2921	1637
4	MAX	1000		12810	588	8000	1038
	MIN	290		0	206	41	0
	MEAN	645		4095	417	1462	274
	n	2		25	3	6	8
	SD	355		3815	158	2927	357
5	MAX		11760			320	957
	MIN		40			3	0
	MEAN		5900			85	961
	n		2			8	10
	SD		5860			107	319
6	MAX			13870	1590	1400	9130
	MIN			2350	149	29	336
	MEAN			7526	1090	642	2471
	n			6	2	6	6
	SD			9988	440	437	3093
7	MAX			2827	604	510	359
	MIN			22	368	10	154
	MEAN			985	509	158	267
	n			8	8	6	7
	SD			1303	10218	188	87

n = number of samples.

[1] Kizlauskas and Pranckevicius (63).

[2] The six surveys were performed by the Michigan Dept. of Natural Resources (MDNR), Ontario Ministry of the

in Monguagon Creek (13,870 ug/kg), although very high PCB concentrations were found near BASF/Federal Marine Terminal Properties and below McLouth Steel, near Trenton. Tributary data collected in 1985 also targets Monguagon Creek as a PCB source, with concentrations in the creek of up to 1,530 ug/kg (55). Since PCB concentrations of up to 9,130 ug/kg were reported in the Trenton Channel proper, other sources are contributing PCBs to the Trenton Channel in addition to Monguagon Creek (56).

Bottom sediments from Ontario tributaries obtained during the 1984-1985 survey revealed PCB concentrations of 1,305 ug/kg, 248 ug/kg and 20 ug/kg at the mouths of Turkey Creek, the Little River and the Canard River, respectively (5).

Many of these PCB sediment concentrations in the Detroit River and its tributaries, in Michigan and Ontario (particularly adjacent to and downstream of Detroit, Windsor and Amherstburg and in the Trenton Channel), exceed dredging guidelines. Guidelines exceeded include the OMOE dredging guidelines (50 ug/kg), the U.S.EPA dredging guidelines (10,000 ug/kg) and are higher than the guidelines recommended for Lake Erie by the Dredging Subcommittee of the Great Lakes Water Quality Board (up to 252 ug/kg).

Hexachlorobenzene:

Sediments collected in 1982 and 1985 in subareas 3, 6 and 7 contained hexachlorobenzene (HCB) exceeding 100 ug/kg. Concentrations of HCB in 1985 downstream of Monguagon Creek ranged from 26 to 140 ug/kg. Inputs from the St. Clair River are probably minor since loadings between the St. Clair River mouth and the head of the Detroit River were reduced at least 95%. Increases noted within the Detroit River may arise through diffuse or unknown minor inputs. The highest concentrations of HCB were found, in Michigan at the mouth and downstream of the Rouge River and in the Trenton Channel; and in Ontario adjacent to Amherstburg and east of Fighting Island. There are no dredging guidelines for HCB.

Polynuclear Aromatic Hydrocarbons:

Polynuclear aromatic hydrocarbon (PAH) analyses were performed on Detroit River sediments in 1982 and 1985. Total PAH values ranged from 620 to 265,000 ug/kg along the Michigan shore downstream of Belle Isle. High total PAH levels (up to 125,000 ug/kg) were also reported in the lower Rouge River. In 1985, PAHs were reported in the Detroit Dearborn Channel and all Michigan Detroit River tributaries, ranging from a low concentration of 600 ug/kg to a high concentration of 600,100 ug/kg in Monguagon Creek. Most tributary PAH samples were dominated by 3-, 4-, and 5-ring PAH compounds. Two-ring naphthalenes were found in appreciable quantities only in the Monguagon Creek and the Rouge River. There are no dredging guidelines for total PAHs.

Phenols:

Phenols ranged from nondetectable to 44,000 ug/kg in localized areas within subarea 6 along the Michigan shore. High levels were generally found in subareas 1, 2, and 3 near the Edward C. Levy Company. There are no dredging guidelines for total phenols.

DDT and Metabolites:

DDT analyses were performed on Detroit River sediments collected in 1982 and 1985. In 1982, the highest total DDT concentrations were found near Belle Isle (2,265 ug/kg). In 1985, total DDT was highest in subarea 1. DDT and metabolites were found in all 1985 samples ranging from 7 to 482 ug/kg (Conners Creek). High levels of total DDT were also found in the Rouge River mouth and Trenton Channel, suggesting recent additions that have not been degraded.

Sediments from the mouths of Ontario tributaries generally contained less than 5 ug/kg p'p'-DDT, while breakdown products p'p'-DDE and p'p'-DDD approached maximum levels of 36 ug/kg and 20 ug/kg, respectively. There are no dredging guidelines for DDT or its metabolites.

Other Pesticides:

Approximately 34 other pesticides were analyzed in sediments in 1985, 14 of which were found in bottom sediments. Alpha-chlordane, gamma-chlordane, dieldrin and methoxychlor were most commonly found. Highest dieldrin levels were found in subarea 5, at the Canard River mouth (30 to 55 ug/kg). Methoxychlor and gamma-chlordane were highest in sub-area 3. Maximum levels in bottom sediments for methoxychlor were 86 ug/kg while gamma-chlordane levels were 10 ug/kg.

Several chlorinated pesticides were found in the Detroit River sediments collected in 1985 with highest levels in Monguagon and Conners Creek sediments. Highest levels of trifluralin (19 ug/kg) were present in the Frank and Poet Drain and the only occurrences of DCPA (Dacthal) were in the Ecorse River and the Detroit River Dearborn Channel, a tributary to the Rouge River. Dieldrin (14 ug/kg) was highest in the Detroit-Dearborn Channel, while aldrin was found primarily in the Rouge River and Conners Creek sediments.

Beta-BHC concentrations were elevated at Belle Isle (170 ug/kg) and near the Ecorse River (195 ug/kg) in 1982 collections. Gamma-chlordane was found throughout the study area with peaks at Conners Creek and the Ecorse River. Concentrations of other pesticides in sediments showed no distinct relation to potential sources.

Phthalate Esters:

Phthalate esters were found in 14 of the 20 Detroit River tributary samples in 1985. Highest levels were found on the Michigan side in Conners Creek, the Rouge River and near the Federal Marine Terminals and BASF properties (17,600 ug/kg). There are no dredging guidelines for phthalate esters.

Volatile Organic Compounds:

Volatile organic compounds were found in 15 of 20 sediment samples analyzed from the Detroit River tributaries in 1985. Dichloromethane appeared in 9 of the 20 samples ranging from 0.8 to 6.9 ug/kg in Monguagon Creek where the great variety of volatile organic compounds were found. Highest concentrations were found in subarea 7, in the Frank and Poet Drain. There are no dredging guidelines for specific volatile compounds.

Metals - Mercury:

Mercury analyses were performed on sediments collected in 1982, 1985 and 1986. The highest levels in subarea 6 (Trenton Channel) were located below the mouth of Monguagon Creek near the Edward C. Levy Company (55.8 mg/kg). However, a 1985 sample in Monguagon Creek (1.5 mg/kg) indicated that Monguagon Creek was not a prominent mercury source. Mercury analyses of sediments in subarea 6 exceeded 3.0 mg/kg, while bottom sediments in subarea 1 exceed 2.5 mg/kg. U.S.EPA and Ontario dredging guidelines for mercury were exceeded at many sampled locations along the Michigan and Ontario shores throughout the length of the river.

Lead:

Lead concentrations exceeded 200 mg/kg in subareas 1, 2 and 6 in 1982 and 1985. Tributary sediment levels were highest in Conners Creek and the Detroit-Dearborn Channel of the Rouge River, ranging from 500 to 750 mg/kg, but declined downstream to less than 100 mg/kg in subarea 1. Sediment lead concentrations for samples collected in 1982 and 1985 were similar at subarea 6 above Elizabeth Park Canal (1,750 mg/kg). Dredging guidelines were exceeded along most of the Michigan shore and downstream of Windsor and Amherstburg in Ontario.

Arsenic:

Sediment data for 1982 and 1985 indicate that Detroit River sediments contain approximately 10 mg/kg arsenic throughout, with elevated levels of 36 and 54 mg/kg found at Elizabeth Park Canal and the Rouge River, respectively. The uniformity of the data suggests no major point or nonpoint sources of arsenic to the Detroit River; however, dredging guidelines for arsenic were exceeded.

Cadmium:

Peak cadmium concentrations were in subareas 1, 3 and 6, ranging between 25 and 96 mg/kg. Cadmium concentrations in suspended and bottom sediments were approximately equal, perhaps indicating a persistent local source. Dredging guidelines for cadmium were exceeded along the full length of the Michigan shore (especially adjacent to Detroit and in the Trenton Channel) and adjacent and downstream of Windsor and Amherstburg.

Copper:

Sediment data from 1986 show copper peaks exceeding 100 mg/kg in subareas 2,3,4, and 6. Sediment data for 1985 showed generally higher copper levels in subarea 1 and 3, than in 5 or 7 (approximately 100 mg/kg versus approximately 50 mg/kg). In 1982 and 1985, copper values exceeded 700 mg/kg in subarea 3, Turkey Creek and the Rouge River. Dredging guidelines for copper were exceeded along the Michigan and Ontario shores, specifically adjacent to the cities of Detroit, Windsor and Amherstburg and in the Trenton Channel.

Zinc:

Sediment data for 1986 indicate levels of zinc exceeding 500 mg/kg in subareas 2 and 6. The 1982 and 1985 sediment data show zinc exceeding 1,000 mg/kg in subareas 1, 2, 3 and 6. The Rouge River, Conners, Turkey and Monguagon Creeks all appear to be contributing zinc to the Detroit River. Dredging guidelines for zinc were generally exceeded at the same locations as for copper.

Chromium:

Sediment data for 1986 indicate chromium levels exceeding 100 mg/kg in subareas 2 and 6. The 1985 sediment data show tributary sediments as chromium sources in subareas 1 and 3, where suspended and bottom sediments contained greater than 300 mg/kg total chromium, indicating a continuing source. Chromium levels were nearly twice as high in the Detroit Dearborn Channel of the Rouge River as the lower Rouge River sediments. The 1982 chromium peaks were not apparent in the 1985 subarea 6 sediments samples, perhaps indicating some source control. Dredging guidelines were exceeded at several locations in the Detroit River (as per copper).

Nickel:

High nickel levels (500 mg/kg) were found in bottom sediments from the Ontario tributary in subarea 1, the Little River. Sediment nickel levels exceeded 50 mg/kg in subareas 2, 3 and 6 in 1986, while 1985 data indicate subareas 1 and 3 as having high nickel contamination. The high nickel levels found during the 1982 survey in subareas 4 and 6 were not evident in 1985 data. Dredging Guidelines were exceeded at several locations (as per copper).

Manganese:

Manganese levels exceeding 1,000 mg/kg were found in subareas 3,4 and 6 (the Rouge and Ecorse Rivers and Monguagon Creek) in 1985, which was about the same as in 1982. High manganese in subarea 7 in 1982 was not reported in 1985, but 5,000 mg/kg manganese was reported in the Ecorse River in 1985 that was not noted in 1982. Dredging guidelines for manganese were exceeded along the Michigan shore. Manganese concentrations in Ontario sediments were not determined.

Iron:

Sediment concentrations of iron from the 1982 survey reached 180,000 mg/kg above Elizabeth Park (subarea 6). Iron levels along the Michigan shore were very high in 1982, with some stations in all subareas exceeding 25,000 mg/kg. The highest iron concentration found during the 1985 survey was 120,000 mg/kg from the Ecorse River. Dredging guidelines were exceeded along the Michigan shore. Iron concentrations were not determined for sediments along the Ontario shore.

Cobalt:

Cobalt was analyzed in 1982, 1985 and 1986. The 1986 cobalt concentrations were relatively uniform with a slight increase downstream. Highest levels (over 10 mg/kg) were found in subarea 6. The 1982 samples were also relatively uniform, although slightly higher than 1986 samples. The highest cobalt levels were found in the 1985 tributary samples in subarea 3 in the Detroit Dearborn Channel (17 mg/kg). No exceedences of dredging guidelines were noted.

Nutrients and Conventional Pollutants - Cyanide:

In 1982, cyanide levels exceeding 10 mg/kg were present in subareas 1,3 and 6. In 1985, high cyanide concentrations were present in subareas 1 and 3 (Conners Creek and Detroit Dearborn Channel). Lower levels were found in the Lower Rouge and Monguagon Creek, indicating that sources other than Monguagon Creek were responsible for high levels found in subarea 6 in

1986. Exceedence of dredging guidelines for cyanide occurred in Michigan and Ontario adjacent to Detroit, Windsor and Amherstburg and in the Trenton Channel.

Oil and Grease:

The highest oil and grease levels found during the 1986 survey were reported in subarea 6 with concentrations over 24,000 mg/kg. In 1985, oil and grease levels were highest in subareas 1 (44,800 mg/kg) and 3 (28,600 mg/kg), and generally decreased downstream from the Detroit River head to its mouth. In 1982, peak oil and grease levels exceeding 30,000 mg/kg were present in subareas 1, 2,3 and 6. Dredging guidelines for oil and grease were exceeded in many areas, primarily along the Michigan shoreline adjacent to and downstream of Detroit and in the Trenton Channel, as well as adjacent to the cities of Windsor and Amherstburg.

Total Phosphorus:

Most total phosphorus concentrations in sediments were lower than 5,000 mg/kg. Along the Michigan side, phosphorus levels up to 6,200 mg/kg in 1982 were found in subarea 6, whereas the highest level in 1985 (6,200 mg/kg) was found in the Detroit Dearborn Channel. Exceedences of phosphorus dredging guidelines were noted in the majority of samples analyzed in both Michigan and Ontario.

Ammonia:

The 1982 concentrations of ammonia exceeded 500 mg/kg in subareas 1,3,4, and 6 with highest levels (1,400 mg/kg) in the Rouge River. In 1985, ammonia levels were below 500 mg/kg in all subareas except subarea 1, where 900 mg/kg was found in Conners Creek. Dredging guidelines for ammonia were exceeded along the Michigan shore. Ammonia concentrations were not determined for sediments from the Ontario shore.

v) Sediment Bioassays

Certain Detroit River depositional zone sediments have demonstrated a range of toxicity to various forms of aquatic life, and some Detroit River sediments have been tentatively classified as hazardous waste. Figure IX-12 shows the status of macrobenthic communities along the Detroit River. Bacterial bioluminescence (Phosphobacterium phosphoreum) assays (Microtox^R) conducted on Detroit River sediment porewater provided dose-response relationships with degree of toxicity inferred by a decrease in light emission. Figure IX-13 indicates that localized western nearshore Trenton Channel stations caused a 50% reduction in bioluminescence with less than 100% porewater while other stations elicited lesser responses and 30 percent of the stations were nonresponsive (78).

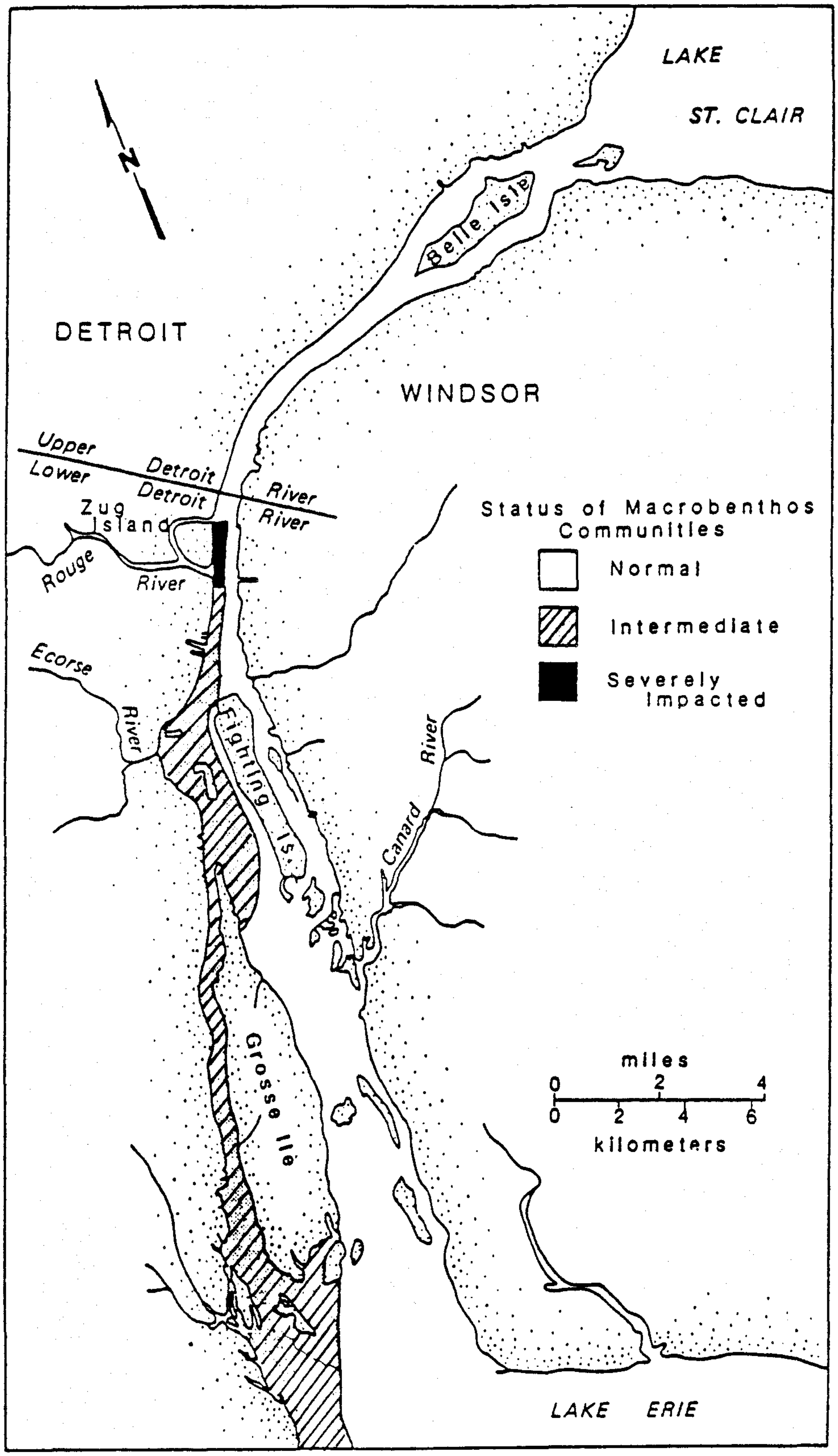

FIGURE IX-12. Macrobenthos distribution in the Detroit River.

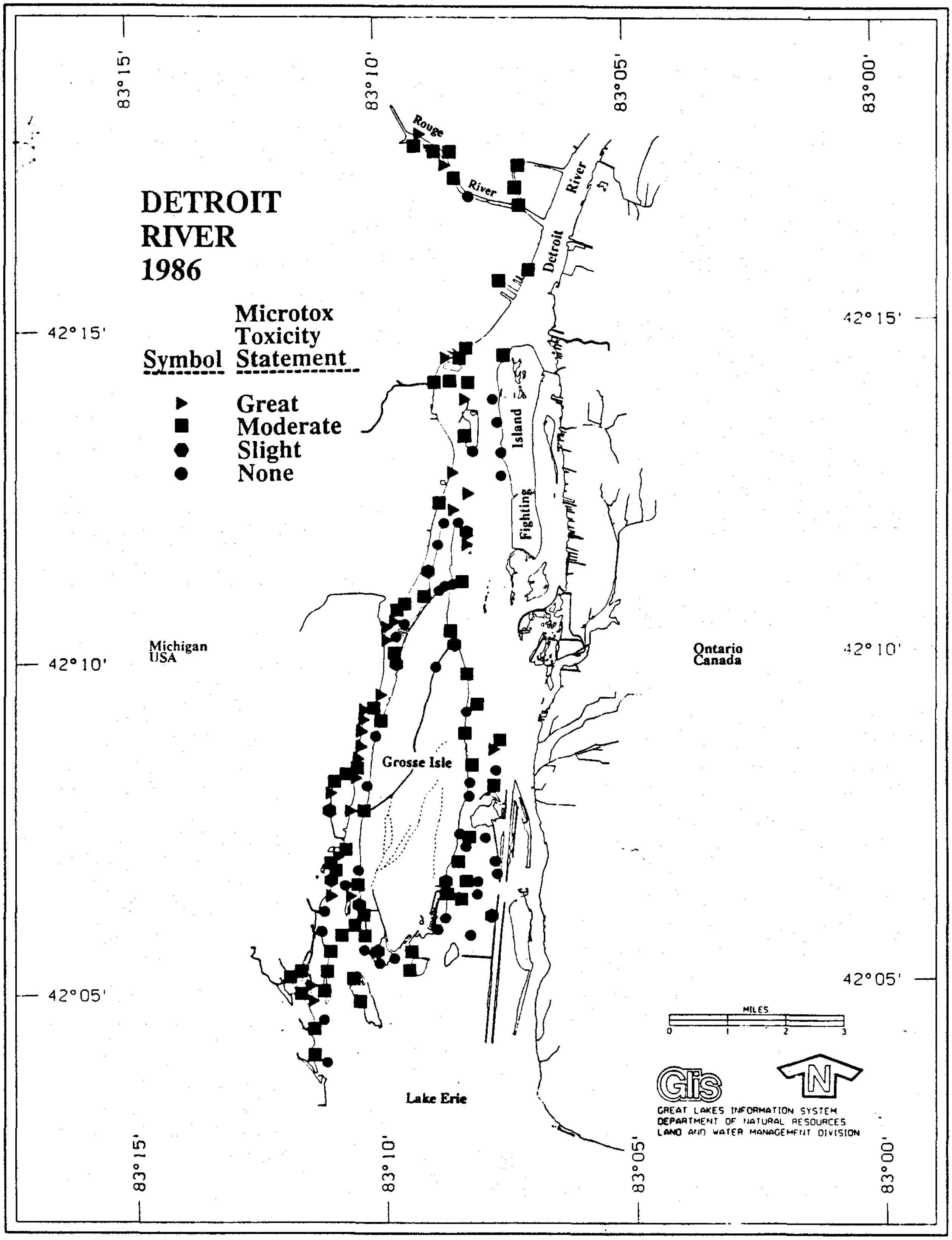

FIGURE IX-13. Detroit River sediments porewater Microtox toxicity.

Mutagenic potential of sediment extracts were measured by the bacterial Salmonella/microsome assay (Ames test). Some mutagenicity was noted at 28 of 30 Detroit River stations, with the most strongly mutagenic sediments from the Trenton Channel (Figure IX-14). Moderately mutagenic sediments were primarily concentrated in the lower river near Lake Erie (44).

Bacterial and phytoplankton bioassays were conducted on control sediments and water along the west end of Fighting Island and the southern end of Grosse Ile, measuring changes in the rate of food uptake in bacteria and phytoplankton photosynthesis. Bacterial uptake rates were suppressed by control and contaminated sediments when sediments exceeded 12 to 1,200 ppm of suspended solids. At 120 ppm suspended solids, control sediments inhibited uptake by 50% whereas contaminated Trenton Channel sediments inhibited uptake by 75%. The impact of sediments on phytoplankton was similar to bacteria, but less accentuated (36).

Daphnia pulicaria feeding was generally inhibited 50 to 75% by Detroit River elutriate with an approximately three fold decrease in ingestion rate at station 34, downstream of McLouth Steel near Trenton. Slight feeding suppression of the control at stations 83 (along the west shore of Fighting Island) and 53 (at the southern tip of Grosse Ile) were reported at high elutriate concentrations (36).

The acute toxicity of Detroit River sediment porewater to Daphnia magna was demonstrated in a study where ten of the thirty stations in the Trenton Channel caused 50% mortality in a 96-hour exposure to 50% or less concentration of porewater (78).

Ten day Chironomus tentans growth tests using whole sediments found the greatest growth inhibition (up to 95%) along the western near-shore Trenton Channel. Growth rates for these stations ranged from 0.02 to 0.08 mg/day, whereas reference stations and three other stations ranged from 0.48 to 0.53 mg/day (36).

Stylodrilus was used to determine avoidance response to Detroit River sediments. In control sediments, all worms burrowed and remained buried with no mortality. At other stations, 70% of the worms remained buried, but a slight increase in mortality rate was evident. At station 34, downstream of McLouth Steel near Trenton, only 10% remained buried, with a 53% mortality (36).

Chironomus tentans respiration, undulation, turning and crawling movements and rest responses to Detroit River sediments showed significant differences in escape, respiration and rest responses, relative to Lake Michigan control sediments. Escape time was higher and respiration and rest time were lower at these stations compared to the Lake Michigan sediments (36).

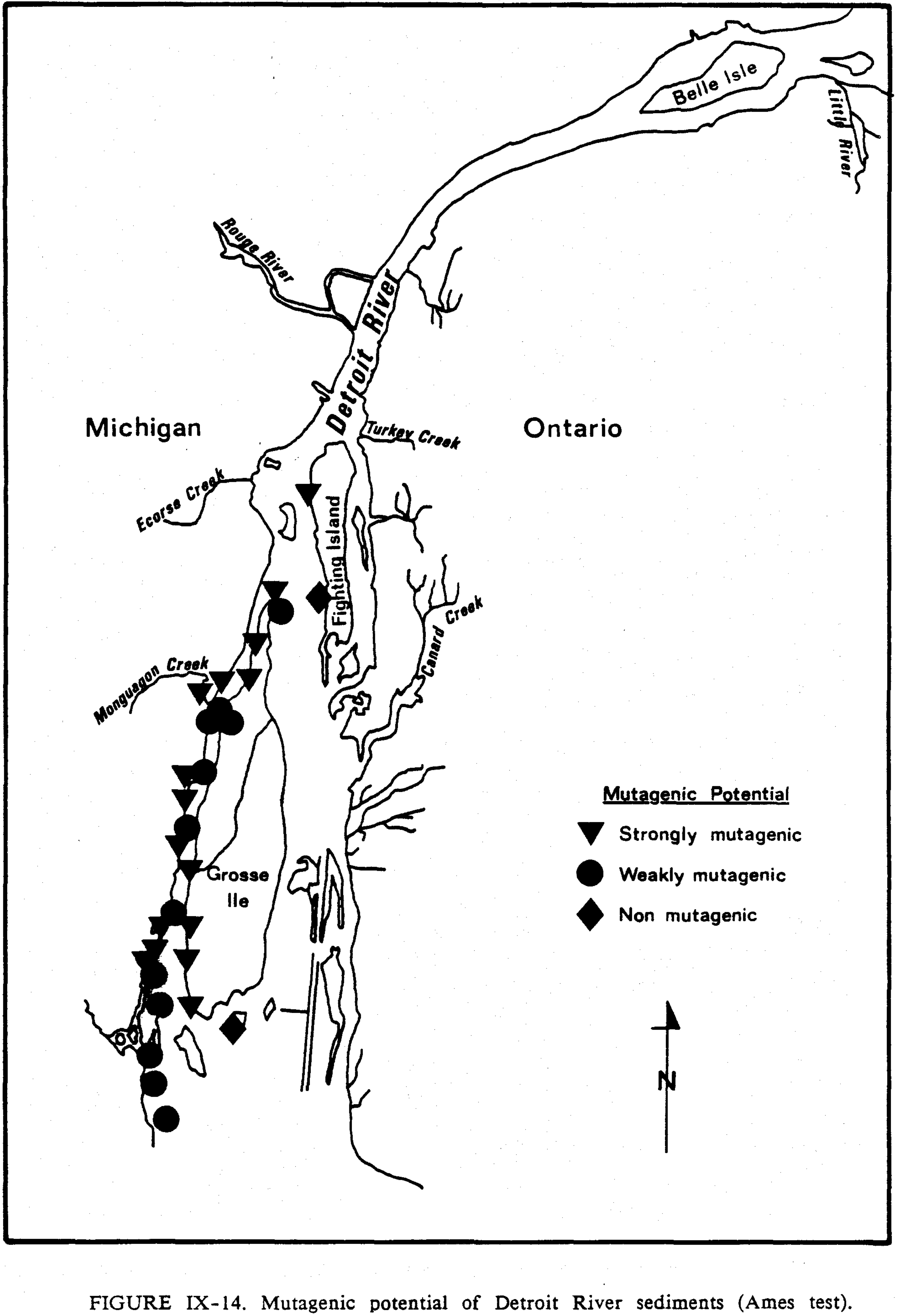

FIGURE IX-14. Mutagenic potential of Detroit River sediments (Ames test).

Feeding rates of larval channel catfish exposed to Detroit River contaminated and control sediments and sediment porewater indicate the greatest inhibition of feeding rates occurred from exposure to Trenton Channel sediments. There were no differences in feeding rates when porewater and water column assays were completed on Trenton Channel stations (36).

Late-eyed stage rainbow trout eggs were injected with serial dilutions of Detroit River sediment extracts; all sediment extracts increased embryo mortality two to three fold relative to the solvent carrier control. Incubated eggs and fry were monitored but increased mortality was not evident in the early sac fry stages. One year after injection, 3% of the survivors' livers exposed to Monguagon Creek sediment extract at 100 ug/egg had liver neoplasms (44).

Schloesser _et_ _al_. (40) demonstrated an inverse relationship between _Hexagenia_ abundance and visible oil in Detroit River sediments. Edsall _et_ _al_. (41) found _Hexagenia_ averaging 2,086 mg dry wt/m^3/year at three locations where sediment contaminants did not exceed dredging guidelines, but only 364 mg dry wt/m^3/year where as many as seven contaminants exceeded these guidelines. Both studies indicate that sediment contaminants had notable negative impacts on the benthic community.

In summary, sediments of the Detroit River were found to be severely impacted by a variety of compounds, including PCBs, HCB, PAHs, total phenols, total cyanide, oil and grease, total phosphorus, ammonia and metals (total mercury, total lead, total arsenic, total cadmium, total copper, total zinc, total chromium, total nickel, total manganese, total iron). In addition, some non-UGLCCS parameters were also found in sediments (pesticides, phthalate esters and volatile organic compounds). Several tributaries appear to be sources of many of these contaminants. Toxic effects of the sediments and sediment porewater on benthic biota were also noted by a variety of toxicity tests.

B. SPECIFIC CONCERNS

The specific chemicals which are impacting the Detroit River ecosystem, as determined in this study, and other concerns, are identified in this section. They are summarized in Table IX-3.

1. Conventional Pollutants

In the past, severe oxygen depletion in the Lake Erie hypolimnion was associated with excessive inputs of phosphorus, and corrective action was undertaken by most jurisdictions to reduce phosphorus loadings. Since the Detroit River is the major tributary to Lake Erie, all phosphorus loadings from the Detroit River are considered important. Concentrations of total phosphorus in the Detroit River have steadily decreased since the late 1960s and are presently below 20 ug/L. Tributary concentrations, however, still currently exceed ambient water quality guidelines.

Chloride concentrations in the Detroit River water were relatively constant, and not excessive; however, one industry which was found to be discharging high levels of chlorides (i.e., General Chemical) was not represented by the water quality survey. High chloride levels may encourage the growth of halophilic phytoplankton in the Great Lakes which could cause a shift in the phytoplankton community and upper trophic levels.

Fecal coliform bacteria are of concern because fecal coliform bacteria standards and criteria are routinely violated on both sides of the river. Beaches along both shores have been closed or not developed because of this continuing problem. Although not demonstrated in this study, ammonia is also problematic, since calculated levels of nonionized ammonia have periodically exceeded the chronic criteria for coldwater fisheries (0.02 mg/L) along the western Detroit River shoreline.

Phosphorus and ammonia concentrations in sediments exceeded dredging guidelines at a number of locations in the Detroit River and in some tributaries.

2. Organic Contaminants

Polychlorinated biphenyl (PCB) concentrations in the Detroit River were found at concentrations exceeding guideline levels. Although the levels are below acutely toxic concentrations, high persistence and bioaccumulative properties of PCBs may (and in fact has) resulted in bioaccumulation of PCBs in aquatic organisms. Similar findings are made for several organochlorine compounds, including hexachlorobenzene, dieldrin, heptachlor, heptachlor epoxide, chlordane and endosulfan. The effects of these contaminants may not be found in the Detroit River itself

TABLE IX-3

Specific concerns and use impairments in the Detroit River, 1988

Impairment or Concern	Causes of Impairment or Concern	Location where Impairment or Concern is Found	Probable Sources of Contaminants Causing Impairment or Concern
Consumption advisory for carp, rock bass, walleye and freshwater drum	Body burdens of PCB or mercury (Other organochlorine compounds and some pesticides may be present but have no criteria	Carp-whole river; other species-limited river sections for some larger sizes	Upstream of Detroit River Watershed; point and nonpoint sources; food chain
Changes in fish species composition and fish toxicity	Toxic concentrations of organic compounds, heavy metals and possibly ammonia in water and sediments	Primarily U.S. shoreline downstream of Rouge River, Detroit River Tributaries	Point and non-point sources; food chain; habitat changes
Tumors and deformities in fish	PNA's, PCB and other organochlorine contaminants, perhaps heavy metals	Primarily lower river and downstream of the Rouge River	Point and nonpoint sources; food chain
Elevated body burdens of organic contaminants in waterfowl and forage fish	PCB, HCB and other organochlorine compounds	Primarily lower Detroit River	Upstream Detroit River watershed; point and nonpoint souces; food chain
Elevated concentrations of organic contaminants in bird livers and eggs	PCB, HCB and other organochlorine compounds	U.S. Detroit River shoreline and Fighting Island	Point and nonpoint sources; food chain
Loss of fish and wildlife habitat	Bulkheading, filling, dredging navigation channels; organics and heavy metals; commercial and industrial development	Primarily along the U.S. Detroit River Shoreline and in navigation channels	Point and nonpoint sources: dredging/filling
Loss of aquatic animals	Contaminants? urbanization? habitat loss	All U.S. Shoreline and most of the Canadian shoreline	Point and nonpoint sources; urbanization? dredging/filling
Phytoplankton population changes	Chlorides and heavy metals	Chlorides-lower Detroit River especially Canadian shoreline Heavy metals-primarily U.S. shoreline and Trenton Channel	Industrial and municipal discharges
Zooplankton toxicity	Organic compounds and heavy metals	Where sediments are heavily contaminated, in Trenton Channel especially	Industrial and municipal discharges
Benthic macroinvertabrate community changes	Heavy metals and organic compound contamination in sediments and water, also nutrient enrichment and oil and grease	From Zug Island downstream along the U.S. shoreline, Trenton Channel and Windsor shoreline	Point and nonpoint sources
Aesthetic degradation-eutrophication	Nutrients, BOD5, oil and grease and organic and heavy metal contaminants	Near shore, U.S. Michigan side, downstream of CSO's and some Canadian and U.S. tributaries	Primarily municipal discharges and CSO's
Sediment contamination and potential loading to the water column	Organic and heavy metals and phenols	Primarily depositional zones near the U.S. shore, Trenton Channel, lower Detroit River and localized spots	Point and nonpoint sources; CSO's
Contaminated Groundwater loadings	Organics, heavy metals phenols, other?	At waste disposal sites	Primarily local industrial waste or spills
Loss of total body contact recreation	Fecal coliform bacteria	Tributaries and both shores of the entire length of the Detroit River into Lake Erie	CSO's, stormwater, municipal WWTP's and septic tank leachate reaching tributaries
Added cost of treatment to industry and agriculture	Excessive concentrations of contaminants from other dischargers leaves little assimilative capacity for other dischargers	Primarily along the U.S. shoreline downstream of the Rouge River	Industrial and municipal discharges
Potential contamination of public potable water supply	Primarily organic chemicals and spills of materials	At public drinking water supply intakes throughout the Detroit River	Upstream industrial discharges waste disposal sites, spills from ships, and WWTP bypasses and upsets

but in Lake Erie, particularly its Western Basin. Significant concentrations of polynuclear aromatic hydrocarbons (PAHs) enter the Detroit River at and near the Rouge River mouth. There is no water quality guideline for PAHs for aquatic life; however, many of these compounds are known or suspected animal or human carcinogens.

Fine-grained sediments in the river are excessively contaminated by a variety of organic contaminants. Several areas along the Michigan shore contain excessive PCB concentrations. Organochlorine contaminants other than PCBs are also found in most Detroit River and tributary sediments. DDT and its metabolites, dieldrin, methoxychlor, chlordane, trifluralin, hexachlorocyclohexane and hexachlorobenzene are present. Polynuclear aromatic hydrocarbons (PAHs) have been found at high concentrations in Detroit River sediments. Excessive phenols were present in sediments of the Trenton Channel. High concentrations of phthalates were present in many sediment samples from Detroit River tributaries, particularly Conners Creek and the Rouge River. Excessive concentrations of oil and grease are present in many Detroit River depositional zone sediments, and have degraded benthic macroinvertebrate communities (24).

Fish from several stations in the lower Detroit River had elevated levels of certain organic chemicals. PCB concentrations exceed consumption guideline levels in the edible portion of Detroit River carp. Consequently, the Michigan Department of Public Health has issued a consumption advisory for these fish. Several Detroit River fish species exceed the GLWQA objective of 0.1 mg/kg (wet weight) total PCBs in whole fish tissue. OMOE has also issued a fish consumption advisory for Detroit River carp because of elevated body burdens of PCBs.

Waterfowl contain elevated PCB levels and other persistent organic chemicals. There are no existing criteria for a consumption advisory to protect children and women of child-bearing age from the potential effects resulting from consumption of these birds. Herring gull eggs collected from Fighting Island in 1985 and 1986 contained high concentrations of PCBs and PAHs, and contained several other organochlorine pesticides.

Native and caged Detroit River clams showed increased levels of PCBs, PAHs and several organochlorine pesticides. Some PAHs found in Detroit River sediments are probable human carcinogens, and are thought to be responsible for some liver, lip and dermal tumors in fish.

3. Metals

Concentrations of metals measured in water during the study were generally all below the ambient water quality guideline, with the exception of mercury, which exceeded Michigan's Rule 57(2) allowable levels throughout the river. Generally, water in the Trenton Channel was of a poorer quality than other portions of the river. During the 1986 Detroit River System Balance Study, some localized areas exceeded water quality guidelines for iron (GLWQA specific objective) cadmium, lead and mercury (Michigan's Rule 57(2) allowable level). Water quality in the Little River, Rouge River, Turkey Creek, the Canard River and Ecorse River is impaired with respect to certain metals.

Heavy metal contamination of Detroit River sediments is found in most depositional areas, with concentrations of many metals exceeding guidelines. Lead, cadmium, copper and zinc levels are significantly elevated in the Rouge River and Turkey Creek and in Detroit River sediments downstream of their confluences. High levels of chromium and nickel are present in the Little River. Manganese and especially iron are strongly elevated in Trenton Channel sediments and other Michigan nearshore and sedimentary zones.

Overall, certain Detroit River sediments are severely degraded by heavy metals, especially in the Trenton Channel. This contamination may reduce or eliminate the viability of Detroit River and Lake Erie sediments as substrate for benthic organisms. Desorption of contaminants and re-solubilization through chemical and biological processes make an unknown portion of these chemicals available to higher aquatic organisms.

OMOE has issued a fish consumption advisory on several fish species because mercury concentrations exceed 0.5 mg/kg in the edible portion of the larger sizes of these fish. Native and caged Detroit River clams showed increased levels of several metals, particularly lead and cadmium.

4. Habitat Alterations

Eighty-five percent of the wetlands and littoral zones along the Michigan Detroit River shoreline have been eliminated by filling, dredging and bulkheading. Aquatic plants which live only in the littoral zone provide food, substrate, cover and nursery production for aquatic organisms, and drive the production and energy flow through the aquatic ecosystem. Loss of the littoral zone results in the loss of large segments of the upper trophic levels, including fish. Habitat loss was the major factor, along with pollution and overfishing, in the demise of the Detroit River commercial fishery around the turn of the century. Large areas of shallow water and marshes associated with tributaries are still found on the Ontario shore, below Fighting Island. Seventy percent of the remaining littoral zone is occupied by submerged plants, macrophytes and other wetland plants.

In the Detroit River, upstream of Zug Island, the benthic community is diverse and dominated by pollution intolerant organisms, except along the Windsor shoreline. Adjacent to Zug Island the community is severely impacted, and downstream, especially in the Trenton Channel, the benthos is dominated by pollution tolerant oligochaetes.

Overall, aquatic biota, especially benthos, show detrimental responses to contamination of Detroit River sediments with organic and inorganic substances, particularly in the lower river and in the Trenton Channel. Laboratory tests with sediments and sediment extracts indicate higher toxicity and increased mutagenicity on a variety of native species. Fish species diversity and fecundity may also be negatively affected in some areas.

C. SOURCES

This section discusses contaminant inputs from point and non-point sources in the Detroit River which were analyzed between 1984 and 1987.

1. Point Sources

Introduction, Qualifications and Criteria

During 1985, 1986 and 1987 the Michigan Department of Natural Resources (MDNR), OMOE, U.S.EPA and Environment Canada collectively monitored flow and effluent quality of major direct and indirect point source dischargers to the Detroit River (direct sources are those which discharge directly to the river and indirect sources discharge to the river via tributaries or drains). Nine municipal treatment plants and 20 industrial facilities were sampled over a 24 hour period (Michigan sources) or 3 to 6 days (Ontario Sources) during 1985 and 1986. Composite samples were analyzed for conventional pollutants, metals and trace organics, including the list of contaminants chosen for the UGLCC Study (Chapter I, Table I-1). Table IX-4 presents the industries surveyed and the parameters which are regulated in their effluent. Table IX-5 presents the municipal facilities and their regulated parameters. Figures IX-15 and 16 show the locations of these, and other, industrial and municipal facilities along the Detroit River.

Shortcomings limit the inferences that can be drawn from the survey, including the small data base, differences in survey timing, and differences in sampling and analytical methods. The U.S. surveys were performed in May, and July through September, 1986, while the Ontario data were collected between October and December, 1985. The U.S. composited four grab samples (1 every 6 hrs), while Ontario samples were collected by automatic composite samplers (1 portion every 15 min).

Differences in detection limits further hinder comparisons. The U.S. generally used lower detection limits than did Canada, allowing calculated loadings from Michigan facilities with no corresponding loadings from Ontario facilities for some parameters (e.g., OCS and HCB). Consequently, the percent of the total point source loadings to the Detroit River for some parameters (depending on corresponding flow volumes) may be skewed towards Michigan dischargers.

Flows

There were a total of 75 known point sources discharging 9,233 x 10^3 m^3/d) to the Detroit River basin in 1986. Three Detroit

TABLE IX-4

Surveyed U.S. and Canadian industrial facilities in the Detroit River area and regulated parameters [1,2].

U.S. FACILITIES	OPERATION	REGULATED PARAMETERS[3]
BASF Corporation	Chemical production	TSS, TOC, alkalinity*, ammonia-N*, temperature*, 1,2-dichloroethane*, 1,2-dichloropropane*, bis(2-chloroisopropyl)ether*
Chrysler Chemical-Trenton	Chemical compounding	TRC, pH, oil and grease, temperature*
Chrysler-Trenton Engine	Auto engine manufacture	BOD_5, TSS, total phosphorus, pH, oil and grease,total phenol
Detroit Coke Corp.	Coke production	pH, temperature, oil and grease*
Double Eagle Steel	Steel galvanization	TSS (noncompliant), oil and grease, total zinc (noncompliant), dissolved oxygen, total toxic organics, pH (noncompliant), temperature*. Entered into Consent decree in October 1986.
Ford-Wayne Assembly	Auto assembly plant	no NPDES permit
Great Lakes Steel (National Steel Corp) 80" Mill	Steel mfg & processing	TSS, oil and grease
Great Lakes Steel Ecorse Plant	Steel mfg and processing	TSS, total lead, total zinc, acrolein (22/365), oil and grease
Great Lakes Steel Zug Island Plant	Pig iron, coke and coke-by-products production	pH, oil and grease, ammonia-N, cyanide, total phenols, total lead, total zinc, TRC, TSS
McLouth Steel-Gibralter	Steel processing	TSS, oil and grease, total lead, total zinc, total iron*
McLouth Steel-Trenton	Steel & pig iron production	pH, TSS, oil and grease, temperature*, unionized ammonia*, free cyanide*, total phenol*
Monsanto Inorganic Chemical Corp	Food-grade specification products manufacture	TSS, phosphorus, arsenic, ammonia-N, temperature* alkalinity*, total cadmium*, hexavalent chromium*, amenable cyanide*, total lead*, total mercury*, total silver*
Pennwalt	Chemical production	TSS (16/365), BOD_5, total zinc, TRC, total phenols, chloride, ammonia-N, total copper, total lead, oil and grease, pH, COD, temperature*,
Rouge Steel	Steel and auto mfg	TSS, total lead, total zinc, oil and grease, ammonia-N, total and oxidizable cyanide, total phenol, TRC, temperature*

TABLE IX-4· (cont'd).

U.S. FACILITIES	OPERATION	REGULATED PARAMETERS[3]
St. Mary's Peerless Cement Company-Foreman Plant	Cement production	pH, temperature*
St. Mary's Peerless Cement Company-Brennan Plant	Clay slip production	pH, TSS, temperature*
Union Carbide-Linde Div.	Nitrogen & argon production	Phosphorus (3/12), TSS (3/12), TRC, oil and grease, temperature*
CANADIAN FACILITIES	**OPERATION**	**REGULATED PARAMETERS[4]**
Ford Motor Company	Auto parts manufacture	No regulated parameters (exceeded TSS and phenol objectives in 1985 and 1986).
General Chemical (Allied Chemical)	Chemical manufacture	TSS, chlorides, ammonia-N, fluorides
Wickes Manufacturing	Auto/truck bumper mfg	No regulated parameters (exceeded objectives for nickel [8/24] and TSS [23/24])

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* indicates that monitoring of the parameter is required; however, there is no concentration or loading limit.

[1] From the UGLCCS Point Source Workgroup Report (6).

[2] Exceedences of limitations during 1986 for Michigan facilities and 1985-1986 for Ontario facilities are denoted in parentheses. For example (16/365) indicated that parameter's daily limitation was exceeded 16 days of 365.

[3] Parameters listed comprise the total regulated by all NPDES permits for all outfalls. Not all outfalls at a facility are necessarily regulated for all parameters. The Point Source Workgroup Report should be consulted for a more thorough and comprehensive description of the facility's discharge requirements.

[4] All Ontario industrial facilities are encouraged to comply with the Ontario Industrial Effluent Objectives, which are described in Chapter III of this report.

TABLE IX-5

Surveyed U.S. and Canadian municipal facilities in the Detroit River area and regulated parameters [1,2].

U.S. FACILITIES	REGULATED PARAMETERS
City of Trenton WWTP	BOD$_5$ (5/12), TSS (5/12), pH, FC, DO (8/12), TRC, total phosphorus (5/12), ammonia-N, cadmium, silver, mercury, chloroform
Detroit WWTP	BOD$_5$, TSS, pH, FC, DO, total phosphorus, temperature
Grosse Ile Township WWTP	BOD$_5$, TSS (11/12 removal; 4/12 loading), pH, FC, DO, TRC, total phosphorus, ammonia-N
Walled Lake-Novi WWTP	BOD$_5$, TSS, pH, FC, DO, total phosphorus, ammonia-N (9/12), CBOD$_5$
Wayne County-Trenton WWTP	BOD$_5$, TSS (9/12), pH, FC (8/12), total phosphorus (6/12), oil and grease
Wayne County-Wyandotte WWTP	BOD$_5$, TSS (4/12), pH, FC (12/12), DO, TRC, total phosphorus, ammonia-N, phenol, oil and grease
CANADIAN FACILITIES	
Amherstburg WPCP	BOD$_5$ (removal in 1985), TSS (removal in 1985 and 1986), total phosphorus (18/24)
Little River WPCP	BOD$_5$, TSS, total phosphorus (4/24)
West Windsor WPCP	BOD$_5$, TSS, total phosphorus (2/24)

Abbreviations: BOD$_5$ = 5-day biological oxygen demand; TSS = total suspended solids; FC = fecal coliform bacteria; DO = dissolved oxygen; TRC = total residual chlorine; CBOD$_5$ = 5-day carbonaceous biological oxygen demand; COD = chemical oxygen demand.

[1] From the UGLCCS Point Source Workgroup Report (6).

[2] Exceedencs of limitations during 1986 for Michigan facilities and 1985-1986 for Ontario facilities are denoted in parentheses. For example, (2/24) indicated that a monthly limitation was exceeded 2 times in a 24 month period.

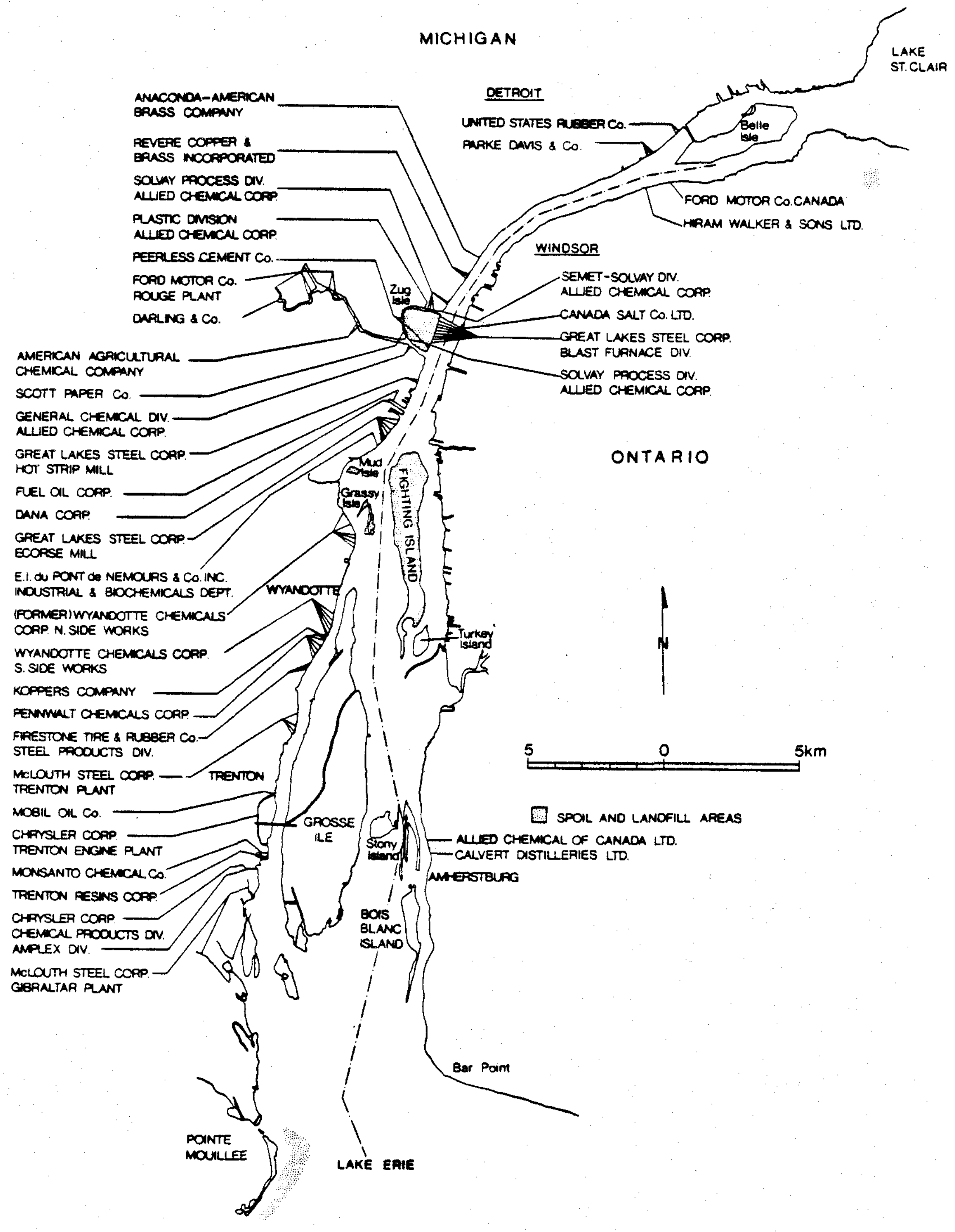

FIGURE IX-15. Industrial dischargers to the Detroit River.

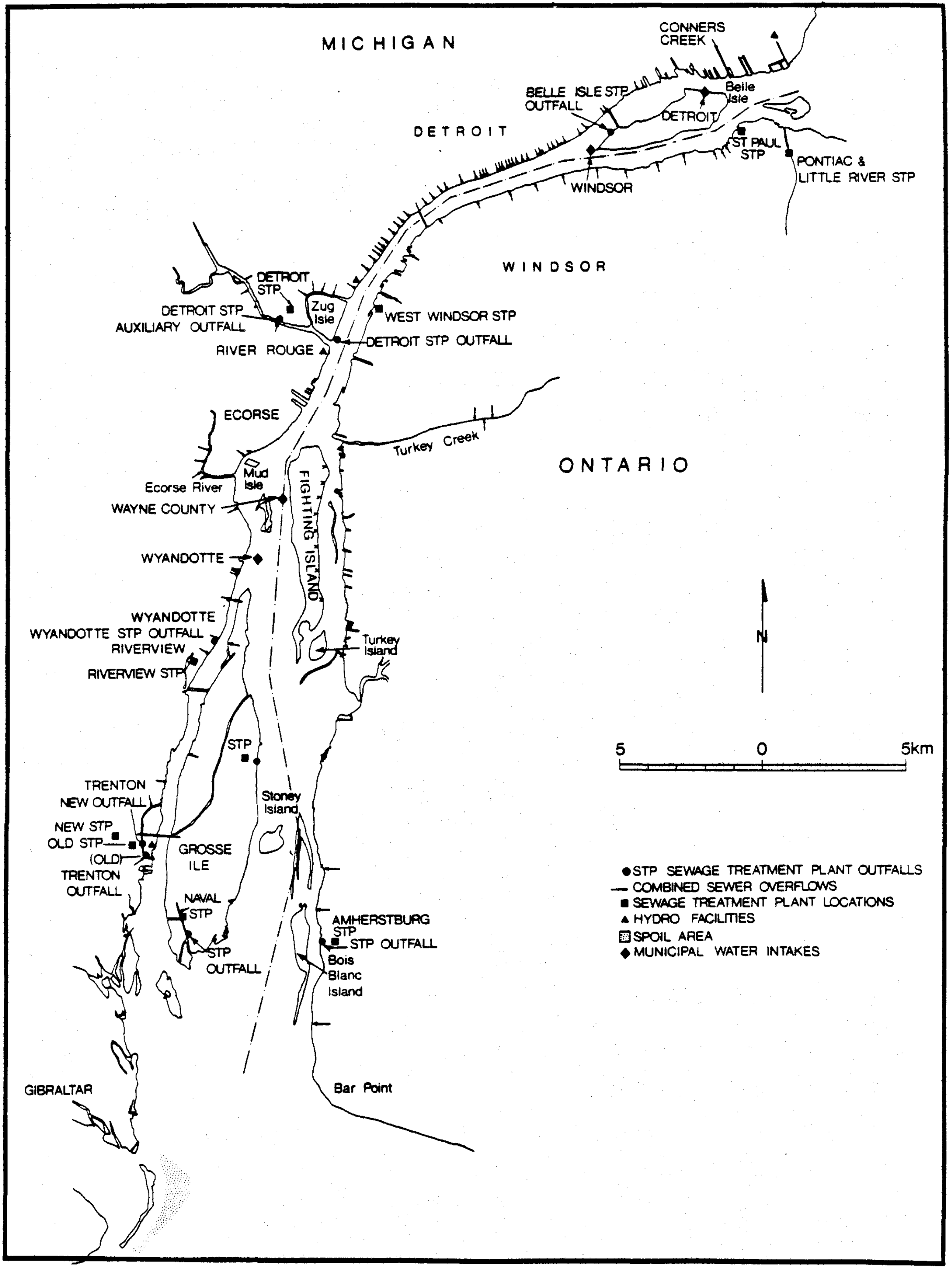

FIGURE IX-16. Municipal dischargers to the Detroit River.

TABLE IX-6. (cont'd 2).

PARAMETER	METHOD DETECTION LIMIT ug/L	FACILITY	FLOW $10^3 m^3/d$	AVERAGE CONC. ug/L	LOADING kg/d	% TOTAL POINT SOURCE CONTRIBUTION[2]
Cobalt	5.0	General Chemical	18.8	300	5.64	43.7
	0.001	Detroit WWTP	2160	1.20	2.59	20.1
	5.0	West Windsor WPCP	142	14.0	1.95	15.1
	0.001	GLS-Zug Island	99.8	19.0	1.9	14.7
	5.0	Little River WPCP	52.5	9.0	0.53	4.1
				Total:	12.61	97.7
Phenols	1.0	Ford Canada	71.3	658	48.2	35.7
	10.0	Detroit WWTP	2160(2695)	21.0(14)	45.4(39)	33.6
	10.0	Rouge Steel	1810	9.53	17.3	12.8
	10.0	Wayne Co-Wyandotte WWTP	268	36.0	9.7	7.2
	10.0	McLouth Steel-Trenton	227	24.0	5.4	4.0
	10.0	GLS-Zug Island	99.8	32.0	3.2	2.4
				Total:	129.2	95.7
Cadmium	0.2	Wayne Co-Wyandotte WWTP	268	22.8	6.1	67.0
	0.2	Detroit WWTP	2160(2695)	0.65(5)	1.4(13)	15.4
	5.0	Ford Canada	71.3	11.2	0.797	8.8
	0.2	Rouge Steel	1810	0.3	0.55	6.0
	0.2	McLouth Steel-Trenton	60	0.6	0.136	1.5
				Total:	8.983	98.7
Lead	5.0	Ford Canada	71.3	425	30.3	58.2
	1.0	Rouge Steel	1810	4.7	8.53	16.4
	1.0	Detroit WWTP	21602695	3.3(51)	7.13 (137)	13.7
	1.0	McLouth Steel-Trenton	227	16.6	3.77	7.2
				Total:	49.73	95.5
Zinc[4]	2.0	Detroit WWTP	2160(2695)	103(106)	223 (283)	34.8
	2.0	McLouth Steel-Trenton	227	603	137	21.4
	5.0	Ford Canada	71.3	1850	132	20.6
	2.0	Rouge Steel	1810	41.1	74.8	11.7
	2.0	Wayne Co-Wyandotte WWTP	268	120	32.3	5.0
				Total:	599.1	93.5

TABLE IX-6. (cont'd 3).

PARAMETER	METHOD DETECTION LIMIT ug/L	FACILITY	FLOW $10^3 m^3/d$	AVERAGE CONC. ug/L	LOADING kg/d	% TOTAL POINT SOURCE CONTRIBUTION[2]
Copper	5.0	General Chemical	174	99	17.2	31.4
	1.0	Rouge Steel	1810	8.3	15.1	27.6
	1.0	Detroit WWTP	2160(2695)	3.3(3.3)	7.13(92.0)	13.0
	1.0	Wayne Co-Wyandotte WWTP	268	18.4	4.95	9.0
	5.0	Ford Canada	71.3	48	3.44	6.2
	5.0	West Windsor WPCP	142	24	3.43	6.2
				Total:	51.25	93.4
Iron	14	Rouge Steel	1810	850	1550	43.4
	14	Detroit WWTP	2160(2695)	274(700)	592(1887)	16.6
	14	McLouth Steel-Trenton	227	2390	545	15.3
	14	Wayne Co-Wyandotte WWTP	268	887	239	6.7
	5.0	Ford Canada	71.3	470	222	6.2
	14	GLS-80" Mill	223	863	215	6.0
				Total:	3363	94.2
Chloride	500	General Chemical	18.9	5.6%	1,050,000	73.3
	1000	Detroit WWTP	2160	130,000	281,000	19.3
	1000	Rouge Steel	1810	20	36,400	2.5
				Total:	1,367,400	95.1
Ammonia-N	10	Detroit WWTP	2160(2695)	9100(2458)	19,700(6628)	79.0
	10	Wayne Co-Wyandotte WWTP	268	12,000	3230	13.0
				Total:	22,930	92.0
Phosphorus-P	10	Detroit WWTP	2160(2695)	430(750)	930(2023)	63.3
	10	Wayne Co-Wyandotte WWTP	268	910	245	16.7
	10	West Windsor WPCP	142	1060	150	10.2
				Total:	1325	90.2
Oil&Grease	2000	Detroit WWTP	2160(2695)	4200(5208)	9090(14,042)	25.7
	2000	Rouge Steel	1810	7080	8090	22.9
	2000	McLouth Steel-Trenton	227	31,100	7060	19.9
	2000	GLS-80" Mill	223	19,000	4260	12.0
	2000	GLS-Ecorse	29.1	125,000	3650	10.3
	100	West Windsor WPCP	142	7900	1130	3.2
	2000	Wayne Co-Wyandotte WWTP	268	2700	727	2.1

TABLE IX-6. (cont'd 4).

PARAMETER	METHOD DETECTION LIMIT ug/L	FACILITY	FLOW $10^3 m^3/d$	AVERAGE CONC. ug/L	LOADING kg/d	% TOTAL POINT SOURCE CONTRIBUTION[2]
Cyanide	5.0	Detroit WWTP	2160(2695)	49(22)	106 (59)	87.6
	5.0	Rouge Steel	1810	3.32	6.12	5.1
	5.0	Wayne Co-Wyandotte WWTP	268	21	5.6	4.6
	1.0	Ford Canada	71.3	20	2.28	1.9
				Total:	120.0	99.2
Total PAH	1-15	Rouge Steel	1810	2.0	5.15	85.0
	1-2	Ford Canada	71.3	6.0	0.44	7.0
	1-2	West Windsor WPCP	142	2.0	0.311	6.0
				Total:	5.90	98.0
Chromium	3.0	Detroit WWTP	2160(2695)	7.1(30)	15.3 (80.8)	29.8
	5.0	Wickes Manufacturing	2.6	3800-6700	13.8	26.8
				Total:	29.1	56.6

[1] From Table 3-4 of the Point Source Workgroup Report (6) (data collected in 1985-86).

[2] >95% of identified point source total unless multiple diffuse sources.

[3] Values in parentheses are based on the City of Detroit 1987 Annual Self-Monitoring Report; see text for more information.

[4] Does not include zinc loadings from Double Eagle Steel. If Double Eagle Steel average loading of 312 kg/day (from 4/86 to 2/87 self-monitoring data) is included, Double Eagle Steel becomes the major contributor at 33%, with Detroit WWTP's contribution falling to 23%. For the period July 1 to December 31, 1987, Double Eagle Steel discharged an average of 0.68 kg/d total zinc.

are placed in parentheses to set them apart from the point source survey data. In the text, these data are referred to as "SMR" data.

Parameters which were "of concern", (by virtue of media guidelines being exceeded or by impacts upon biota), and the point sources which provided inputs, are discussed below.

i) Conventional Pollutants

i) Total Phosphorus: The total loading for the UGLCCS survey was 1,470 kg/d, contributed primarily by the Detroit WWTP (930 kg/d; self monitoring report for 1987 (SMR) indicates loading of 2,023 kg/d), the Wayne County-Wyandotte WWTP (245 kg/d) and the West Windsor WWTP (150 kg/d). The Wayne County-Trenton WWTP (1.6 mg/L) and the City of Trenton WWTP (4.7 mg/L), discharged concentrations in excess of the GLWQA effluent objective of 1.0 mg/L. Both the Detroit and Wayne County-Wyandotte facilities are generally in compliance with their permitted concentrations for total phosphorus.

ii) Ammonia-nitrogen: The total loading was 25,000 kg/d, contributed primarily by the Detroit WWTP (19,700 kg/d; SMR=6,628 kg/d) and the Wayne County-Wyandotte WWTP (3,230 kg/d; 12 mg/L). General Chemical (14.3 mg/L) discharged ammonia in excess of the Ontario Industrial Discharge Objectives of 10 mg/L. The Wayne County-Trenton WWTP effluent concentration for ammonia-nitrogen was 15 mg/L.

iii) Chloride: The total point source loading was 1,440,000 kg/d, contributed primarily by General Chemical (1,050,000 kg/d). Concentrations in the General Chemical North Drain ranged from 5.5 to 6.6% (55-66 gm/L). No effluent guidelines exist for chlorides; but these concentrations do greatly exceed drinking water recommendations of 250 mg/L. The Detroit WWTP and Rouge Steel discharged 281,000 kg/d and 36,400 kg/d of chloride, respectively, to the Detroit River.

ii) Organic Pollutants

i) Polychlorinated Biphenyls (PCB): The total loading was 0.296 kg/d, contributed primarily by the Detroit WWTP (0.2 kg/d; SMR=0.256 kg/d) and by Ford Canada (0.039 kg/d). Elevated concentrations were found above the method detection limit (MDL, which was 0.0001 ug/L for Michigan and 0.1 ug/L for Ontario), at Ford Canada (0.55 ug/L) and the Wayne County-Wyandotte WWTP (0.088 ug/L).

ii) Hexachlorobenzene (HCB): The total loading was 0.0024 kg/d, contributed primarily by the Detroit WWTP (0.001 kg/d; SMR=0.011 kg/d). HCB was not detected at Ontario sources at their MDL of 0.02 ug/L. Pennwalt discharged the highest concentrations (0.012 ug/L).

iii) Octachlorostyrene (OCS): The loading from the seven Michigan sources surveyed was 0.000087 kg/d, and only detected at or near the MDL (0.000001 ug/L). Wayne County-Wyandotte had the highest concentration (0.21 ng/L) and loading (45 mg/d). OCS was not found in Ontario effluents (MDL 0.02 ug/L).

iv) Polynuclear Aromatic Hydrocarbons (PAHs): The total loading was 6.0 kg/d, contributed primarily by Rouge Steel (5.2 kg/day), at a concentration of 2 ug/L. Other point sources contributed PAHs at loadings over an order of magnitude less.

v) Total Phenols: The total loading was 135 kg/d, contributed primarily by Ford Canada (48.2 kg/d; 658 ug/L), the Detroit WWTP (45.4 kg/d; 21 ug/L) and Rouge Steel (17.3 kg/d). Concentrations for the Wayne County-Wyandotte WWTP, McLouth Steel-Trenton and Great Lakes Steel-Zug Island were 36 ug/L, 24 ug/L and 32 ug/L, respectively. The Ontario Industrial Discharge Objective is 20 ug/L.

vi) Oil and Grease: The total loading was 35,400 kg/d, contributed primarily by the Detroit WWTP (9,090 kg/d, 4.2 mg/L; SMR=14,041 kg/d, 5.2 mg/L), Rouge Steel (8,090 kg/d, 7 mg/L) and McLouth Steel-Trenton (7,060 kg/d, 31.1 mg/L). Great Lakes Steel-Ecorse (125 mg/L), Great Lakes Steel-80" Mill (19 mg/L), and Mclouth Steel-Trenton (31 mg/L) discharged elevated concentrations of oil and grease through their combined outfalls.

iii) Metals

i) Total Cadmium: The total loading was 9.1 kg/d, contributed primarily by the Wayne County-Wyandotte WWTP (6.1 kg/d, 23 ug/L) and the Detroit WWTP (1.4 kg/d, 0.65 ug/L; SMR=13 kg/d, 5 ug/L). Elevated concentrations were also discharged from Ford Canada (11.2 ug/L) and General Chemical (10-21 ug/L). The Ontario Industrial Effluent Objective for total cadmium is 1 ug/L.

ii) Total Copper: The total loading was 54.9 kg/d, contributed primarily by General Chemical (17.2 kg/d, 99 ug/L), Rouge Steel (15 kg/day, 8.3 ug/L) and the Detroit WWTP (7.1 kg/d, 3.3 ug/L; SMR=92 kg/d).

iii) Total Cyanide: The total loading was 121 kg/d, contributed primarily by the Detroit WWTP (106 kg/day; SMR=59 kg/d). This facility also discharged the highest concentration of cyanide in effluent (49 ug/L; SMR=22 ug/L). Other facilities contributed loadings over one order of magnitude less than the Detroit WWTP.

iv) Total Iron: The total loading was 3,570 kg/d, contributed primarily by Rouge Steel (1,550 kg/d, 850 ug/L), the Detroit WWTP (592 kg/d, 274 ug/L; SMR=1,887 kg/d) and McLouth Steel-Trenton (545 kg/d, 2,400 ug/L). Wayne County-Trenton WWTP discharged concentrations of 6,960 ug/L.

v) Total Lead: The total loading was 52.1 kg/d, contributed primarily by Ford Canada (30.3 kg/d, 425 ug/L), Rouge Steel (8.53 kg/d, 4.7 ug/L) and the Detroit WWTP (7.13 kg/d, 3.3 ug/L; SMR=137 kg/d).

vi) Total Mercury: The total loading was 0.115 kg/d, contributed primarily from the Detroit WWTP (0.064 kg/d, 0.029 ug/L; SMR=0.54 kg/d, 0.2 ug/L) and the Wayne County-Wyandotte WWTP (0.014 kg/d, 0.05 ug/L).

vii) Total Nickel: Total loading was 120 kg/d, contributed primarily by the Detroit WWTP (95.8 kg/d, 44.3 ug/L; SMR=197 kg/d). Concentrations at Wickes Manufacturing (average 3,500 ug/L) exceeded the Ontario Industrial Discharge Objective of 1,000 ug/L.

viii) Total Zinc: The total loading from all sources, except Double Eagle Steel, was 641 kg/d, contributed primarily by the Detroit WWTP (223 kg/d, 103 ug/L; SMR=283 kg/d), McLouth Steel-Trenton (137 kg/d, 603 ug/L) and Ford Canada (132 kg/d, 1,850 ug/L). Extremely high loadings of zinc were found at Double Eagle Steel during the survey and were rectified soon after discovery, so were not included in the total loading. Effluent concentrations at Ford Canada exceeded the Ontario Industrial Discharge Objective of 1,000 ug/L.

iv) Non-UGLCCS Parameters

i) Total Suspended Solids (TSS): The total loading was 65,300 kg/d, contributed primarily by the Detroit WWTP (21,610 kg/d, 10 mg/L; SMR=35,490 kg/d), Rouge Steel (7,160 kg/d, ND-17 mg/L) and General Chemical (North Drain; 6,930 kg/d, 7-353 mg/L). Wickes Manufacturing (48-89 mg/L) and Ford Canada (24-44 mg/L) discharged concentrations in excess of the Ontario Industrial Discharge Objective of 15 mg/L. The Wayne County-Trenton WWTP (53 mg/L) and the City of Trenton WWTP (240 mg/L) discharged similarly elevated concentrations.

ii) Total Chromium: The total loading was 51.4 kg/d, contributed primarily by the Detroit WWTP (15 kg/d, 7 ug/L; SMR=70 kg/d) and Wickes Manufacturing (13.8 kg/d, 3,800-6,700 ug/L). Wickes Manufacturing discharged concentrations of chromium exceeding the Ontario Industrial Discharge Objective of 1,000 ug/L.

iii) Total Volatiles: The total loading was 220 kg/d, contributed primarily by the Wayne County-Wyandotte WWTP (94 kg/d, 348 ug/L), the Detroit WWTP (85.4 kg/d, 39.5 ug/L) and the West Windsor WWTP (37.6 kg/d, ND-298 ug/L).

Major Loading Contributors

Summarized below are eleven point source facilities which were found to be major contributors of chemicals of concern in the Detroit River, contributing 10% or more of the total identified point source load. Primary contributors indicate the parameters for which the identified facility is the largest single source, based on the UGLCCS point source data.

i) Michigan Facilities

Detroit WWTP
Primary contributor: Total PCBs, HCB, total mercury, total nickel, total chromium, total zinc, ammonia-nitrogen, total phosphorus, oil and grease, total cyanide, suspended solids

Additional: OCS, total cobalt, total phenols, total cadmium, total lead, total copper, total iron, chlorides, total volatiles

Wayne County-Wyandotte WWTP
Primary contributor: OCS, total cadmium, total volatiles

Additional: HCB, total mercury, ammonia-N, total phosphorus

McLouth Steel-Trenton
Primary contributor: None

Additional: HCB, total zinc, total iron, oil and grease

Rouge Steel
Primary contributor: Total iron, PAHs

Additional: Total phenols, total lead, total zinc, total copper, oil and grease, suspended solids

Great Lakes Steel-Ecorse
Primary contributor: None

Additional: OCS, oil and grease

Great Lakes Steel 80" Mill
Primary contributor: None

Additional: Oil and grease

Monsanto
Primary contributor: None

Additional: HCB

ii) Ontario Facilities

Ford Canada
Primary contributor: Total phenols, total lead

Additional: PCBs, total zinc

General Chemical
Primary contributor: Total copper, chlorides

Additional: Suspended solids

Wickes Manufacturing
Primary contributor: None

Additional: Total chromium

West Windsor WWTP
Primary contributor: None

Additional: Total phosphorus, total volatiles

Loading estimates are based on limited sampling, and contain some inherent uncertainty. Comparisons based on these estimates contain that uncertainty, as well.

A summary of parameters considered in the National Pollution Discharge Elimination System (NPDES) permit effluent limits for major Michigan Detroit River dischargers were presented in Tables IX-4 and 5. For a more in-depth description of the permit limitations for each facility, the Point Source Workgroup Report (6) should be consulted. Also shown are the effluent requirements for Ontario facilities. Ontario industrial facilities are also encouraged to comply with the Ontario Industrial Effluent Objectives, discussed in Chapter III. Most facilities have only a few constituents which they are required to measure. Most constituents monitored are conventional pollutants, although some monitor regularly for metals. Only a few have monitoring requirements for organic contaminants.

An effort was made to determine if the facilities surveyed were in compliance with the appropriate effluent requirements, by comparing the effluent with such requirements. Occurrences of effluent limitation exceedences are noted for the appropriate parameters in Tables IX-4 and 5.

2. Urban Nonpoint Sources

United States Storm and Combined Sewer Overflows

Stormwater reaches the Detroit River directly through storm sewers and CSOs or through tributaries receiving storm and CSO discharges. Contaminant loading from stormwater and CSOs discharging directly to the Detroit River were measured or estimated. Contaminant loadings from storm water and CSOs to tributaries are reflected by the contaminant loading of the tributaries themselves.

There are 243 CSOs discharging to the Detroit River from Michigan and Ontario. Seventy-six discharge directly to the river and 167 discharge indirectly via tributaries. There are 45 directly discharging CSOs along the Michigan shoreline and 28 discharging to the Rouge River (Figure IX-17), and a few others discharging to small creeks, such as Conners and Fox creeks. The mean concentration and loading of selected chemical constituents from the discharge of 42 City of Detroit CSOs to the Detroit River and three City of Detroit CSOs to the Rouge River (downstream of the tributary monitoring location) are shown in Tables IX-7 and 8, respectively. Major loadings are from the Lieb (4,957 million gal/yr) and Conners Creek/ Freud/Fairview (2,766 million gal/yr) overflows located near Belle Isle along the western shore, and the First Hamilton/ Bates/Woodward (386 million gal/yr) and Summit CSOs located approximately 1 km up and downstream, respectively, of the Ambassador Bridge (79).

As an illustration, (79), in the late 1970s Detroit CSOs accounted for 13% of the total phosphorus, 15% of the suspended solids, 21% of the oil and grease, 25% of the cadmium, 29% of the chromium, 20% of the copper, 32% of the lead, 96% of the mercury and 34% of the total PCB loading to the Detroit River. Subsequent more restrictive controls as well as industrialization changes are believed to have reduced these contributions, however, this has not been documented.

There are no documented direct stormwater discharges to the Detroit River from the municipalities of Detroit, River Rouge,

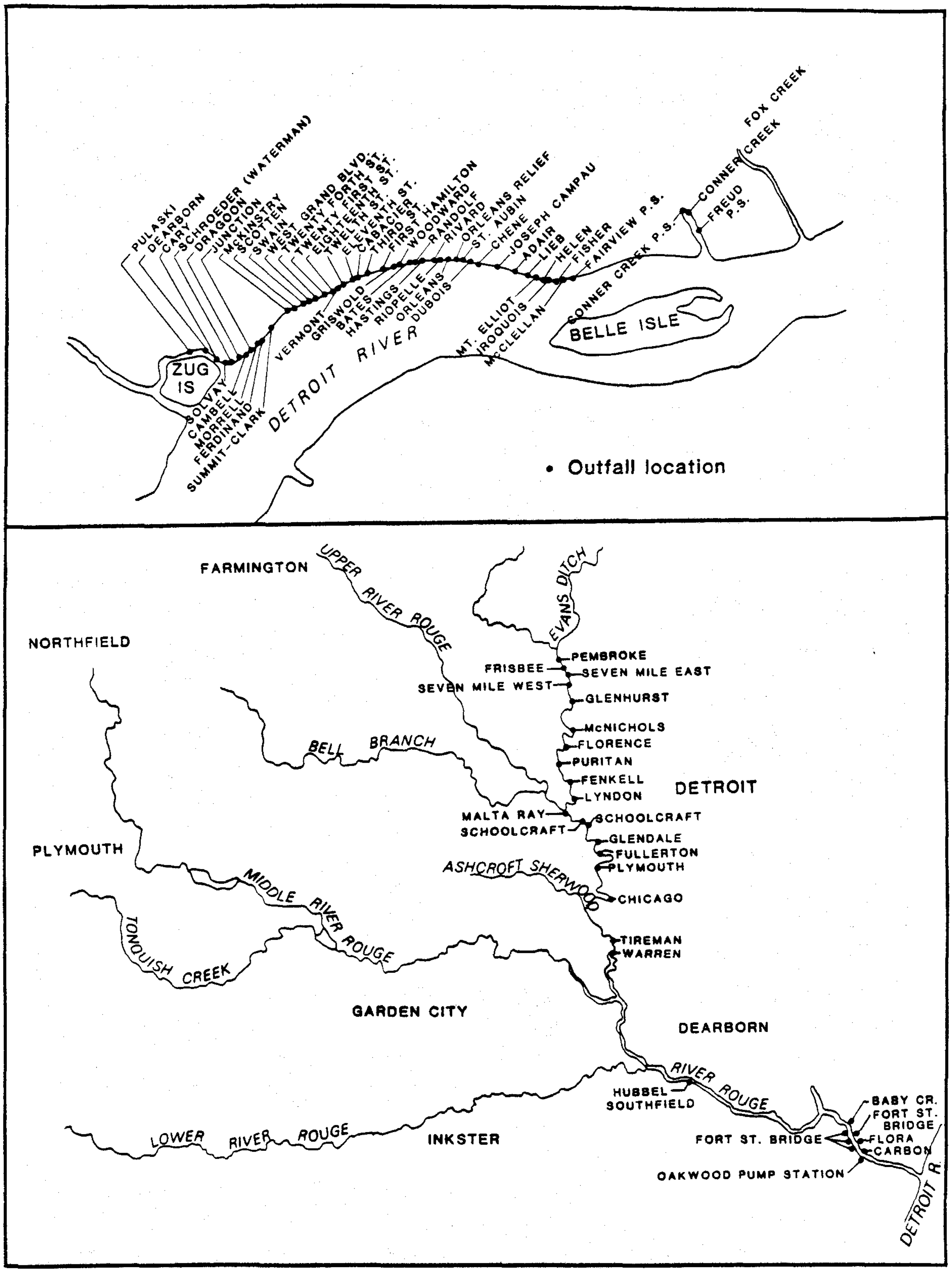

FIGURE IX-17. U.S. Combined sewer overflows discharging to the Detroit and Rouge Rivers.

TABLE IX-7

Mean contaminant concentrations measured in stormwater and combined sewer overflows in Windsor (1985-1986) and Detroit (1979).

		WINDSOR[1]				DETROIT[2]
		Storm Water				
Parameters	Units	Residential	Commercial	Industrial	Combined Sewer Overflows	Combined Sewer Overflows
Ammonia	mg/L	0.28	0.30	0.43	2.5	-
Total Phosphorus	mg/L	0.24	0.17	0.31	0.54	3.9
Chloride	mg/L	-	120[3] 240[3]	-	26.0	44.0
Susp. Solids	mg/L	-	-	-	-	205
Arsenic	mg/L	-	-	-	-	0.069
Cadmium	mg/L	0.00 0.01	0.001 0.009 0.006[4]	0.0006 0.0086	0.001 0.0072 0.008[4]	0.041
Chromium	mg/L	-	-	-	-	0.129
Cobalt	mg/L	0.00 0.02	0.0014 0.017 0.0035[4]	0.0004 0.017	0.0006 0.017 0.003[4]	-
Copper	mg/L	0.018	0.03	0.048	0.10	0.218
Iron	mg/L	5.8	3.0	6.9	1.2	2.27
Lead	mg/L	0.13	0.184	0.21	0.05	0.447
Mercury	ug/L	0.018 0.06	0.03	0.043 0.05	0.043	45.0
Nickel	mg/L	0.008 0.021	0.026	0.017 0.028	0.010 0.044	0.139
Silver	mg/L	-	-	-	-	0.038
Zinc	mg/L	0.16 0.25	0.23	0.30	0.34 0.50	0.555
Oil/Grease	mg/L	1.4	2.3	1.7 5.8	12.3	94.0
Phenols	mg/L	0.0025	0.004	0.005	0.008	0.017
Cyanide	mg/L	0.003	0.003	0.003	0.003	-
HCB	ng/L	1.4	0.0 0.4	0.2 0.92	1.09	-
OCS	ng/L	-	-	-	-	-
Total PCBs	ng/L	31.6	25.8	109.0	100.0	2.4
PAHs (17)	ug/L	1.1 1.6	2.1 2.6	4.6 5.7	4.0 4.4	-

[1] From Marsalek and Ng (80).
[2] From Giffles et al. (79).
[3] Equivalent mean concentration.
[4] Mean of concentrations detected in all three subareas.

TABLE IX-8

Contaminant loadings to the Detroit River from stormwater and combined sewer overflow from the cities of Detroit and Windsor (kg/yr).

Parameter	WINDSOR[1] Stormwater	WINDSOR[1] Combined Sewer Overflows	WINDSOR[1] Total	DETROIT[2] Combined Sewer Overflows
Ammonia (as N)	7,200	13,000	20,200	-
Total Phosphorus	5,600	2,800	8,400	116,514
Chloride	2,550,000	135,000	2,685,000	1,545,713
Cadmium	6.5	5.2	11.7	1,440
	133.8[3]	41.6[3]	175.4[3]	
Cobalt	6	3	9	-
	420(78)[3]	88(16)[3]	508(94)[3]	
Chromium	-	-	-	4,532
Copper	613	520	1,133	7,658
Iron	127,600	6,200	133,800	79,745
Lead	3,539	260	3,790	15,703
		830	4,360	
Mercury	0.6	0.2	0.8	1,581
	1.1		1.3	
Nickel	285	52	337	4,883
	524	229	753	
Zinc	4,600	1,770	6,370	19,497
		2,600	7,200	
Oil and Grease	35,700	64,000	99,700	3,302,206
	59,700		123,700	
Total Phenols	75	42	117	597
Cyanide	67	16	83	-
HCB	0.021	0.006	0.027	-
	0.026		0.032	
OCS[4]	0.045	0.010	0.055	-
Total PCBs	0.5	0.5	1.0	84.31
	1.1		1.6	
PAHs (17)	49	21	70	-
	63	23	86	
Susp. Solids	-	-	-	7,201,609

[1] From Marsalek and Ng (80).
[2] From Giffles et al. (79).
[3] Calculated from data above detection limit.
[4] Based on Sarnia data (St. Clair River area).

Ecorse, Lincoln Park, Grosse Ile or Gibraltar. Stormwater from these cities enters the combined sewer system and is treated at the Detroit WWTP, or is discharged directly through CSO outfalls to the Detroit River. The municipalities of Wyandotte and Trenton have 13 and 18 direct stormwater discharges to the Detroit River, respectively. Riverview has 17 and Trenton has 19 stormwater discharges through Monguagon Creek and Frank and Poet Drains. The contaminant loadings from these outfalls are unknown.

Ontario Storm and Combined Sewer Overflows

Mean concentration and loadings of selected chemical constituents discharged in stormwater and CSOs in Windsor are shown in Tables IX-7 and 8 (80). Windsor has 28 CSOs which discharge directly to the Detroit River, these are shown in Figure IX-18. Industrial runoff and CSOs contained higher concentrations of most constituents than commercial and residential land use areas. Some constituents (ammonia and lead) were an order of magnitude lower in residential than in other areas. Approximately 72 to 94% of the Windsor loads occurred during storm events (about twice a month and 20 to 42 hours per event). Sixty-five percent of the load occurred in February, March and April with the greatest loads during March. Mixed stormwater/sanitary waste water discharges to the river whenever flow in the combined sewers exceeded 2.5 times the dry weather flow, otherwise the mixed waste water discharges to one of the two Windsor WWTPs. Based on these data, Windsor CSOs contribute from less than 1 to 9% of the conventional, metal, and organic contaminant loading to the Detroit River.

3. Groundwater Contamination/Waste Sites

Groundwater movement was investigated in an area extending 19 km (12 mi) along the Detroit River, which is about 50 km (31 mi) long. Factors which control and influence groundwater movement, such as geological formations, were investigated for this study (53,70,71,81,82,83).

In Michigan, general groundwater flow is east towards the Detroit River. Locally, the direction of groundwater flow is influenced by surface water drainage, dewatering projects (such as in the Sibley Quarry in Wayne County) and glacial landforms. Groundwater discharges to the Detroit River from two hydrogeologic units: a shallow glacial unit and a bedrock unit. The shallow glacial unit consists of mostly silty-clay till and glaciolacustrine deposits with discontinuous stringers of sand and gravel. In the upper river (down to about Fighting Island), the bedrock unit is comprised of carbonate rocks of the Traverse and Dundee formations, overlain by at least 15 m of glacial deposits.

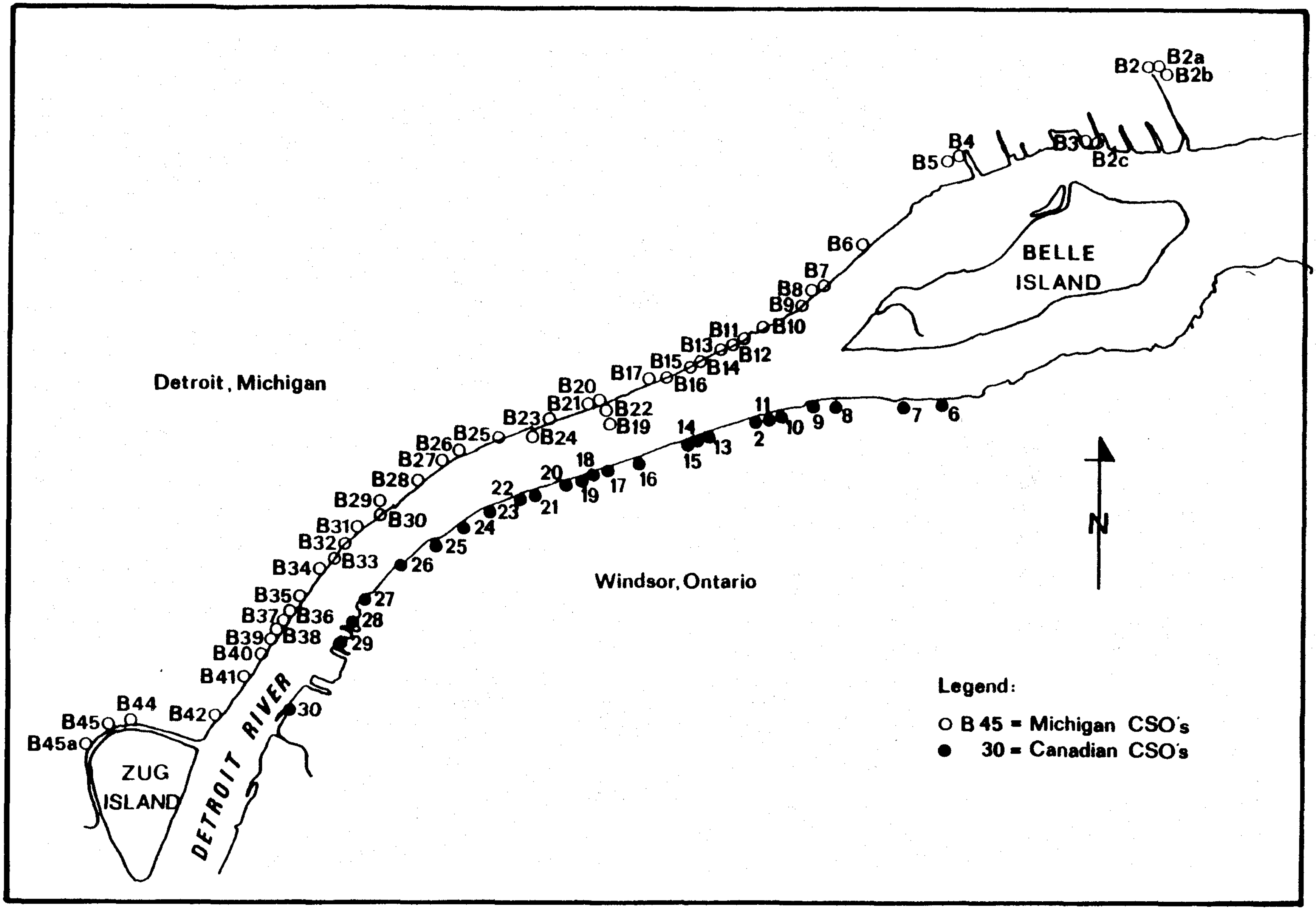

FIGURE IX-18. Detroit and Windsor combined sewer overflows to the upper Detroit River.

South of Fighting Island, the bedrock is comprised of limestone, dolomite and sandstone of the Detroit River Group, overlain by about 8 m of fine-grained glacial deposits. Near the mouth of the river, the Detroit River Group forms the river channel.

In Ontario, the groundwater flow is generally west towards the Detroit River. Three levels of groundwater discharge exist: local, intermediate and regional (or bedrock). The local unit is contained in surficial sands and gravels, and the weathered and fractured zone of lake clay and clay tills. Similar to the Michigan surficial unit, flow in this system is influenced strongly by local surface events and conditions. The intermediate unit is comprised of intact lacustrine clay and clay till, ranging from less than 3 meters to 40 meters in thickness. It is believed most of the groundwater flow from this unit is downward towards the bedrock unit. The bedrock unit is comprised primarily of carbonate rocks of the Hamilton and Dundee Formations and the Detroit River Group. Flow in this unit is towards the Detroit River and Lake Erie.

The estimated total discharge of groundwater from the Michigan side of the Detroit River study area (from Belle Isle to Point Mouillee) is between 1.5 m^3/sec (54 ft^3/sec) and 3 m^3/sec (107 ft^3/sec)(82,83). Rates of groundwater seepage are highest in the northern portion of the Detroit River, in the vicinity of Belle Isle, and generally decrease downstream, increasing again below the Ecorse River mouth. Groundwater and surface water systems are highly interconnected in the Trenton Channel and the lower Detroit River, due to thin or absent sediments overlying bedrock. Estimates of groundwater seepage to the Detroit River from Ontario were not made. In relation to the flow of the Detroit River, the groundwater discharge to the river is approximately 0.05%; therefore, quantitatively, contributing a very small amount to the total river flow.

Waste Disposal Sites

An inventory of active and inactive waste sites within 19 km of the Detroit River was conducted as part of this investigation. Ninety four sites of known and potential groundwater contamination have been found in Monroe and Wayne counties as of January 1987. The majority of sites are solid waste landfills, hazardous waste disposal sites, regulated storage sites and spills. Twenty three sites along the Ontario side of the Detroit River were also identified (84,85). Locations of selected Michigan waste sites and monitoring wells are shown in Figure IX-19.

Sites which are located in groundwater discharge areas directly discharging to the Detroit River were ranked and prioritized for potential impacts upon the Detroit River. Ranking of sites was based on their potential for contributing contaminants to the

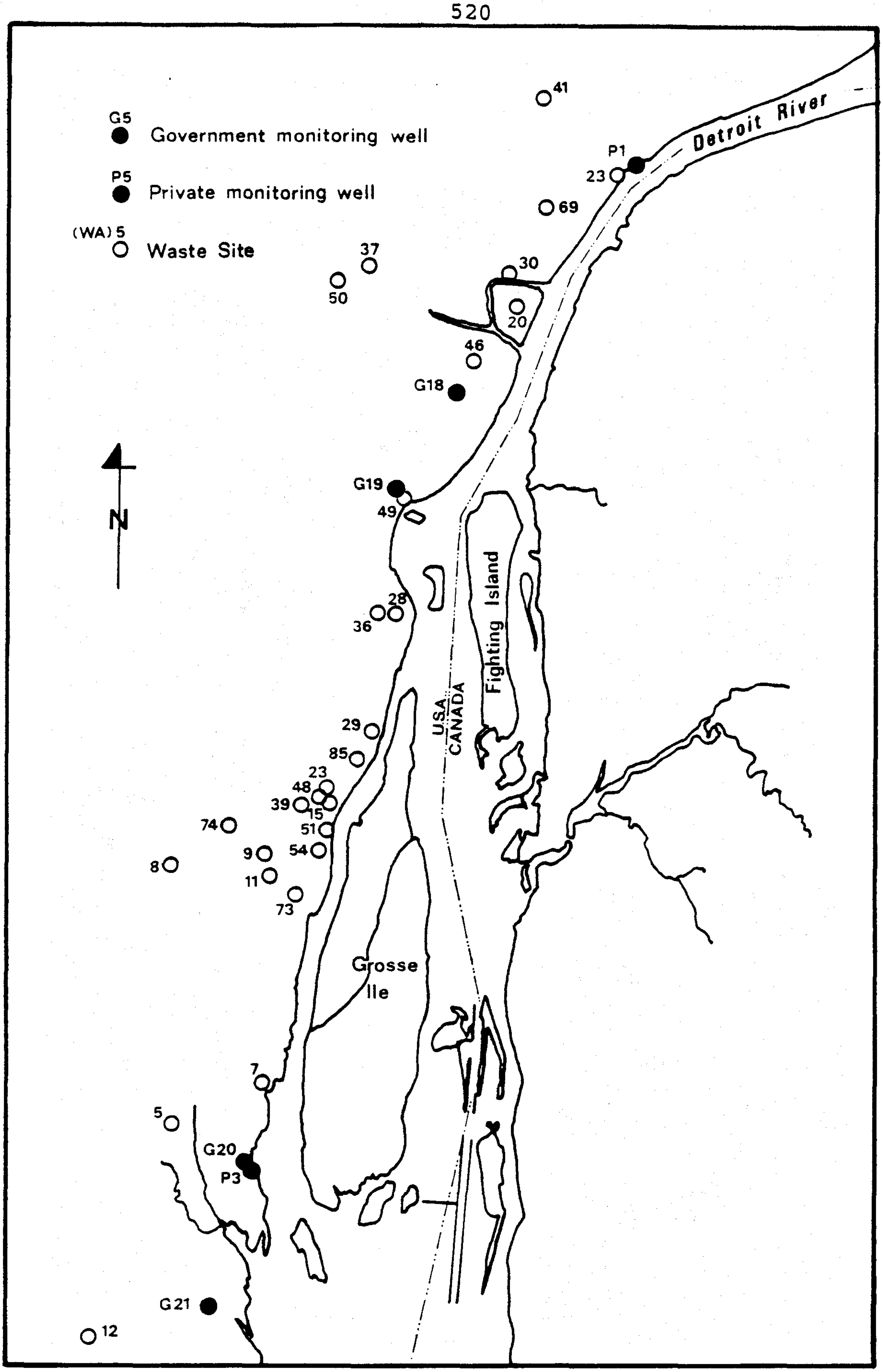

FIGURE IX-19. Sites of known or suspected groundwater contamination and private wells located near the Detroit River.

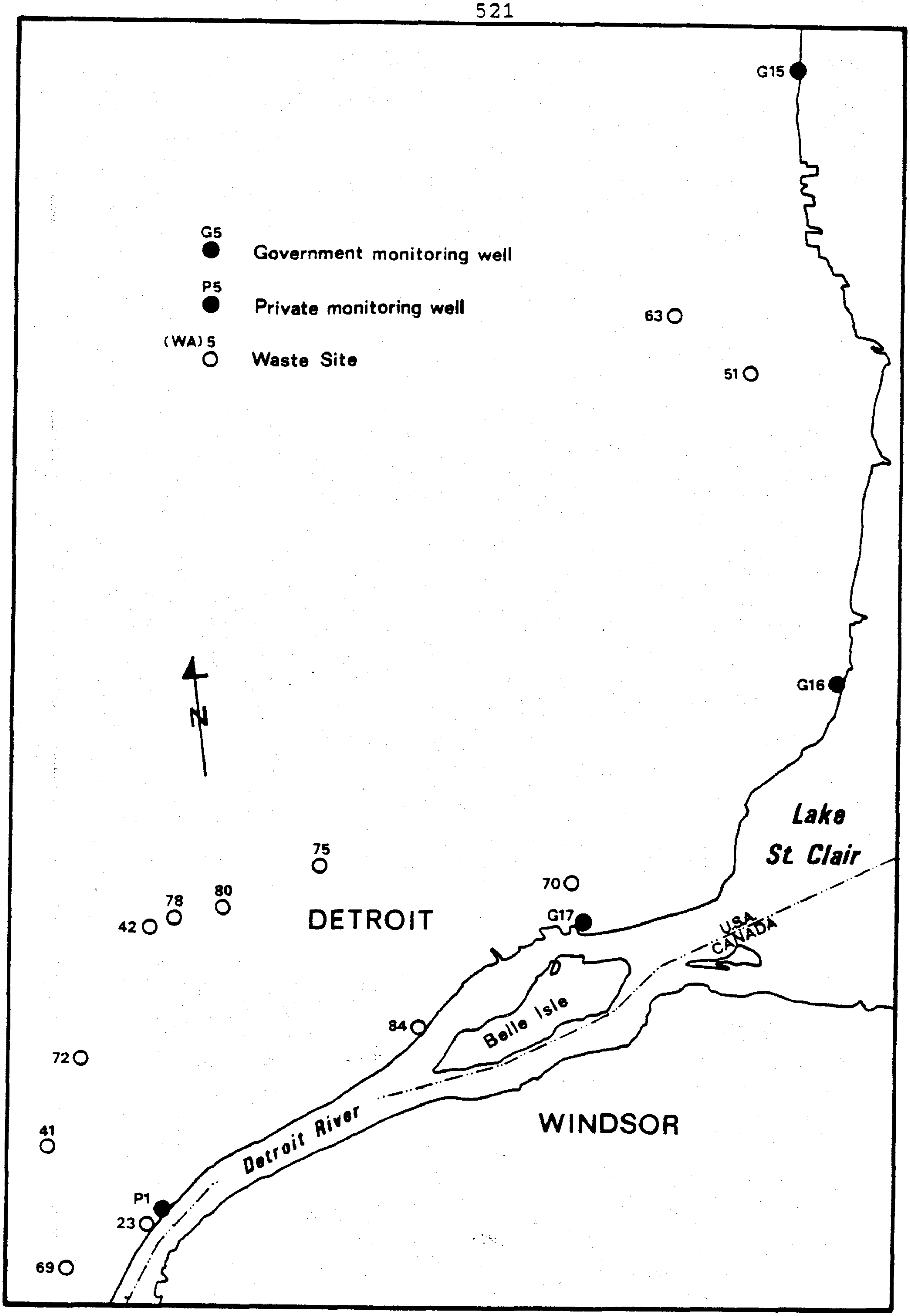

FIGURE IX-19. (Cont'd.) Sites of known or suspected groundwater contamination and private well located near the Detroit River.

Detroit River via groundwater. Sites were ranked by the United States Geological Survey (USGS) using the U.S.EPA'S DRASTIC system, with additions and minor modifications. The USGS ranking system assesses the potential impact of a site by evaluating the hydrogeology, nature of the waste material and the distance to the Detroit River. Table IX-9 lists the 16 highest ranked sites of the 94 sites considered in the Detroit River area. In general, these sites are in areas of sandy, unconsolidated surficial materials, and are located adjacent to, or near, the Detroit River. The water table at the highest ranked sites is generally less than 4.5 m below land surface.

i) Michigan Waste Sites

Analysis of groundwater quality from eight wells (5 observation and 3 private) within the Michigan Detroit River discharge area was obtained. Of these eight wells, three were located downgradient of 3 of the 15 top ranked waste sites: Michigan Consolidated-Riverside Park (P1 on Figure IX-19), Pennwalt Corporation (P2) and Petro-Chem Processing (G17). Unfiltered groundwater samples from these wells were found to contain concentrations of organic and inorganic constituents suggesting groundwater contamination, as shown below:

P1: Total volatiles 1,440 ug/L; total PAHs 287 ug/L; dissolved barium 2,000 ug/L; total cadmium 40 ug/L; total arsenic 58 ug/L; total chromium 120 ug/L; total cobalt 160 ug/L; total copper 660 ug/L; total lead 2,500 ug/L; total mercury 55 ug/L.

P2: Total volatiles 5.9 ug/L; total PAHs 269 ug/L; total phthalates 150 ug/L; total phenolics 95 ug/L; total copper 530 ug/L; total lead 800 ug/L; total nickel 1,500 ug/L.

G17: Total PAHs 58 ug/L; total phthalates: 364 ug/L; total copper 2,500 ug/L; total lead 4,700 ug/L; dissolved barium 2,400 ug/L; dissolved beryllium 13 ug/L; total cobalt 50 ug/L; total iron 570 ug/L; total mercury 2.2 ug/L.

Other wells located downgradient of other lower-ranked waste sites also showed some contamination. On-site monitoring wells at each waste site generally revealed much higher concentrations of metal and organic contaminants. These data are provided in the Nonpoint Source Workgroup Report (86). The contaminant concentrations of the analyses are based on unfiltered samples and are not indicative of contaminant loadings to the Detroit River from groundwater discharge. However, it is clear that groundwater at some of these locations contain high chemical concentrations. This suggests that important loadings of contaminants to the Detroit River may be occurring through contaminated groundwater discharge. A quantitative estimate of such input cannot be determined with the present data.

TABLE IX-9

Confirmed or Possible Michigan Contamination Sites Within Detroit River Groundwater Discharge Areas[1].

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1. Zug Island Great Lake Steel (CERLIS/RCRA/Act 307)
The Zug Island Great Lake Steel site is an island in the Detroit River near the mouth of the River Rouge. Industrial wastes were used to enlarge the island. Wastes which have been disposed of here contained heavy metals, asbestos and oily wastes and sludges.

2. Federal Marine Terminal Properties (CERCLIS/RCRA/Act 307)
The Federal Marine Terminal Properties site is an unpermitted landfill located adjacent to the Trenton Channel of the Detroit River. Mercury, chlorinated hydrocarbons, phenols and anthracene have been identified in the groundwater, ponded surface water and sediments on the site (MDNR). One-half of the on-site groundwater drains to the Detroit River and one-half drains to Monguogon Creek.

Unpermitted dumping of chemical manufacturing waste, primarily soda ash, from BASF Wyandotte took place prior to initial efforts to prepare the site as a docking facility. Mercury, arsenic, naphthalene, and benzo(a)pyrene have been found in groundwater samples. The Consent Agreement signed by BASF, USEPA, and MDNR outlines a Remedial Action plan for the site, and the provisions of the Consent Decree include clay capping of the site, shoreline stabilization, and a monitoring and inspection program.

3. Industrial Landfill (Firestone) (CERCLIS/RCRA/Act 307)
The Industrial Landfill was owned and operated by Firestone Steel Products Company. General plant wastes including scrap metal, phosphate sludge, paint sludge, treatment pond sludge and degreasing solvent residue were placed in the landfill. The site is crossed by surface drainage (Monguagon Creek and Huntington Drain) which empties into the Trenton Channel of the Detroit River. Groundwater and surface water contamination is indicated in the Act 307 listing. There are some monitoring wells located on-site.

4. Michigan Consolidated Riverside Park (CERCLIS/RCRA/Act 307)
The Michigan Consolidated Riverside Park site is a former coal gasification facility which has been converted to a park. All waste materials are covered by at least 2 feet of soil. The soils consist primarily of sandy clay and rubble interspersed with sands and organic material. Groundwater contamination is not indicated in the Act 307 listing. There are no monitoring wells.

5. B.A.S.F. Wayandotte South Works (CERCLIS/RCRA/Act 307)
The B.A.S.F. Wayandotte South Works site is a former chemical company plant site. The plant has been closed and demolished. The eastern half of the site is mostly reclaimed river bottom and marsh land consisting of fill material. There are several groundwater contamination sites on the South Works property. Ground and surface water contamination are indicated in the Act 307 listing. There are some monitoring wells onsite.

6. B.A.S.F. Wyandotte North Works (CERCLIS/RCRA/Act 307)
The B.A.S.F. Wyandotte North Works site is a chemical company plant site. In addition to permitted solid waste management units, there are several sites of unidentified fill material. The fill sites contain black odoriferous "cinders" and clay-like sludge material. Groundwater, surface-water, and soil contamination are indicated in the Act 307 listing. There are some monitoring wells located on-site.

MDNR sampling of groundwater showed contamination of the top aquifer with chloroform, and of the lower aquifer with lead, cyanide and benzo(a)pyrene. MDNR sampling of a site outfall shows contamination with 1,2-dichloropropane, 1,2-dichloroethane, phenol and benzene.

TABLE IX-9. (cont'd 2).

7. Huron Valley Steel Corporation (RCRA)
The Huron Valley Steel Corporation site is a RCRA-permitted facility that stores emission control dust/sludge (from the primary production of steel in electric furnaces) in tanks. There are no monitoring wells.

8. Edward C. Levy Co. Plant No. 3 (RCRA)
The Edward C. Levy Co. Plant No. 3 site is a RCRA transporter and treatment/storage/disposal facility. This plant stores and treats spent pickle liquor from steel finishing operations. There are 4 monitoring wells.

9. Edward C. Levy Co. Trenton Plant (RCRA)
The Edward C. Levy Co. Trenton Plant site is a RCRA transporter and treatment/storage/disposal facility. This plant stores and treats spent pickle liquor from steel finishing operations. There are 4 monitoring wells.

10. McLouth Steel Products Corporation (RCRA)
The Edward C. Levy Trenton Plant is located on the property of McLouth Steel Products Corporation. The facility is located in a mainly heavy industrial area. There is a small strip of residential land within 1000 feet of the facility to the west. The Detroit River borders the facility on the east. Inspection of tanks storing spent pickle liquor (K062) indicate that releases to the surrounding soils have occurred. The company has not performed closure including cleanup of their releases. No known hydrogeological information on the site exists.

11. Diversey Corporation (CERCLIS/RCRA)
The Diversey Corporation site is a generator and treatment, storage and/or disposal facility. There are no monitoring wells.

The site received a high modified DRASTIC score due to a shallow water table, sandy surficial material and close proximity, within one-half mile of the Detroit River.

12. Pennwalt Corporation (CERCLIS/RCRA/Act 307)
The Pennwalt Corporation site is a RCRA generator and treatment, storage and/or disposal facility. The Pennwalt property east of Jefferson Avenue consists of 50% fill which was placed along the Detroit River. The nature of the material used for filling is not known. Groundwater contamination is not indicated in the Act 307 listing.

13. Monsanto Company (CERCLIS/RCRA)
The Monsanto Company site is a RCRA generator and a treatment, storage and/or disposal facility located on the shore of the Trenton Channel of the Detroit River. One-half of the site property is composed of fill which was placed in the river. A monitoring system consisting of twenty wells have documented groundwater contamination with arsenic.

Monsanto has been on location since 1941. The 175 acre facility, which is bounded on the east by the Detroit River produces, or has produced phosphate for industrial metal cleaning, food-grade inorganic chemicals and plastic sheet for safety glass. Like virtually all industrial riverfront sites in the down-river area, land facing the river has been considerably modified by fill, much of which came from industrial sources. Groundwater here contains elevated levels of arsenic, as well as elevated pH, sodium, and sulphates. Groundwater elevations are significantly affected by recharge from wastewater ponds. Groundwater discharge is to the Detroit River and Elizabeth Park Canal.

TABLE IX-9. (cont'd 3).

14.Jones Chemicals Inc. (RCRA)
The Jones Chemicals Inc. site is a RCRA transporter and treatment, storage and/or disposal facility. Corrosive wastes are treated, or stored in tanks. There are no monitoring wells.

15.Petro-Chem Processing Inc. (RCRA)
The Petro-Chem Processing site is a RCRA generator, transporter, and treatment, storage and/or disposal facility. This company processes petroleum products, the primary product produced is Chem-Fuel #5. The site is underlain by 6 to 10 ft of heterogeneous fill which overlies 1 to 5 ft of peat, and a thick layer of clay. Groundwater chemical analysis revealed only trace levels of petroleum-related chemicals despite nearly a century of heavy industry in the area. There are no underground storage tanks and the above ground tanks are diked. There are 6 monitoring wells. Petro-Chem has only been in operation since 1982, but previous site owners have carried out fuel blending since 1976 (KOI Petroleum) and petroleum distribution activities for many years prior to that (Amoco).

16.Chrysler Trenton Plant (RCRA/Act 307)
A MDNR site inspection discovered 3000 drums of solvents on site as well as saturated, ignitable soils. Wells are located on-site.

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[1] From the addendum to the Nonpoint Source Workgroup Report (86).

CERCLIS:	Site is listed within the information system for Superfund and is considered for clean-up under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), as amended.
RCRA:	Facility has a Resource Conservation and Recovery Act (RCRA) identification number.
ACT 307:	Site is listed on Michigan's compilation of sites of known and possible environmental degradation.

ii) Ontario Waste Sites

One Ontario waste disposal site was determined to have potential for impact on human health and safety. This site, used by Wickes Manufacturing Ltd., is located near the Little River and had elevated levels of chromium and iron in the groundwater. The waste ponds were drained in 1985 and the materials moved to a certified disposal site in 1986. Subsequent tests indicate some limited remaining groundwater contamination. This site is presently under investigation. Little information on other Ontario waste disposal sites in the Detroit River area was available.

iii) Island Waste Sites

In addition to shoreline waste sites, two waste disposal sites are located on islands in the Detroit River: Fighting Island (Ontario) and Point Hennepin, Grosse Ile (Michigan).

Fighting Island, the second largest island in the Detroit River, has an area of approximately 3 km^2. Except for its northern tip, the entire island was used by BASF Wyandotte Corporation (North Works) to dispose of chemical process wastes. Samples from 51 test sites on Fighting Island were collected between 1982 and 1984. Groundwater and leachate samples contained high levels of zinc, cadmium, phenols, phthalates, and other chemicals (87). Compared to groundwater contaminant levels at some Michigan waste sites, the Fighting Island concentrations are low and the volume of leachate is small, but all the leachate and groundwater will eventually reach the Detroit River.

Point Hennepin, on Grosse Ile, has an area of approximately 1 km^2. This site was an industrial waste lagoon/disposal site by BASF Wyandotte (South Works). Little is known about the type and quantity of wastes disposed here, but other waste sites operated by this corporation (eg., site 5, Table IX-9) contain high concentrations of zinc, copper, lead, chromium, mercury, and several organic compounds including tetrachlorobutadienes and trichloroethylenes. Also, large sinkholes exist on this peninsula which may provide a connection between the surface water and groundwater aquifers. A surface leachate sample taken on the eastern side of the peninsula in 1983 was highly toxic in the Microtox toxicity bioassay (88). More detailed investigations of this site appear warranted.

Underground Injection Wells

Pressurized injection of industrial liquid wastes has occurred in the Detroit River watershed for many years at depths ranging from 200 m to over 1,200 m and injection pressures ranging from 580 to 1,600 psi (approximately 20 to 50 kBar). There are five classes of injection wells regulated by U.S. law. Class I wells are industrial and municipal wells which discharge below the lowermost formation containing an underground source of drinking water (USDW). Class II injection wells are associated with oil and gas production and liquid hydrocarbon storage. Class III wells are special process wells used in conjunction with solution mining of minerals. Class IV wells, which were banned in 1985, are hazardous waste wells which inject into or above a USDW, and Class V injection wells are those not fitting into any of the above categories, such as cesspools and heat exchange wells.

On the Michigan side of the Detroit River, 234 injection wells have operated or are currently operating. Of the six Class I wells, three are plugged and abandoned and three are currently operating at the Detroit Coke facility. The facility disposed of waste that contained chloride, ammonia, phenols, cyanide and sulfide. Class II well records indicate a total of 12 wells operating near the Detroit River, and consist of six salt water disposal wells and six hydrocarbon storage wells. Two Class III facilities (Pennwalt and BASF-Wyandotte) operated a total of 150 wells, of which only five are still active, and are scheduled to be plugged and abandoned soon. Approximately 66 Class V wells are presently operating in the Detroit River area. The impact of these underground injection wells on the Detroit River and its ecosystem is unknown, and warrants investigation.

It is beyond the scope of this investigation to determine the environmental soundness of the injection well disposal method. Historically, there is evidence for problems resulting from such wastes. In general, there is little knowledge of the pathways and fates of injected solutions.

4. Spills

An inventory of Michigan and Ontario spills occurring in or to the Detroit River in 1986 is contained in Table IX-10. A variety of chemical, oil and raw sewage spills occurred during 1986 (presumably indicative of present day spill events). Since insufficient information was available from spill reports on all spill events, such as volume or constituents of spills, no contaminant loading estimates were made. It is difficult to ascertain the impact of spills to the Detroit River ecosystem relative to point source inputs, but what is known suggests that contaminant loading from spills may be important.

5. Rural Runoff and Tributary Input

Land use determines the type, quantity and quality of chemical constituents present in tributaries which contribute approximately 117,900 million gal/year to the total Detroit River flow.

TABLE IX-10

Reported U.S. and Canadian spill incidents to the Detroit River (1986)[1].

U.S. SPILLS

Constituent	Source	Volume	Receiving Water	Amount Recovered
Unknown	Pennwalt Corp.	850 barrels	Detroit River	unknown
Metal finishing wash solution	GMC Truck & Bus	40,000 gal	Upper Rouge	30,000 gal
Raw sewage	Detroit Boat Club	5000 gal/min	Detroit RIver	none
Raw sewage	Beverly Hills Water Department	unknown	Rouge River	none
Raw sewage	Michigan Industrial Mechanical Co.	68 gal	Rouge River	none
Raw sewage	Hubble So. Field Interceptor	unknown	Rouge River	none
Raw sewage	Trenton WWTP	unknown	Detroit River	none
Raw sewage	Detroit Boat Club	unknown	Detroit River	none
Raw sewage	Trenton WWTP	7200 gal/min	Rouge River	none
Raw sewage	City of Farmington	1000 gal	Rouge River	none
Raw sewage	Wayne Co-Wyandotte WWTP	$130x10^6$ gal	Detroit River	none
Raw sewage	Wayne Co-Wyandotte WWTP	$140x10^6$ gal	Detroit River	none
Ferrous chloride	Pennwalt Corp.	unknown	Detroit River	none
Trivalent chromium-containing water conc: 3 ug/L	Detroit Diesel	10,000 gal	Rouge River	none
Xylene washwater	Ford Motor Co.	500-750 gal	Rouge River	none
Hydrochloric acid	Pennwalt Corp.	10 gal	Detroit River	none
Ammonia and mono-ethylene	Pennwalt Corp.	10 gal	Detroit River	8 gal

TABLE IX-10. (cont'd).

U.S. SPILLS

Constituent	Source	Volume	Receiving Water	Amount Recovered
Oil[2]	Unknown	100 gal	Rouge River	none
Oil	Trailer Park	300 gal	Detroit River	unknown
Oil	McLouth Steel	unknown	Detroit River	none
Oil	Unknown	unknown	Trenton Channel	none
Oil	Grosse Ile Airport	2-3 gal	Trenton Channel	none
Oil	Consolidated Freight	230 gal	Rouge River	none

CANADIAN SPILLS

Constituent	Source	Volume	Receiving Water	Amount Recovered
Oil	Ford Engine Plant	unknown	Detroit River	none
Oil	Allied Chemical (General Chemical)	15-25 gal	Detroit River	none
Chromic acid and nickel salts	Wickes Manufacturing	unknown	Little River[3]	none

[1] From the Point Source Workgroup Report (6).
[2] "Oil" refers to non-PCB-containing oil.
[3] per R. Bowen, OMOE (Point Source Workgroup Report reports as occurring to Detroit River).

Land use in the Detroit River area is almost equally divided between urban/residential/industrial and agriculture (5,86,89).

Forty six percent of the approximately 200,000 hectare watershed is intensively farmed, primarily for corn and soy beans. Beef and swine are the dominant livestock, but dairy cattle are also raised. Fertilizer and manure have the potential to be a major nitrogen and phosphorus source to the Detroit River since approximately 17,100 tons per year (11,355 in Ontario and 5,755 in Michigan) are applied within the Detroit River watershed. This could be substantially reduced, since phosphorus and fertilizer application rates are generally more than twice the required amount in these areas, and only 8% of the Michigan and 10 to 20% of the Ontario Detroit River watershed farms use recommended agricultural soil and water conservation practices (5,86).

Michigan applies about 37,000 kg and Ontario applies about 53,000 kg of pesticides annually, including atrazine, alachlor, cyanazine and metolachlor. Reports indicate that 60% of the Detroit River watershed has a high potential for pesticide transport to the surface and groundwater systems. Instantaneous pesticide loadings were calculated for all Ontario tributaries for total atrazine, lindane, and p'p-DDE. Loadings were estimated at 33 ug/sec, 13.4 ug/sec and 4.4 ug/sec, respectively (34).

Tributary contaminant loadings were determined for the Ecorse and Rouge rivers in Michigan, and Turkey Creek and Little and Canard rivers in Ontario. Selected chemical constituents were measured every 12 hours for two 1 week periods during 1986. Concentrations multiplied by tributary flow determined chemical mass loadings to the Detroit River. Calculated contaminant loadings for these tributaries are shown in Table IX-11 (5,30). Tributary loadings generally account for only a minor portion of that contributed by point sources. However, for some parameters, tributary loadings (when expressed as kg/d), approach some point source loadings.

6. Atmospheric Deposition

No data were obtained for direct atmospheric deposition of contaminants to the Detroit River by this study. Contaminant loadings from indirect atmospheric deposition to the watershed are reflected in tributary contributions. Air concentrations of selected constituents for Wayne County are shown in Table IX-12, and sampling locations are shown in Figure IX-20. The highest concentrations of these constituents are near Zug Island. Areas located 2 to 3 km north of Zug Island generally had the lowest concentrations. Total suspended particulates exceeded the primary annual geometric mean of 75 ug/m^3 at station 5 just north of Zug Island during the 1980 to 1986 period. Cadmium and chromium also exceeded the primary annual geometric mean at all three stations monitored.

TABLE IX-11

Comparison of U.S. and Canadian Detroit River tributary contaminant loadings, 1984-1986 (kg/yr).

	CANADIAN TRIBUTARIES		U.S. TRIBUTARIES	
Tributaries Sampled	Little, Canard and Turkey	Little and Turkey	Rouge	Rouge and Ecorse
Year Sampled	1984 & 1985	1986	1984-1986	1986
Number of Samples	7-31	2-28	36-167	2-28
% of Drainage Basin	20%	4%	54%	77%
Reported by:	Wall *et al.*[1]	Richardson[2]	MDNR[3]	Richardson[2]
Chemical Constituents				
Total Phosphorus	103,689	15,547	151,718	109,903
Nitrate-N	628,404	-	720,267	-
Chloride	7,334,728	3,579,336	76,771,600	76,564,047
Suspended Solids	-	1,103,445	28,944,500	30,231,356
Total Lead	836	-	9,624	-
Total Cadmium	-	3.4	740	2,151
Total Copper	-	178	9,587	7,496
Total Iron	-	1,313	-	41,394
Total Mercury	-	0.6	-	18.2
Total Nickel	-	17,941	7,373	3,541
Total Zinc	-	1,947	53,582	174,896
Total PCBs	-	0.36[4]	-	55.1

[1] From Wall *et al.* (5).

[2] From Detroit River System Mass Balance Study (30).

[3] Michigan DNR data from high flow event monitoring, 1984-1986 (unpublished).

[4] This value applies to Turkey Creek only.

TABLE IX-12

Mean concentrations of selected chemical constituents in air of Wayne County, Michigan, within four miles of the Detroit River, 1980-1986[1].

	STATION NUMBER							
CONSTITUENT	2	60/61	4	5	9	8	10	34
Benzo(a)pyrene ng/m^3	1.27	-	1.50	3.49	-	1.10	-	-
Beryllium ug/m^3	-	-	0.0004	0.0003	-	-	-	0.0007
Cadmium ug/m^3	-	-	0.027	0.058	-	-	-	0.0038
Carbon Monoxide ug/m^3	-	-	1.16	-	-	1.06	-	-
Chromium ug/m^3	-	-	0.007	0.012	-	-	-	0.009
Iron ug/m^3	-	-	0.99	1.53	-	-	-	1.21
Lead ug/m^3	-	-	0.24	0.27	-	-	-	0.14
Mercury ug/m^3	-	-	0.0003	0.0003	-	-	-	0.0004
Nickel ug/m^3	-	-	0.015	0.013	-	-	-	0.010
Nitrogen Dioxide ug/m^3	-	65	51	-	-	-	-	-
Ozone ppm	-	-	0.022	-	-	0.019	-	-
Sulfur Dioxide ug/m^3	16	34	-	39	24	18	-	-
Total Susp. Particles ug/m^3	57	66	-	89	68	59	52	-
Zinc ug/m^3	-	-	0.24	0.33	-	-	-	0.37

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[1] From Michigan DNR, Wayne County yearly air quality data.

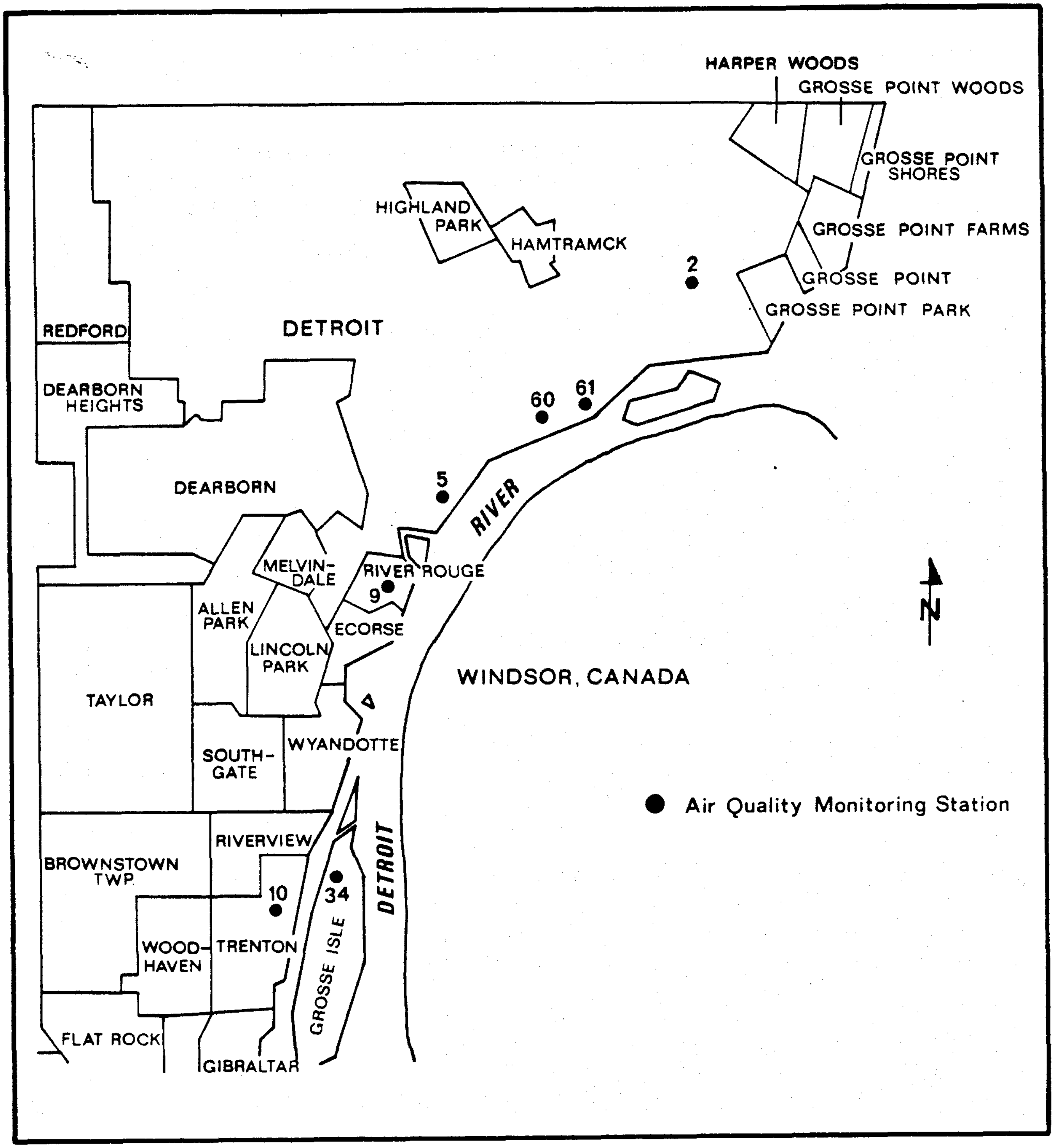


FIGURE IX-20. Wayne County air quality monitoring network.

7. Integrated Contaminant Input

The total measured loadings of UGLCCS parameters from all point source facilities were added to the combined measured loadings of stormwater, combined sewer overflows and tributary loadings to determine the total measured loading of each UGLCCS parameter discharged to the Detroit River. These loadings and their respective percentages by various categories are shown in Tables IX-13 and 14.

Michigan's point sources contribute 49% or more of the measured ammonia, total phosphorus, oil and grease, cadmium, chromium, cobalt, iron, nickel, zinc, cyanide, total phenols, HCB, PCBs and PAHs. Ontario point sources contributed 64% of the measured chlorides. Michigan CSOs contributed a substantial proportion of total phosphorus, suspended solids, oil and grease, cadmium, chromium, copper, lead and mercury loadings as of 1979. There are no data on contaminant loadings from Michigan CSOs more recent than 1979.

An attempt was made to determine changes in concentrations of UGLCCS parameters between the Detroit River head and mouth during the Detroit River System Mass Balance Survey, described in a later section. Most parameters measured had higher concentrations at the mouth than the head, indicating input of these materials along the river. Measured point sources, tributaries and CSO loadings accounted for 50% or more of these increases (30). These data suggest that other sources, possibly including atmospheric deposition, direct shoreline runoff, groundwater discharge, spills and sediments may be contributing to increases in these chemical constituents between Lake St. Clair and Lake Erie. Uncertainty in the measurements resulting from limited sampling may also play a part. These data also suggest that the Detroit River corridor is a source for waterborne phosphorus, copper, zinc, suspended solids, chloride and PCB, but is a sink for waterborne mercury, nickel, iron and cadmium. These latter metals may be adsorbing or chemically bonding to particulate matter which settles in Detroit River depositional zones. Some portion of these substances probably settle out, but during this study their export exceeded the measured input.

TABLE IX-13

Total loadings of selected chemical constituents of the Detroit River from Michigan and Ontario point and nonpoint sources measured between 1979 and 1986 (kg/yr).

PARAMETER	TOTAL MEASURED LOADING	MEASURED MICHIGAN POINT SOURCE LOADINGS[1]	MEASURED ONTARIO POINT SOURCE LOADINGS[2]	MEASURED DETROIT CSO LOADINGS[3]	MEASURED WINDSOR STORMWATER & CSO LOADINGS[4]	MEASURED MICHIGAN TRIBUTARY LOADINGS	MEASURED ONTARIO TRIBUTARY LOADINGS
Ammonia	11,692,656	9,088,500	617,000	618,285	20,200	720,267[5]	628,404[6]
Phosphorus	915,821	452,600	82,900	166,514	8,400	151,718[5]	103,689[6]
Chloride	623,207,041	134,320,000	398,000,000	1,545,713	5,235,000	76,771,600[5]	7,334,728[6]
Susp. Solids	57,607,849	19,199,000	-	8,360,904	-	30,231,356[8]	1,103,445[7]
Oil/Grease	15,719,506	12,227,500	66,800	3,302,206	123,000	-	-
Cadmium	5,681	2,986	337	1,440	175	740[5]	3.4[7]
Cobalt	17	1,737	8	-	9	-	-
Chromium	15,774	11,242	-	4,532	-	-	-
Copper	38,554	10.548	9,450	7,658	1,133	9,587[5]	178[7]
Iron	1,560,852	1,182,600	122,000	79,745	133,800	41,394[8]	1,313[7]
Lead	49,490	8,067	10,900	15,703	4,360	9,624[5]	836[7]
Mercury	1,642	39.4	2	1,581	1	18.2[8]	0.6[7]
Nickel	74,005	36,865	6,190	4,883	753	7,373[5]	17,941[7]
Zinc	316,006[9]	172,280	61,500	19,497	7,200	53,582[5]	1,947[7]
Total Phenols	50,061	32,047	17,300	597	117	-	-
Cyanide	44,361	43,435	843	-	83	-	-
HCB	0.9	0.9	-	-	0.03	-	-
Total PCBs	249	94	14	84.3	1.6	55.1[6]	0.36[10]
17 PAHs	2,281	1,891	304	-	86	-	-

[1] Based on UGLCCS 1986 Point Source Survey (6).

[2] Based on UGLCCS 1985 Point Source Survey (6).

[3] Based on City of Detroit CSOs (1979), from Giffles *et al*. (79).

[4] Based on Windsor stormwater and CSOs 1985-1986, Marsalek and Ng (80).

[5] Based on Rouge River loadings, 1984-1986, Michigan DNR, unpublished data, 1988.

[6] Based on loadings from the Little and Canard rivers and Turkey Creek, 1984-1985. Wall *et al*. (5).

[7] Based on loadings from the Little River and Turkey Creek, 1986 (30).

[8] Based on loadings from the Rouge and Ecorse rivers, 1986 (30).

[9] Does not include loadings from Double Eagle Steel.

[10] Based on loadings from Turkey Creek only, 1985. Wall *et al*. (5).

TABLE IX-14

Estimated annual contaminant loadings to the Detroit River based on measured point and nonpoint sources between 1979 and 1986, and the percent of this total loading contributed by the sources compared with measured increased loadings between the head and the mouth of the Detroit River.

Parameter	Total Measured Loading kg/yr	Michigan Point Source[1] %	Ontario Point Source[2] %	Detroit CSOs[3] %	Windsor Storm-water & CSOs[4] %	Michigan Tribu-taries %	Ontario Tribu-taries %	Changes Between Head & Mouth kg/yr	Percent Change Accounted for by Measured Point & Non-Point Sources	Source or Sink
Ammonia	11,692,656	77.7	5.3	5.3	0.2	6.2[6]	5.4[7]	---	--	---
Phosphorus	915,821	49.4	9.1	12.7	1.0	16.6[6]	11.3[7]	+ 1,450,656	63	Source
Chloride	623,207,041	21.6	63.9	0.2	0.8	12.3[6]	1.2[7]	+ 729,625,072[10]	86	Source
Susp.Solids	57,607,849	33.9	NM	14.5	NM	50.2	1.9[8]	+ 527,660,352	11	Source
Oil&Grease	15,719,506	77.8	0.4	21.0	0.8	NM	NM	---	--	---
Cadmium	5,681	52.6	5.9	25.3	3.1	13.0[6]	0.1[8]	+ 2,586	220	Sink
Cobalt	17	99.0	0.5	NM	0.5	NM	NM	---	--	---
Chromium	15,774	71.3	NM	28.7	NM	NM	NM	---	--	---
Copper	38,554	27.4	24.5	19.9	2.9	24.9[6]	0.5[8]	+ 73,006	53	Source
Iron	1,560,852	75.8	7.8	5.1	8.6	2.7[9]	0.1[8]	- 199,717	--	---
Lead	49,490	16.3	22.0	31.7	8.8	19.4[6]	1.7[8]	---	--	---
Mercury	1,642	2.4	0.1	96.3	0.1	1.1[9]	0.1[8]	+ 45.4	3,617	Sink
Nickel	74,005	49.6	8.4	6.6	1.0	10.0[6]	24.3[8]	+ 37,149	200	Sink
Zinc	316,006[11]	54.5	19.5	6.2	2.3	17.0[6]	0.6[8]	+ 429,835[12]	74[13]	Source[13]
Total Phenols	50,061	64.0	34.6	1.2	0.2	NM	NM	---	--	---
Cyanide	44,361	97.9	1.9	NM	0.2	NM	NM	---	--	---
HCB	0.9	96.7	NM	3.3	NM	NM	NM	---	--	---
Total PCBs	249	37.8	5.6	33.9	0.6	22.1[9]	0.1[14]	+ 364	68	Source
17 PAHs	2,281	82.9	13.3	NM	3.8	NM	NM	---	--	---

NM Not Measured

[1] Based on 1986 Point Source Surveys (6).

[2] Based on 1985 Point Source Surveys (6).

[3] Based on City of Detroit CSOs, 1979 and Giffles et al (79).

[4] Based on Windsor Stormwater and CSOs in 1985-1986. Marsalek and Ng (80).

[5] Based on U.S.EPA's System Mass Balance (30). Measured loading changes between the Detroit River head and mouth from ambient monitoring. (+) equals mouth loading greater than the head value shown; (-) equals mouth loadings less than value shown.

[6] Based on loadings from the Rouge River, 1984-1986. MDNR unpublished data, 1988.

[7] Based on loadings from the Little River, Canard River and Turkey Creek, 1984 and 1985 (5).

[8] Based on loadings from the Little River and Turkey Creek, 1984 and 1985 (5).

[9] Based on loadings from the Rouge River and Ecorse River, 1986 (30).

[10] Includes the discharge from General Chemical (390,550,000 kg/yr) discharging below the Detroit River System Mass Balance lower transect.

[11] Does not include loadings from Double Eagle Steel.

[12] Includes loading from Double Eagle Steel.

[13] This is uncertain due to footnotes 11 and 12.

[14] Based on loadings from Turkey Creek only, 1985 (5).

D. DATA QUALITY ASSURANCE AND CONTROL

1. Limitations

A total of 13 interlaboratory performance evaluation studies were conducted for the UGLCC Project. All laboratories supplying analytical data participated in at least one of these round-robin studies. The parameters tested in the interlaboratory studies were: PCBs, PAHs, organochlorine pesticides, chlorinated hydrocarbons, total phenol, chlorophenols, trace metals, major ions, nutrients, and cyanide (see Chapter IV).

2. General Observations

The Michigan Department of Natural Resources laboratory results for the UGLCC studies were compared with similar effluent and surface water samples collected in years in other river systems. Point sources were evaluated based on field blanks replicates, reagent blanks, duplicates, sample spikes, annual laboratory precision and accuracy summaries and UGLCCS interlaboratory comparisons (round robin). Field blanks contained only a few constituents and did not impact loadings estimates. Field replicates, describing the relative system variation, varied by less than 20% for all parameters with three or more field replicates. Accuracy, described as the percent recovery, was 80 to 100% for most organic compounds, and 70 to 130% for most conventional compounds. Precision control (duplicate analyses) showed recoveries of 98 to 100% with a mean of 99%.

The U.S.EPA Large Lakes Research Station Laboratory, also did quality control analysis for PCBs and metals. For PCBs, average blank concentrations were substantially less than the concentrations observed in the samples. The duplicate analyses were within 17%. Additionally, the analyses of the 111 prepared laboratory standards were within 20% of the known concentration. Based on this summary, the PCB data are considered adequate. For metals, blanks were all less than the river or point source samples. Duplicate analyses were within 16%. Replicate analyses were within 27%. Reference standards were within 16% of known concentration except for chrome which was within 30%. Based on this information, the point source workgroup concluded the data were adequate and within the confines of the quality control-quality assurance management plan for the UGLCCS.

E. MODELING AND MASS BALANCE CONSIDERATIONS

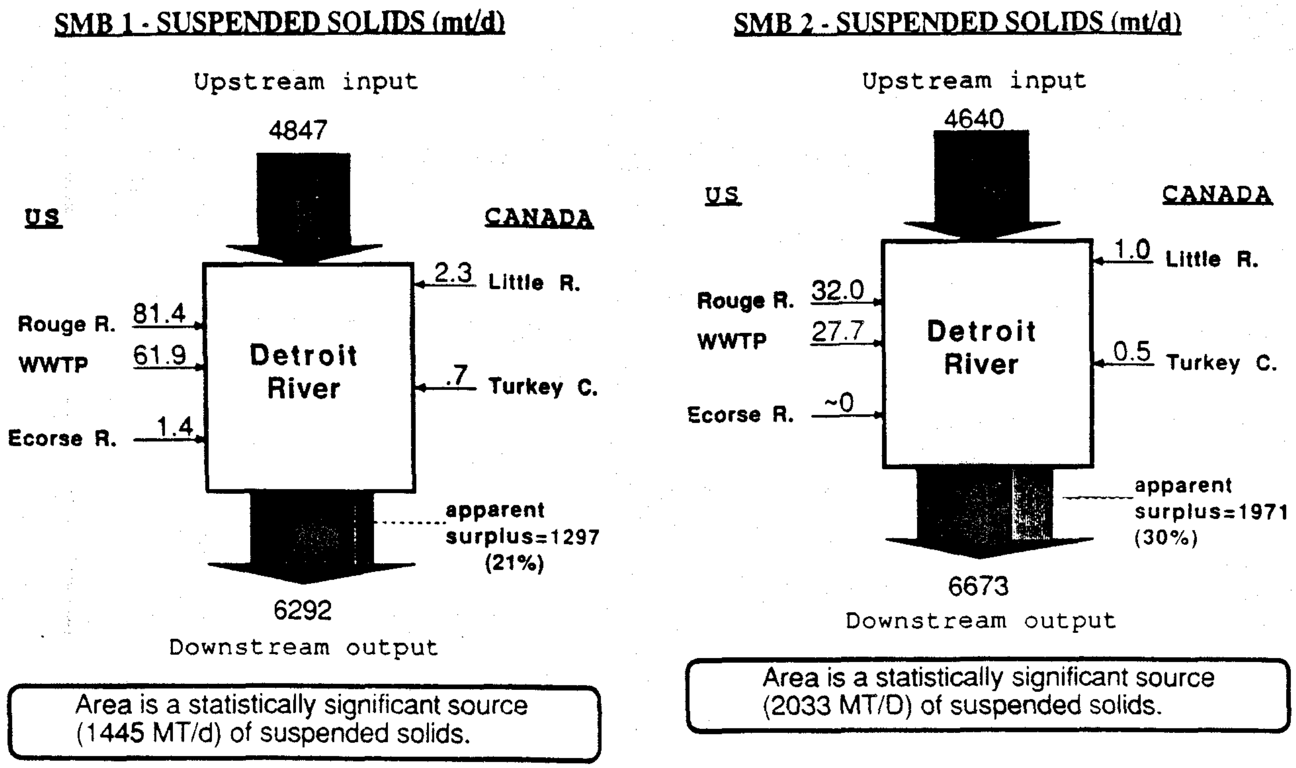
Mass balance and process oriented models were developed for the Detroit River. These are identified in Chapter V along with an explanation of mass balance and process modeling.

1. Mass Balance Models

Mass balance models permit the evaluation of whole rivers or river segments as a source or sink of measured contaminants.

Mass balance studies were conducted for the entire Detroit River system and a section of the lower Detroit River, the Trenton Channel. These studies represent snapshots of contaminant conditions. Figure IX-21 shows the relative importance of loads in the Detroit Systems Mass Balance (DRSMB) including Michigan and Ontario tributaries and the Detroit WWTP (90). Figure IX-22 shows the same relationship for the Trenton Channel Mass Balance (TCMB) but also includes some tributaries and point sources. The arrow shaft width indicates the importance of the average contaminant load or loss. Estimates marked with a \`?' denote data unavailability. At the bottom is a mass balance interpretation with statistical conclusions. Diagrams for each contaminant during the DRSMB periods and diagrams for each contaminant during the TCMB periods can be compared directly. Missing data for the Detroit River System Mass Balance include loadings from the Canard River, all direct point sources except the City of Detroit WWTP, nonpoint sources including CSOs, storm water, atmospheric deposition, groundwater, sediment fluxes, and contaminants associated with floating aquatic macrophytes. Missing data for the Trenton Channel Mass Balance include all of the above except direct point source discharges within the Trenton Channel.

Errors in these calculations may be due to 1) insufficient temporal or spatial sampling, or 2) analytical analysis. Concentrations less than the analytical detection level are particularly difficult to incorporate into modeling efforts. In the Detroit River Systems Mass Balance (30) and Trenton Channel Mass Balance (31), these errors were minimized by using only data generated by the U.S.EPA Large Lakes Research Station (LLRS) for the Detroit River, the tributaries and point sources, and City of Detroit WWTP daily monitoring data for the precise days of each survey. The method of managing values at less than detection is called the maximum likelihood method of singly censored data and has been applied to all U.S.EPA-LLRS results.

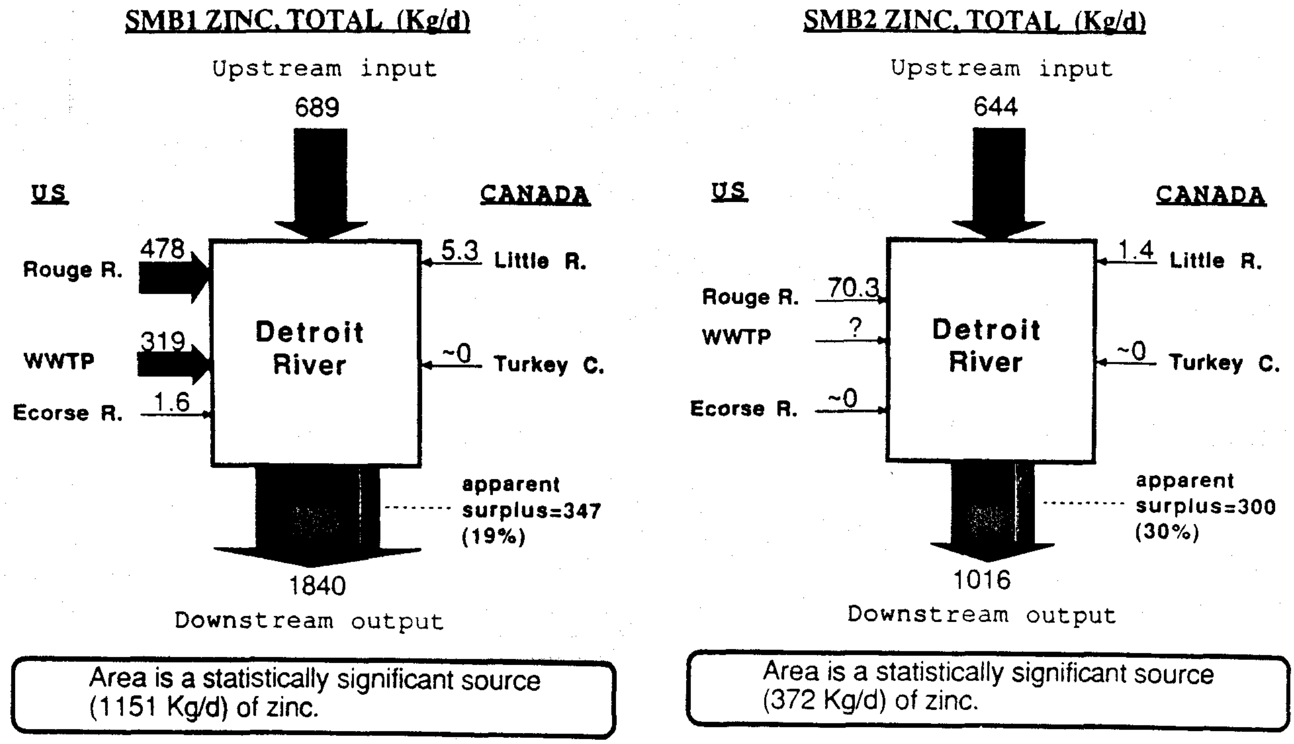


SMB 1 - SUSPENDED SOLIDS (mt/d)

Area is a statistically significant source (1445 MT/d) of suspended solids.

SMB 2 - SUSPENDED SOLIDS (mt/d)

Area is a statistically significant source (2033 MT/D) of suspended solids.



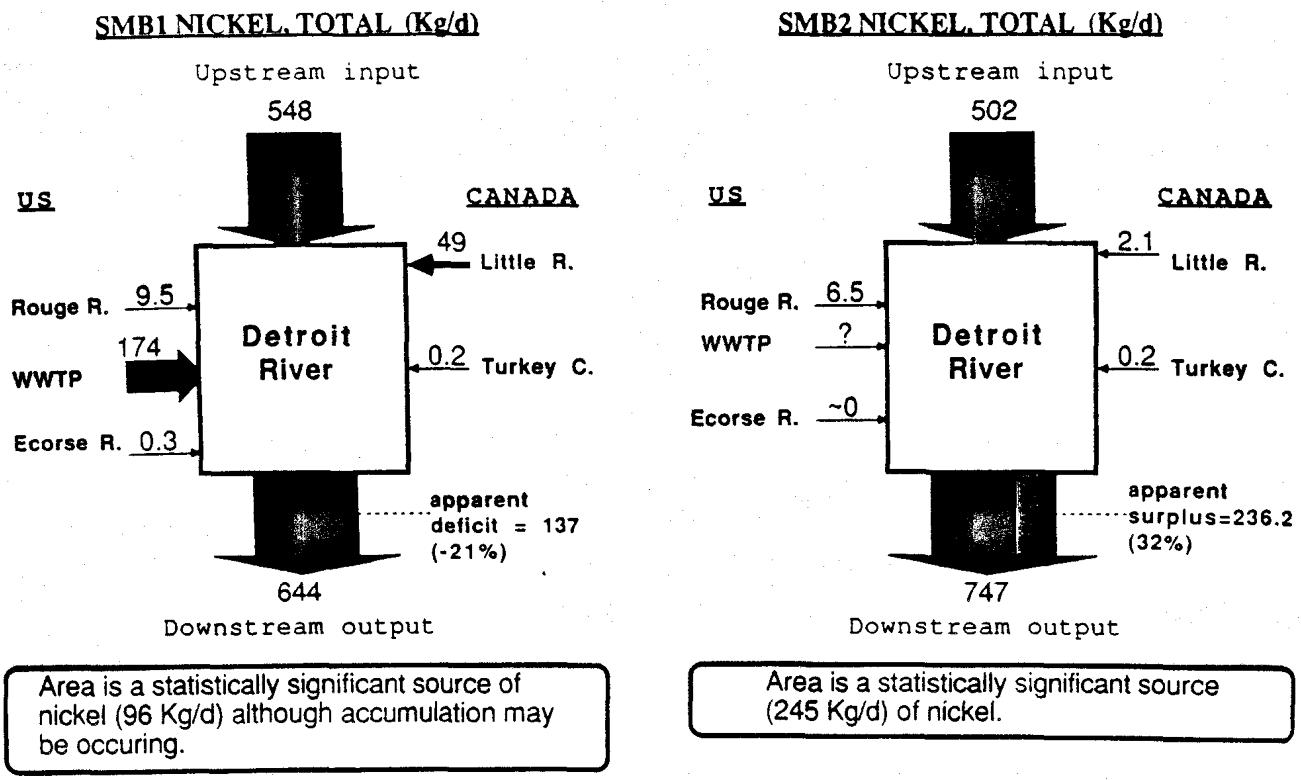
SMB1 ZINC, TOTAL (Kg/d)

Area is a statistically significant source (1151 Kg/d) of zinc.

SMB2 ZINC, TOTAL (Kg/d)

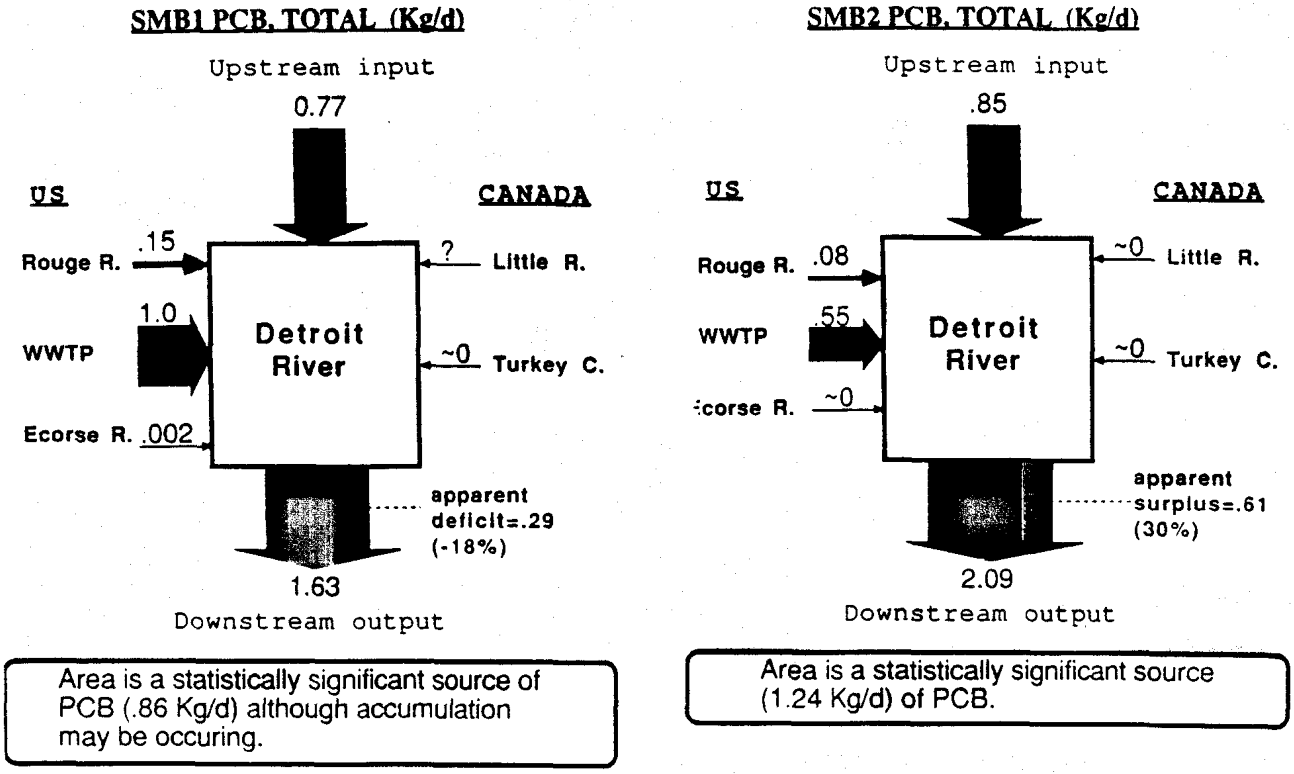
Area is a statistically significant source (372 Kg/d) of zinc.

FIGURE IX-21. Detroit River mass balance results.



Area is a statistically significant source of nickel (96 Kg/d) although accumulation may be occuring.

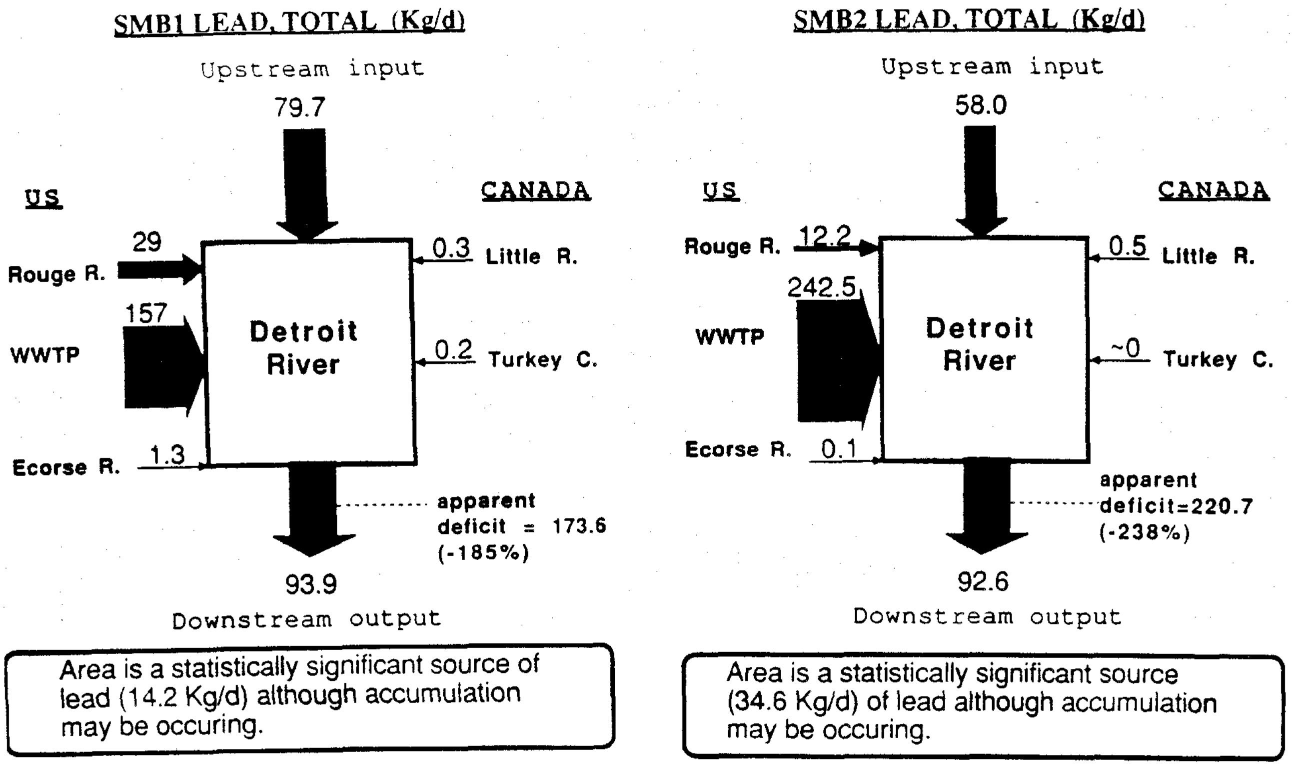
Area is a statistically significant source (245 Kg/d) of nickel.



Area is a statistically significant source of PCB (.86 Kg/d) although accumulation may be occuring.

Area is a statistically significant source (1.24 Kg/d) of PCB.

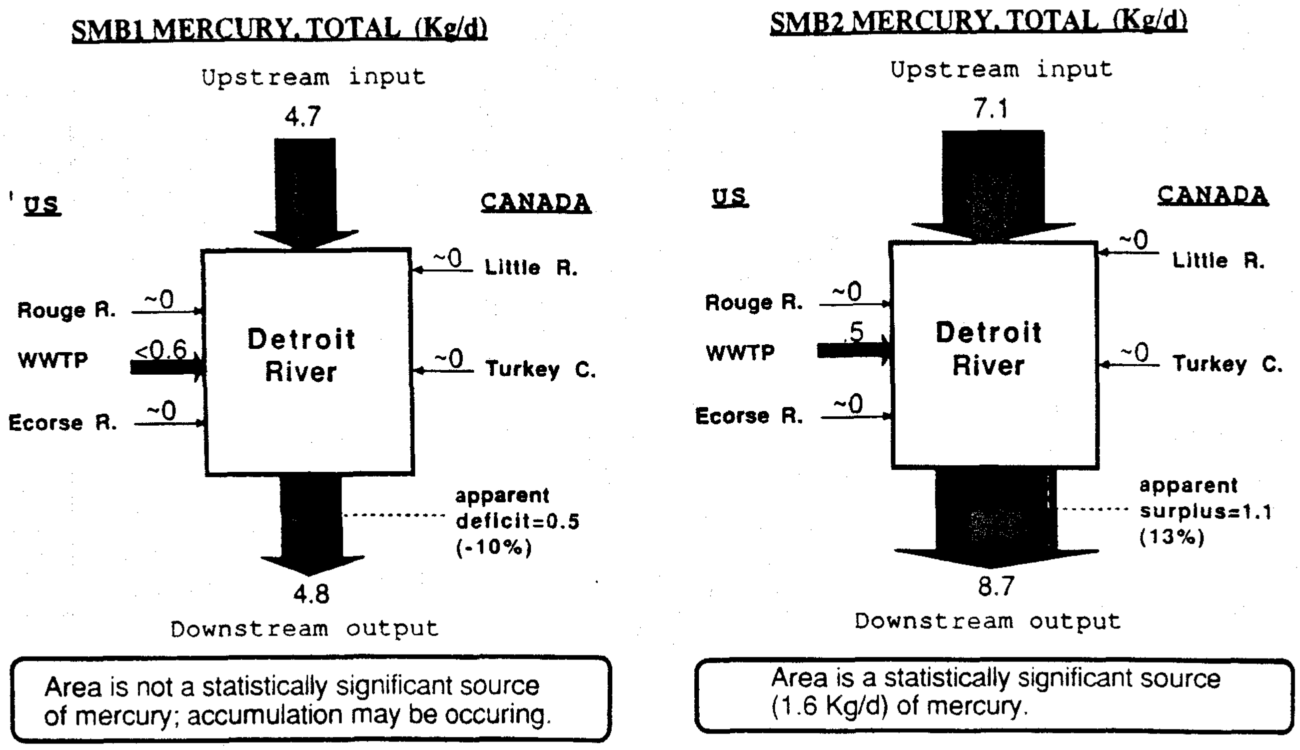
FIGURE IX-21. (Cont'd.) Detroit River mass balance results.


SMB1 LEAD, TOTAL (Kg/d)

SMB2 LEAD, TOTAL (Kg/d)

Area is a statistically significant source of lead (14.2 Kg/d) although accumulation may be occuring.

Area is a statistically significant source (34.6 Kg/d) of lead although accumulation may be occuring.

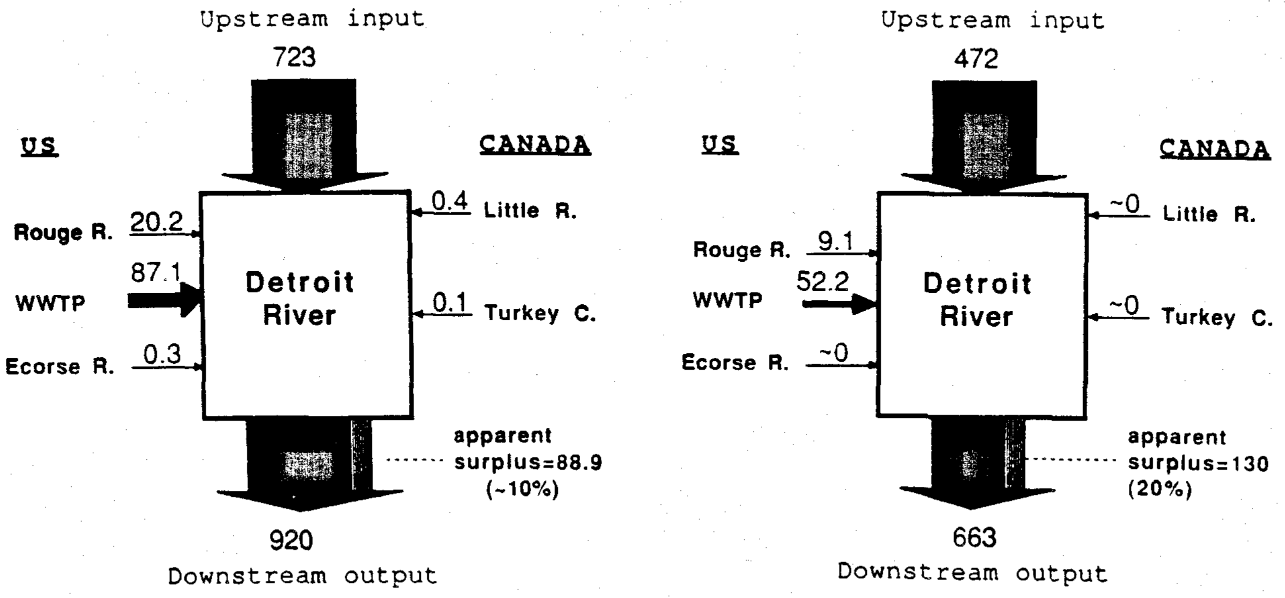

SMB1 MERCURY, TOTAL (Kg/d)

SMB2 MERCURY, TOTAL (Kg/d)

Area is not a statistically significant source of mercury; accumulation may be occuring.

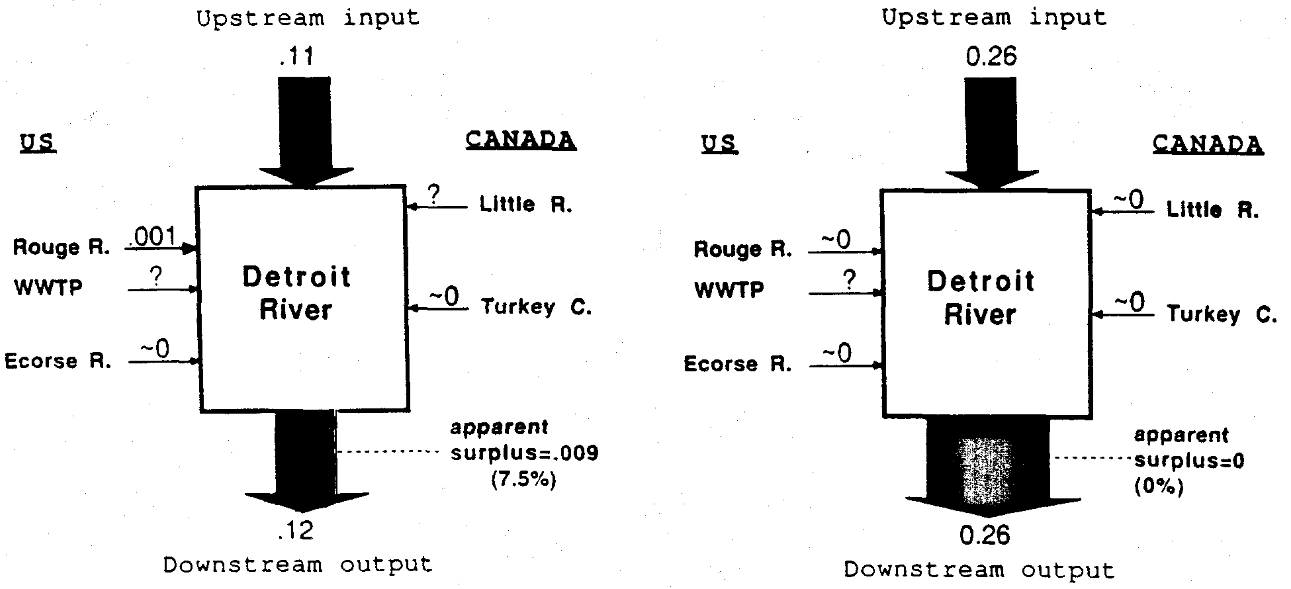
Area is a statistically significant source (1.6 Kg/d) of mercury.

FIGURE IX-21. (Cont'd.) Detroit River mass balance results.



Area is a statistically significant source of copper (197 Kg/d).

Area is a statistically significant source (191 Kg/d) of copper.

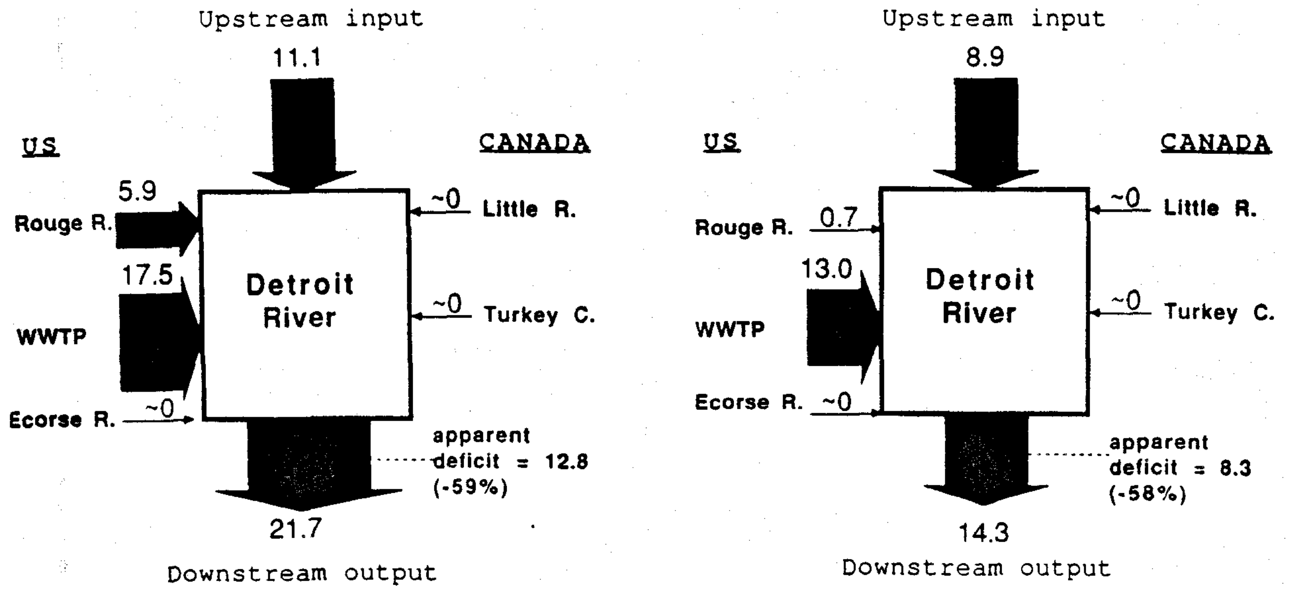


Area is a not a statistically significant source of HCB.

Area is a not a statistically significant source of HCB.

FIGURE IX-21. (Cont'd.) Detroit River mass balance results.

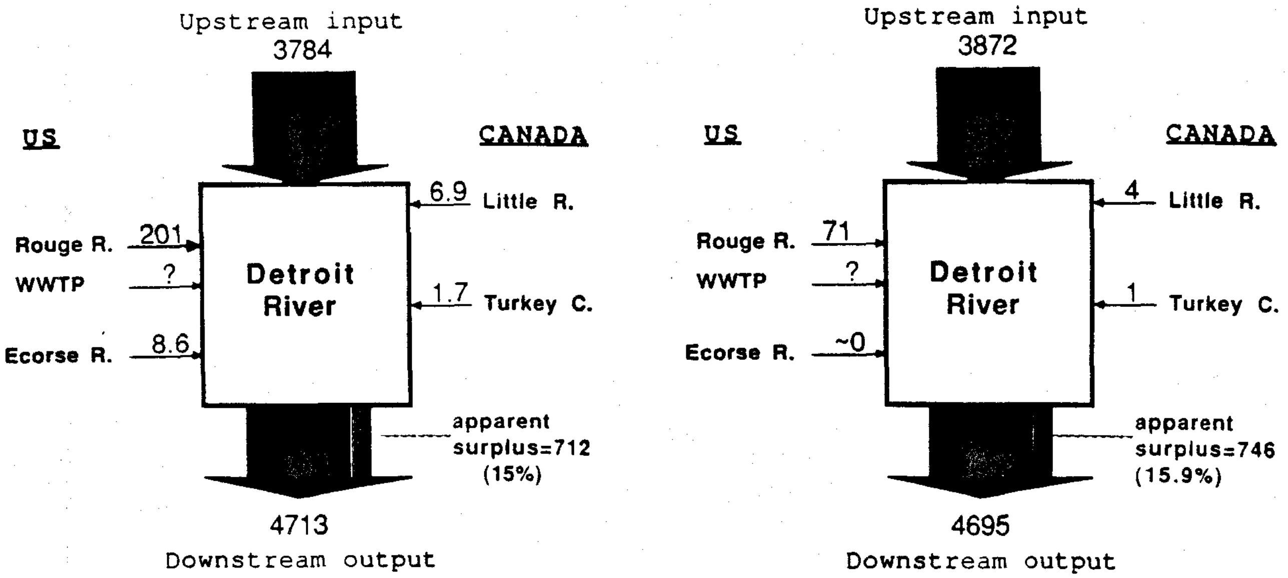
SMB1 CADMIUM, TOTAL (Kg/d) **SMB2 CADMIUM, TOTAL (Kg/d)**



Area is a statistically significant source of cadmium (10.6 Kg/d), although accumulation may be occuring.

Area is a statistically significant source of cadmium (5.4 Kg/d) although accumulation may be occuring.

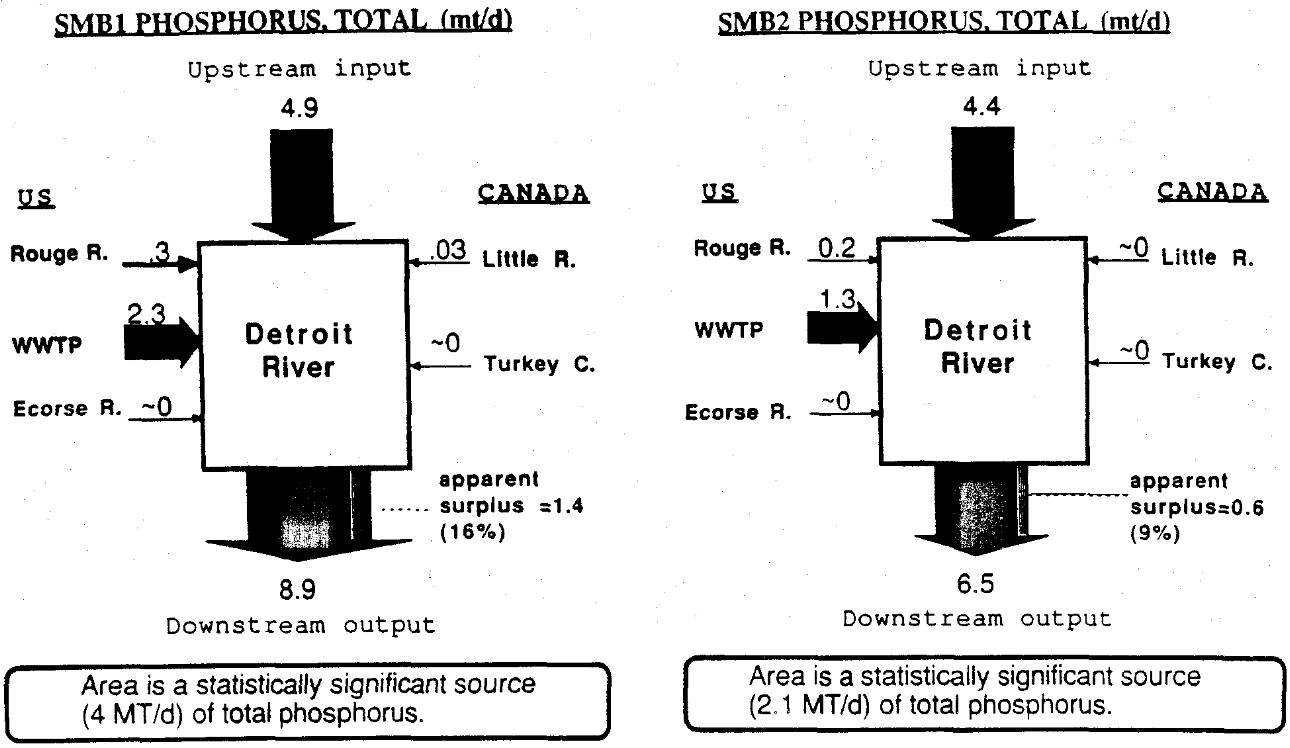
SMB1 CHLORIDE, FILTERED (mt/d) **SMB2 CHLORIDE, FILTERED (mt/d)**



Area is a statistically significant source of chloride (929 MT/d).

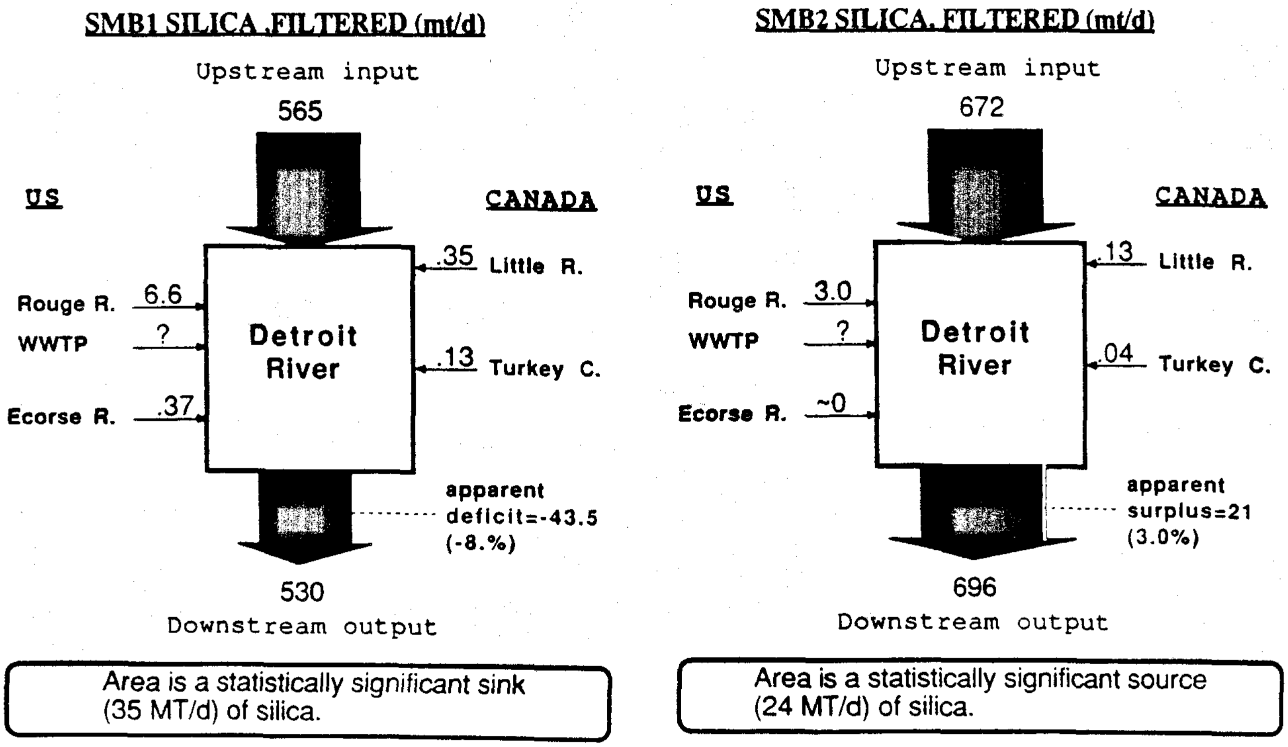
Area is a statistically significant source (823 MT/d) of chloride.

FIGURE IX-21. (Cont'd.) Detroit River mass balance results.



Area is a statistically significant source (4 MT/d) of total phosphorus.

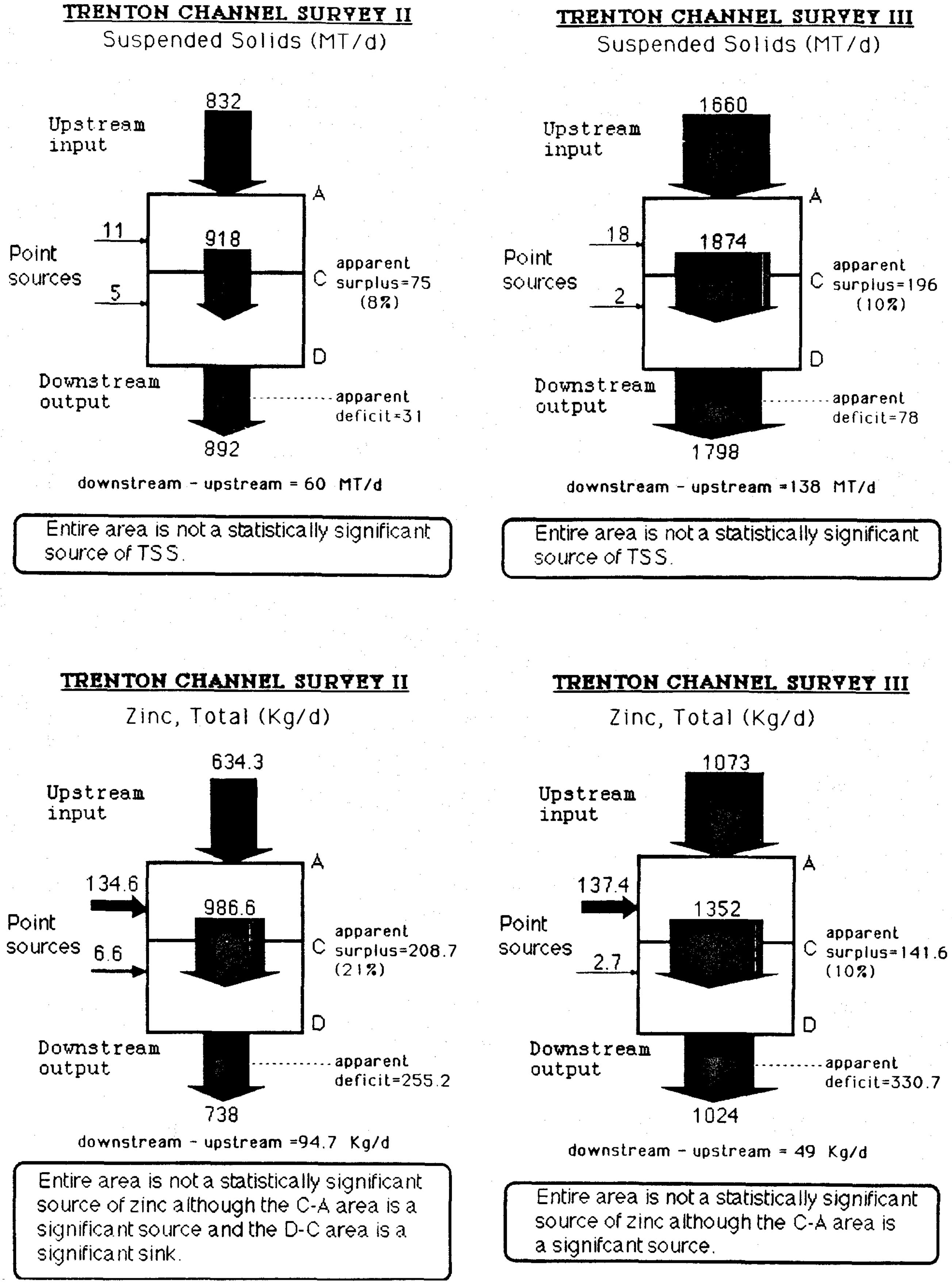
Area is a statistically significant source (2.1 MT/d) of total phosphorus.



Area is a statistically significant sink (35 MT/d) of silica.

Area is a statistically significant source (24 MT/d) of silica.

FIGURE IX-21. (Cont'd.) Detroit River mass balance results.



TRENTON CHANNEL SURVEY II
Suspended Solids (MT/d)

downstream - upstream = 60 MT/d

Entire area is not a statistically significant source of TSS.

TRENTON CHANNEL SURVEY III
Suspended Solids (MT/d)

downstream - upstream =138 MT/d

Entire area is not a statistically significant source of TSS.

TRENTON CHANNEL SURVEY II
Zinc, Total (Kg/d)

downstream - upstream =94.7 Kg/d

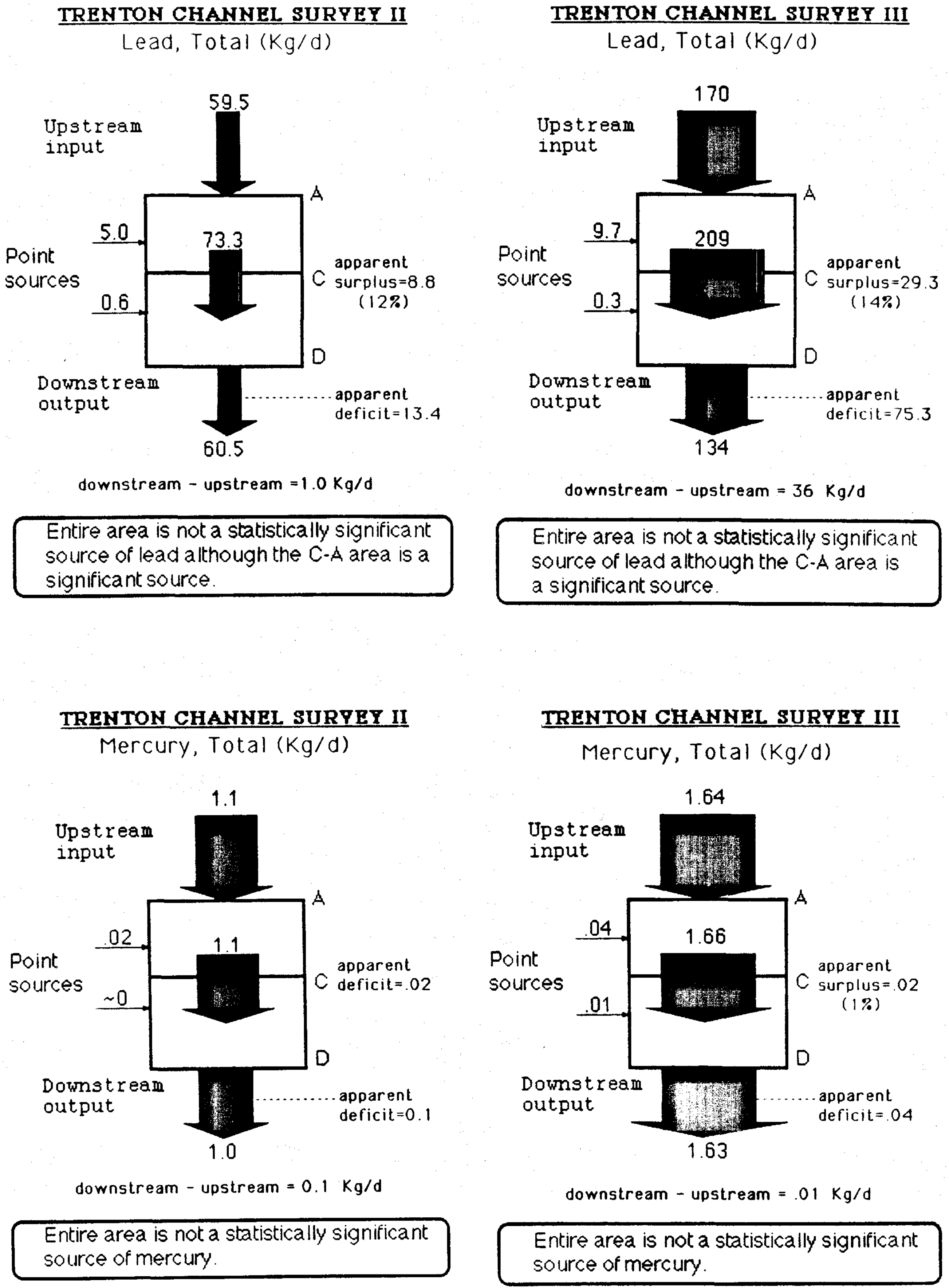
Entire area is not a statistically significant source of zinc although the C-A area is a significant source and the D-C area is a significant sink.

TRENTON CHANNEL SURVEY III
Zinc, Total (Kg/d)

downstream - upstream = 49 Kg/d

Entire area is not a statistically significant source of zinc although the C-A area is a signifcant source.

FIGURE IX-22. Trenton Channel mass balance results.



TRENTON CHANNEL SURVEY II

Lead, Total (Kg/d)

Entire area is not a statistically significant source of lead although the C-A area is a significant source.

TRENTON CHANNEL SURVEY III

Lead, Total (Kg/d)

Entire area is not a statistically significant source of lead although the C-A area is a significant source.

TRENTON CHANNEL SURVEY II

Mercury, Total (Kg/d)

Entire area is not a statistically significant source of mercury.

TRENTON CHANNEL SURVEY III

Mercury, Total (Kg/d)

Entire area is not a statistically significant source of mercury.

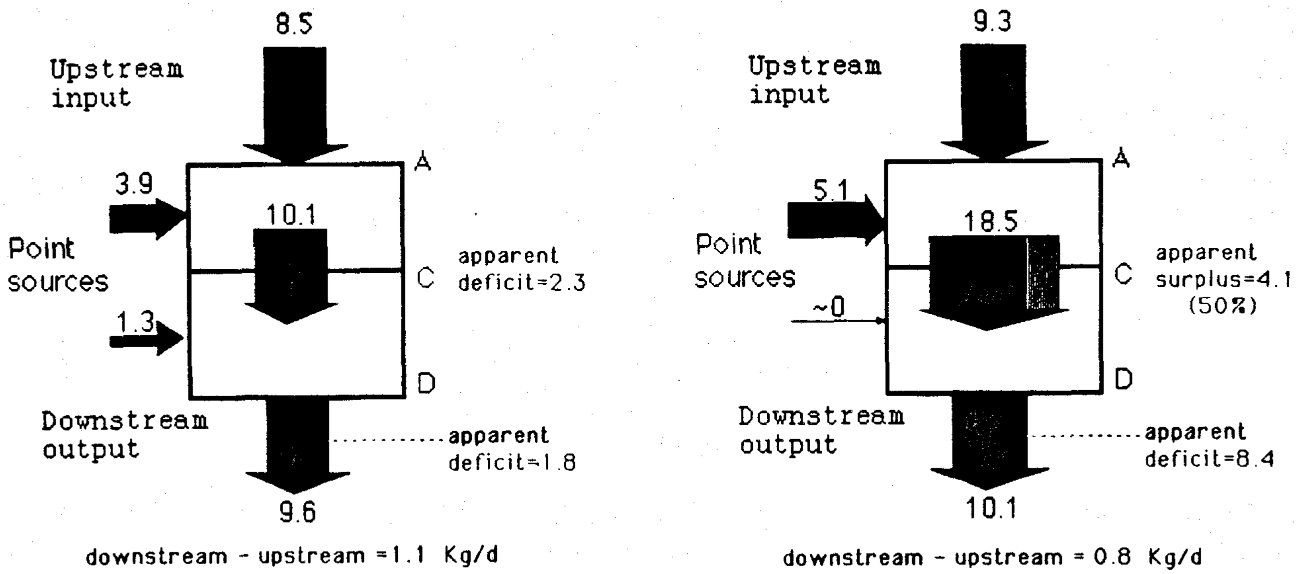
FIGURE IX-22. (Cont'd.) Trenton Channel mass balance results.

TRENTON CHANNEL SURVEY II

Cadmium, Total (Kg/d)

TRENTON CHANNEL SURVEY III

Cadmium, Total (Kg/d)



Entire area is not a statistically significant source of cadmium.

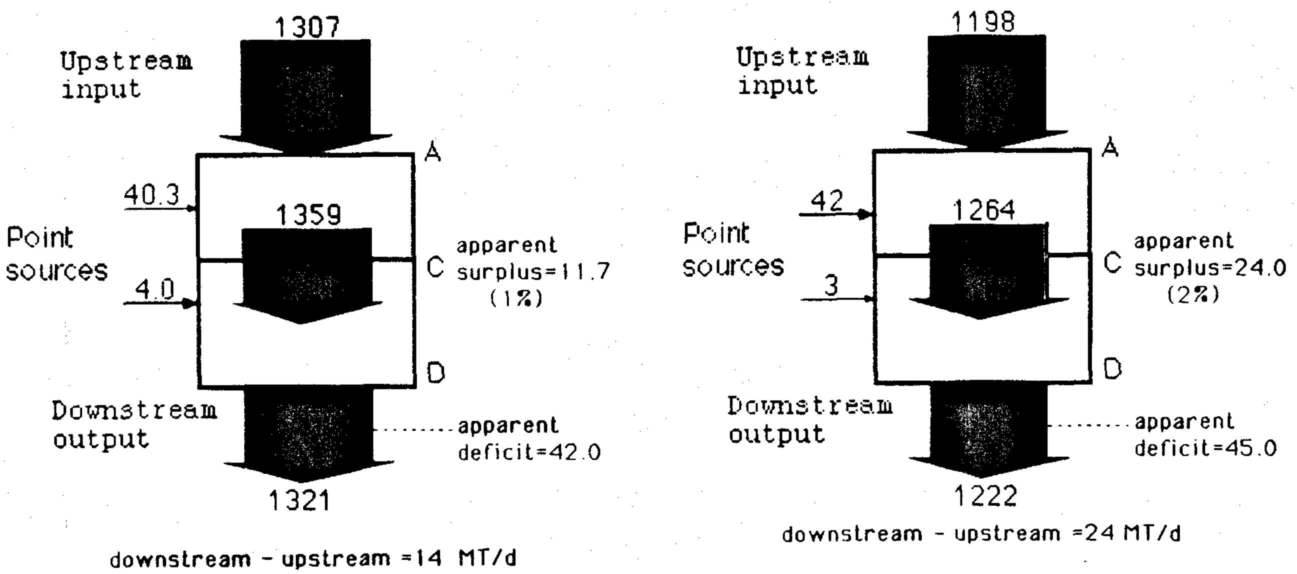
Entire area is not a statistically significant source of cadmium although C-A area is a significant source.

TRENTON CHANNEL SURVEY II

Chloride, Filtered (MT/d)

TRENTON CHANNEL SURVEY III

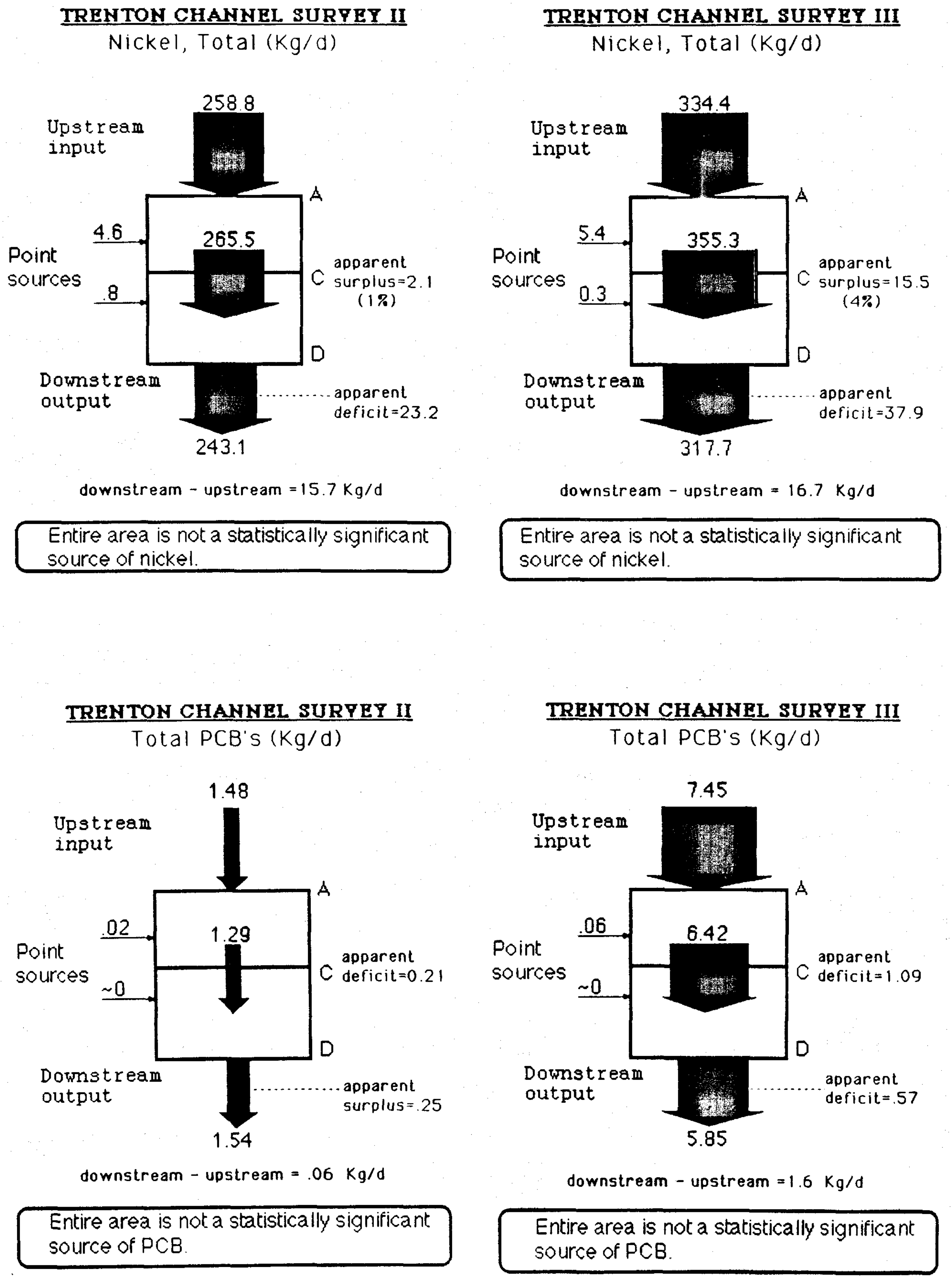
Chloride, Filtered (MT/d)



Entire area is not a statistically significant source of chloride although the C-A area is a significant source.

Entire area is not a statistically significant source of chloride.

FIGURE IX-22. (Cont'd.) Trenton Channel mass balance results.



Survey II, Nickel: downstream - upstream = 15.7 Kg/d

Entire area is not a statistically significant source of nickel.

Survey III, Nickel: downstream - upstream = 16.7 Kg/d

Entire area is not a statistically significant source of nickel.

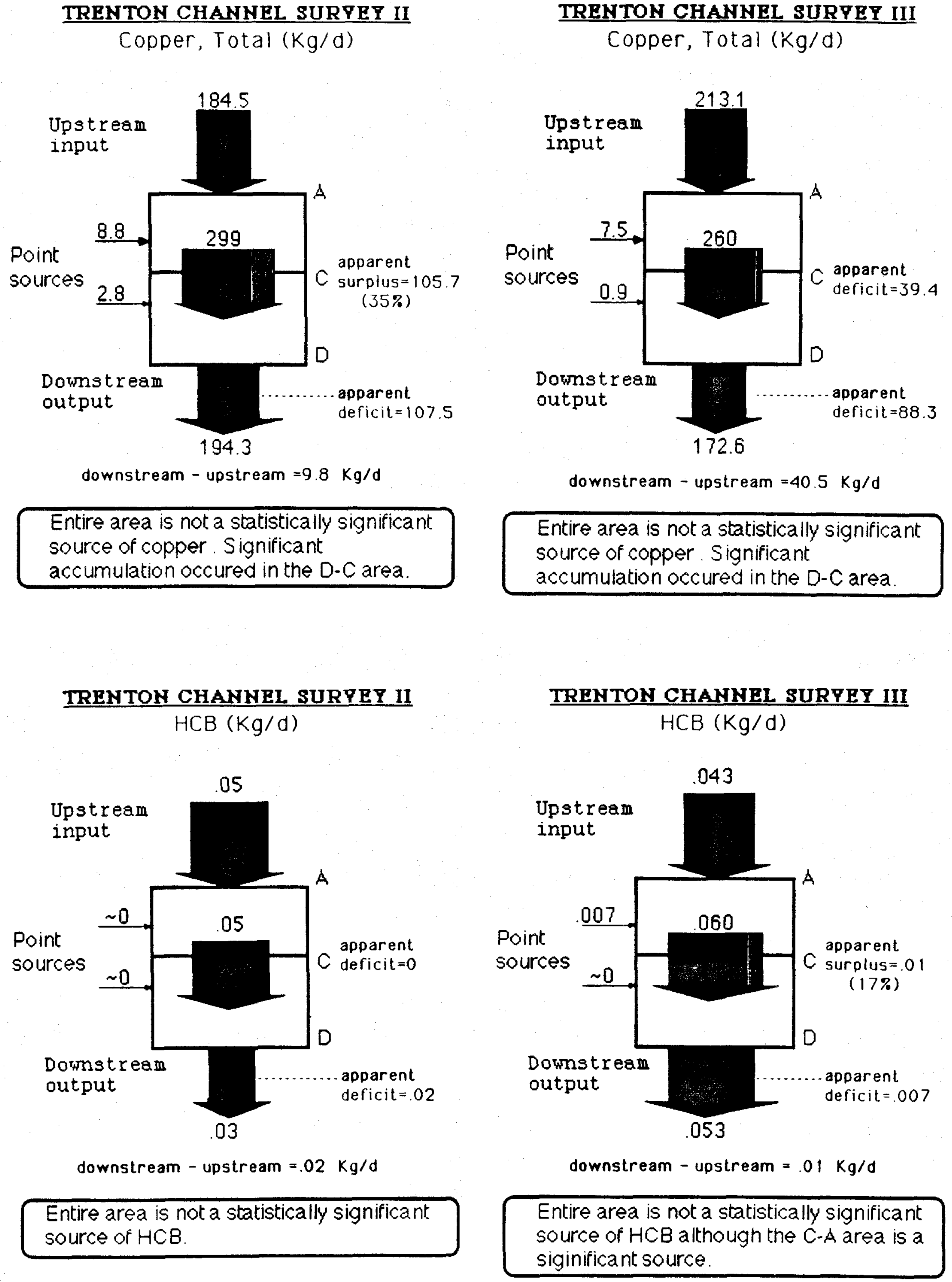
Survey II, PCB's: downstream - upstream = .06 Kg/d

Entire area is not a statistically significant source of PCB.

Survey III, PCB's: downstream - upstream = 1.6 Kg/d

Entire area is not a statistically significant source of PCB.

FIGURE IX-22. (Cont'd.) Trenton Channel mass balance results.



Entire area is not a statistically significant source of copper. Significant accumulation occured in the D-C area.

Entire area is not a statistically significant source of copper. Significant accumulation occured in the D-C area.

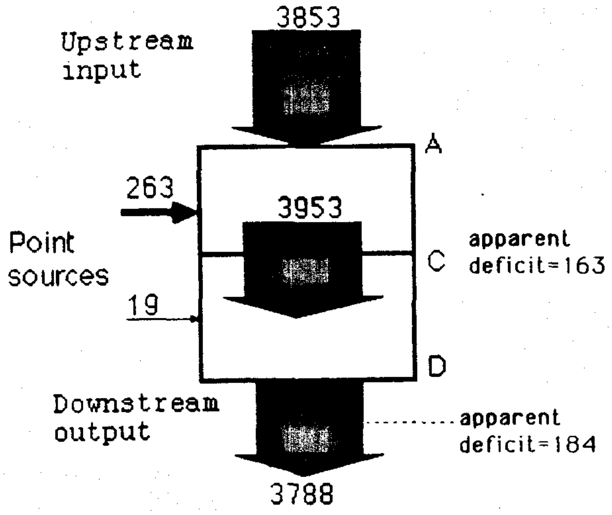
Entire area is not a statistically significant source of HCB.

Entire area is not a statistically significant source of HCB although the C-A area is a siginificant source.

FIGURE IX-22. (Cont'd.) Trenton Channel mass balance results.

TRENTON CHANNEL SURVEY II

Phosphorus, Total (Kg/d)

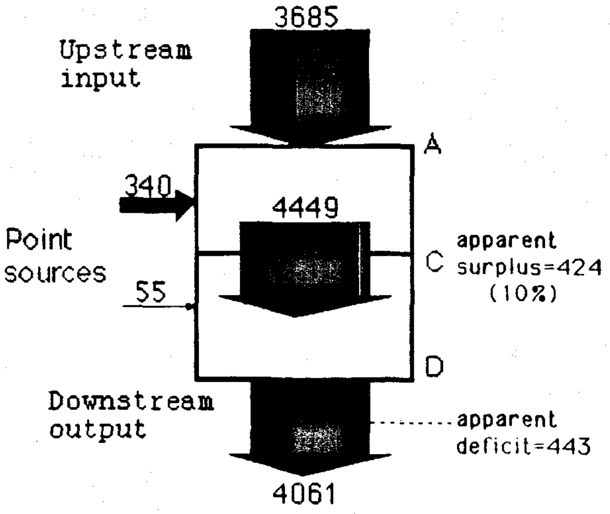


downstream - upstream = 65 Kg/d

Entire area is not a statistically significant source of phosphorus.

TRENTON CHANNEL SURVEY III

Phosphorus, Total (Kg/d)

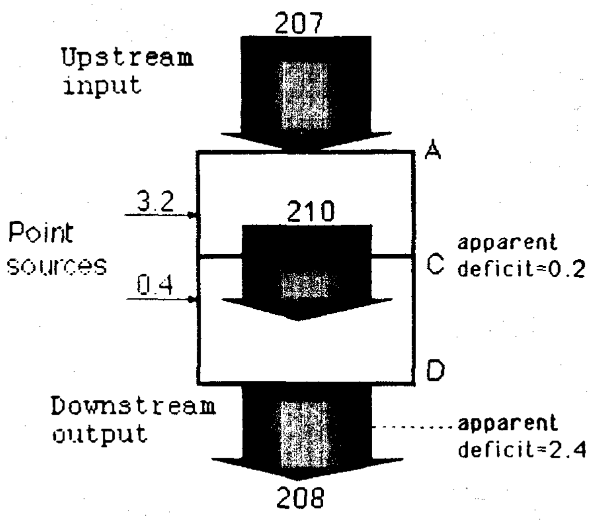


downstream - upstream = 376 Kg/d

Entire area is not a statistically significant source of phosphorus although the C-A area is a significant source.

TRENTON CHANNEL SURVEY III

Silica, Filtered (MT/d)

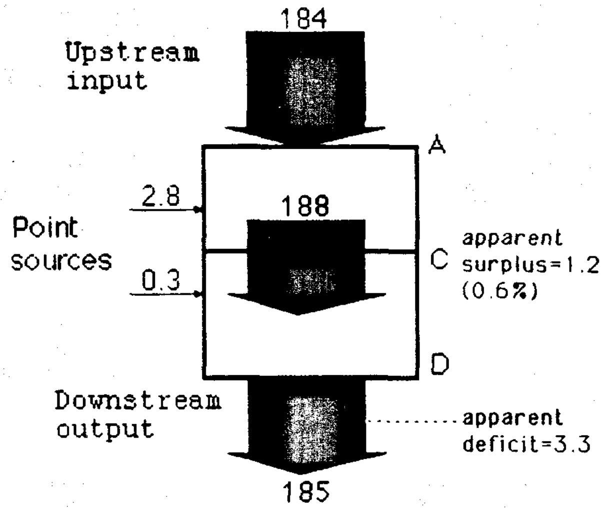


downstream - upstream =1.0 MT/d

Entire area is not a statistically significant source of silica.

TRENTON CHANNEL SURVEY II

Silica, Filtered (MT/d)



downstream - upstream = 1.0 MT/d

Entire area is not a statistically significant source of silica.

FIGURE IX-22. (Cont'd.) Trenton Channel mass balance results.

Detroit River System Mass Balance 1 and 2

The Detroit River System Mass Balance studies 1 and 2 were conducted between April 21 to 29, 1986, and July 25 to August 5, 1986, respectively (30). Sampling transects were located at the head of the Detroit River at Peach Island and the mouth of the Detroit River just downstream of the Grosse Ile bridge (see Figure IX-3). The results of these analyses indicate that the Detroit River is statistically significant source of several heavy metals (Cd, Cu, Pb, Ni and Zn) total phosphorus and PCBs. These data also suggest that some contaminants may be continuing to accumulate in the sediments.

Trenton Channel Mass Balance

The Trenton Channel Mass Balance II and III were conducted between May 6 and 7, 1986, and August 26-27, 1986 (31). Results of these analyses are shown in Figure IX-22. Letters on the right hand side of the diagrams refer to the transects indicated in Figure IX-23. These data suggest that lead and zinc enter the Trenton Channel in significant amounts. The data also suggest that cadmium and copper may also enter the Trenton Channel in significant amounts between certain transects. During the TCMB II, zinc was a source in segment A-C and a sink in segment C-D indicating rapid loss of zinc from the water column, probably to the sediments.

2. Process Modeling

Process oriented models investigate the relative importance of the processes controlling the simulated system to identify needed field measurements and experimental studies. Process models developed for the Detroit River range from physical water movement models to temporal and spatially complex contaminant fate and behaviour models. Verification is difficult without the necessary data, but these models can be used to speculate upon the contaminant fate and organism exposure. Process model output is uncertain because loading information, boundary conditions, initial conditions, and parameter estimates are uncertain. Uncertainty analyses were not completed for these data. Sensitivity analysis helped to identify some parameters and processes needing further research to improve contaminant fate models.

Detroit River, Detroit WWTP Plume Model

A two dimensional hydrodynamic and water quality model of the Detroit River was developed to simulate the impact of the Detroit WWTP effluent on water quality (28). The model contains two independent finite elements, a hydrodynamic model which predicts

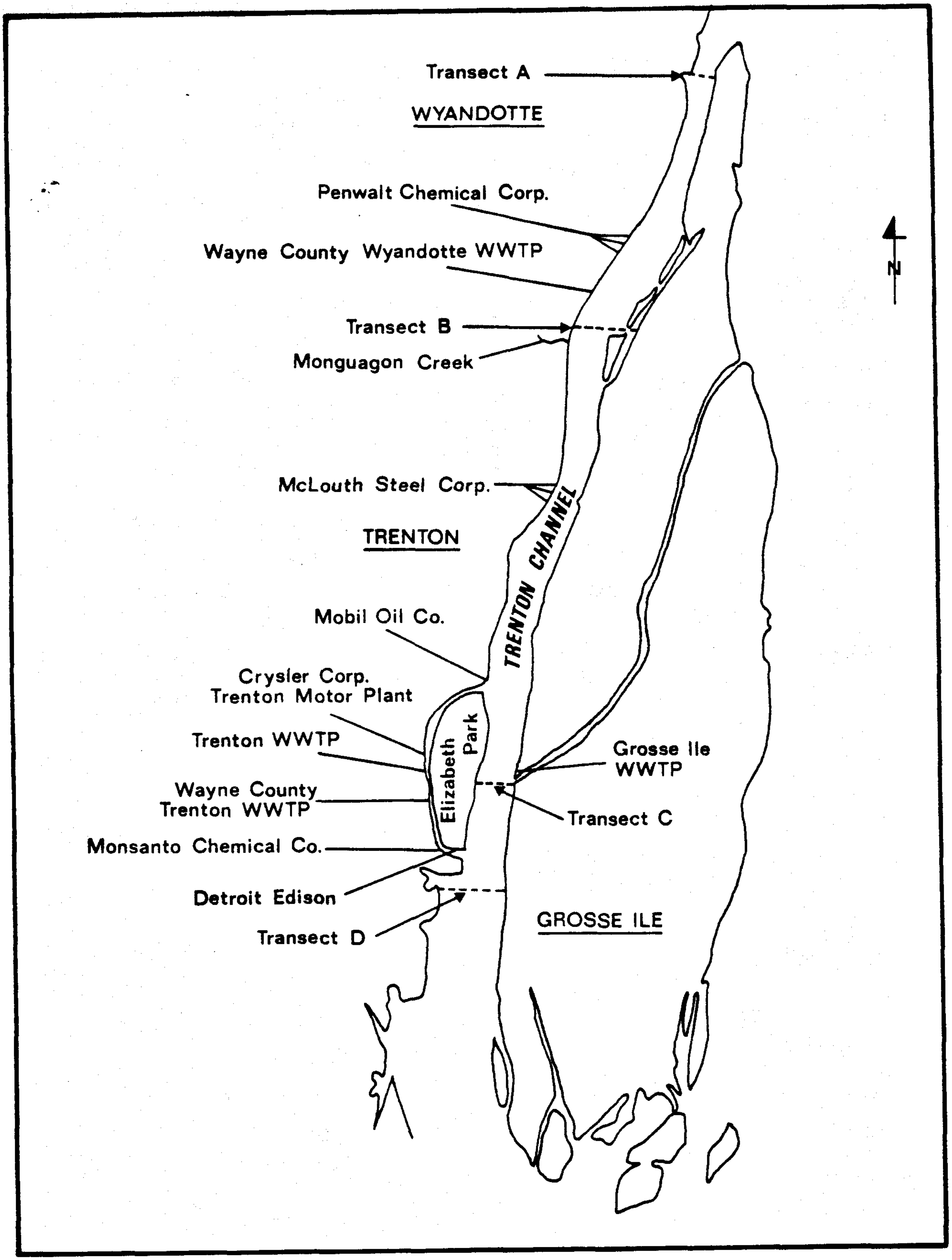


FIGURE IX-23. Major point source dischargers and Trenton Channel mass balance sampling transects, Detroit River (1986).

the two dimensional flow field and river water concentrations and a finite element transport and kinetic model.

The two dimensional model was used because the river is not laterally mixed, has rapidly changing bottom geometry, and flow is divided by islands. The NELEUS TM model simulates and assesses environmental impacts under varied ambient and effluent conditions including 1) two dimensional velocity flow fields; 2) free surface elevations; and 3) flow distribution in individual panels and branches. The contaminant transport component simulates the temporal and two dimensional contaminant concentration distribution using the predicted flow field.

This model was validated with intensive water quality surveys and could provide a basis for evaluating water quality issues from upstream of the Detroit WWTP discharge downstream to the Trenton Channel. The NELEUS TM contaminant transport model was calibrated and verified using survey data from both dye and water quality surveys. Model coefficients were developed for longitudinal and lateral diffusion partitioning coefficients describing the distribution of contaminants between particulates and dissolved fractions, characteristic suspended solids concentrations, settling velocities and decay rates for each contaminant.

Eight effluent management scenarios were chosen by the Detroit WWTP for model evaluation of environmental fate. Results indicate incremental impacts of Detroit WWTP effluent on the Detroit River and the water quality responses to various management alternatives. Although the model made these predictions, unfortunately the results were not compared to Michigan Rule 57(2) allowable levels. Mercury and PCB concentrations would both exceed these levels at all points in the river. In addition, the size of the mixing zone for the Detroit WWTP is currently under review. A reduction in its size will alter the interpretation of model conclusions.

Trenton Channel Transport Model

A transport model is being developed and calibrated for the Trenton Channel using specific conductance as a tracer for toxics. When completed, it will calculate the probability distribution of toxicity in water due to sediment resuspension. The model requires specific locations of toxic sediments, time between resuspension events, magnitude of sediment resuspension and toxicity associated with resuspended materials.

A hypothetical application was developed to predict water column toxicity resulting from sediment resuspension in the Trenton Channel near Monguagon Creek. Introduced toxicity was assumed to remain in the water with no settling occurring. The time between resuspension events were assumed to follow a Poisson distribution. During resuspension, both porewater and suspended solids are scoured into the water column. Resuspension magnitude was assumed to be a random variable described by a log-normal distribution with a median resuspension volume of 4,300 cubic meters of bed material (the top 3 cm).

Toxic unit concentrations were assigned to the resuspension volume. The equivalent mass input of toxicity to the water column was the product of a toxic unit concentration and the resuspension volume. A single sediment concentration determined from the dose response analyses of bioassays from the site were used to describe the site.

Model results for this hypothetical application indicate that sediment resuspension below Monguagon Creek will increase water column toxicity along the western shore of the channel. Toxicity increased as the time between events decreased or as the sediment toxicity increased. An approximately 1:1 relationship existed between sediment toxicity and water column toxicity. Toxicity ranged over several orders of magnitude as a consequence of the large resuspension variability. Resuspension frequency had the largest impact on the aquatic toxicity.

The model predicted a slight overall decline in toxicity between Monguagon Creek and the end of the modeled segment near the bottom of the Trenton Channel.

F. OBJECTIVES AND GOALS FOR REMEDIAL PROGRAMS

By evaluating the specific concerns in the Detroit River identified by this survey, in light of the contaminant input provided by point and nonpoint sources, an overall approach to addressing contaminant inputs can be derived. Remedial programs are to be developed in areas that fail to meet the general or specific objectives of the Great Lakes Water Quality Agreement of 1978, as amended (1987), where such failure has caused or is likely to cause a change in the chemical, physical or biological integrity of the Great Lakes. The general goals and objectives for remediation of the Detroit River and contaminant sources are discussed below. Specific recommendations are provided in Section H.

1. Water Quality

Water quality in the Detroit River, as determined by this study, is generally better than applicable water quality guidelines for most parameters measured. However, there are some exceptions. PCB concentrations exceeded various water quality guidelines throughout the river. Homologue analysis suggests that an active source of PCB exists in the river. Chlorobenzene concentrations in the Detroit River are below the Ontario water quality objective for hexachlorobenzene. However, concentrations of chlorobenzenes at the mouth of the Rouge River exceed this and other guidelines for HCB. A substantial increase in PAH concentration from the head of the Detroit River to the mouth, especially along the Michigan shoreline, indicates an input source. No appropriate ambient water quality guideline exists for total PAHs. Several metals exceeded water quality guidelines throughout, or at specific locations, in the Detroit River, specifically mercury, lead and cadmium.

Objective 1: **Reduction, with the goal of virtual elimination, of industrial and municipal point source inputs of contaminants to the Detroit River which are resulting in exceedences of ambient water quality guidelines.**

Objective 2: **Development of ambient water quality guidelines for contaminants without such guidelines, which are present in the Detroit River water.**

Tributaries of the Detroit River exceeded applicable water quality guidelines for several parameters: the Rouge River (total cadmium, total phosphorus, total zinc, total mercury), the Canard River (total cadmium, total phosphorus, total mercury, total lead), Turkey Creek (total cadmium, total phosphorus, total lead, total mercury, chlorides), the Little River (total cadmium, total phosphorus, total lead, total mercury, total zinc) and the Ecorse River (total phosphorus, total mercury). These tributaries provide inputs of these parameters approaching that provided by point sources. Of all Detroit River tributaries, the Rouge River provides the largest loading of most contaminants.

Objective 3: **Identification of contaminant input sources to tributaries of the Detroit River, and reduction, with the goal of virtual elimination, of such inputs.**

Contaminants in the Detroit River may have occurred, in part, through the discharge of groundwater contaminated by waste disposal sites or underground injection wells. Actual loadings of contaminants from groundwater were not obtained. However, confirmed or possible contamination sites within the Detroit River groundwater discharge areas were identified. The information was inadequate to assess the impact of the site on the Detroit River.

Objective 4: **Verification of groundwater contamination from waste sites or underground injection wells which threaten the ecosystem quality of the Detroit River, and removal or control of wastes and resulting contaminated groundwater.**

Detroit WWTP combined sewer overflows (CSOs) were a major contributor (>10%) of PCBs, total mercury, oil and grease, total cadmium, total chromium, total lead, total copper and total phosphorus to the Detroit River. About 55% of the CSOs discharge directly into the Detroit River and about 40% discharge to the Rouge River.

Objective 5: **Eliminate the impact of City of Detroit CSOs on water quality of the Detroit River and its tributaries.**

Limited information on Windsor urban runoff to the Detroit River suggests that urban runoff (stormwater) may be a source of certain contaminants. While stormwater runoff from many municipalities in and around Detroit is treated at the Detroit WWTP through its combined sewer system, other municipalities (Wyandotte, Trenton and Riverview) have numerous stormwater discharges to the Detroit River or its tributaries.

Objective 6: **Determine the significance of Michigan urban runoff through monitoring and sampling. Remedial or management action may be required.**

Numerous spills of chemicals, oil and raw sewage to the Detroit River or its tributaries were reported during 1986, which is presumably representative of present day spill incidents. Pennwalt Corporation experienced several chemical spills during 1986; Wickes Manufacturing experienced a spill of nickel salts and chromic acid; large volumes of raw sewage were spilled from

Michigan, as well. Information regarding spills is inadequate and incomplete, providing no information on spill volume or constituents, making impact assessment difficult.

Objective 7: Ensure that accurate and complete spill incident reports are maintained at the appropriate agencies, to allow proper remediation, enforcement and preventive measures to be taken.

To protect human health, there are periodic beach closings along the Detroit River, due to elevated bacterial concentrations. Standards and guidelines for fecal coliform bacteria concentrations have been exceeded in the Detroit River.

Objective 8: Ensure that the Detroit River water is of high quality to permit total body contact without deleterious human health impacts.

2. Sediments

Detroit River sediments, especially on the Michigan side and particularly in the Trenton Channel, contain elevated concentrations of several contaminants. Concentrations of PCBs, cyanide, oil and grease, cadmium, zinc, mercury, lead, copper, nickel, iron, chromium, arsenic, manganese, total phosphorus and nitrogen exceed dredging guidelines at various river locations. Sediments also contain concentrations of contaminants, such as total phenols and total PAHs, for which no guidelines exist. Other chemicals, such as pesticides, phthalates and volatile chemicals, were also found.

Objective 9: Reduction, with virtual elimination as a goal, of industrial and municipal point source inputs of contaminants resulting in sediment contaminant concentrations exceeding dredging guidelines.

Objective 10: Reduction, with virtual elimination as a goal, of nonpoint sources of contaminants (tributaries, urban runoff, waste sites, CSOs, spills) resulting in sediment concentrations exceeding dredging guidelines.

Objective 11: Determination of the areal and vertical extent of seriously contaminated sediments, to permit classification and prioritization of sediment remediation.

Objective 12: Development of sediment criteria based on aquatic life health effects and other pertinent parameters for contaminants found in the Detroit River which do not currently have such guidelines.

Certain Detroit River sediments, sediment porewater and near-bottom water were toxic to benthic and/or pelagic organisms. Nearshore Trenton Channel sediment porewater was toxic in bacterial luminescence assays. Sediment extracts were mutagenic in the Ames test, particularly those from Trenton Channel and the lower river, near Lake Erie. Comparable toxicity was demonstrated in *Daphnia pulicaria* feeding studies, *Daphnia magna* acute toxicity tests, *Ceriodaphnia* reproduction assays, *Chironomus tentans* growth tests, and others. Studies on the effect of Detroit River sediments and sediment porewater on feeding rates of larval channel catfish and on toxicity to rainbow trout eggs confirms sediment toxicity to fish species, as well. The greatest degree of toxicity was invariably found in Trenton Channel sediments.

Objective 13: **Eliminate sediments in the Trenton Channel and elsewhere in the Detroit River which are toxic to benthic and pelagic organisms. Work presently taking place to determine the specific reasons for degradation and toxicity to benthic organisms should be supported.**

Contaminated Detroit River dredged materials require disposal in confined disposal facilities and, in some cases, hazardous waste landfills. Costs for such disposal are high, and may result in future restrictions on recreational and other uses of the Detroit River.

Objective 14: **Anticipate future dredging rates through planning and prioritization, and identify potential disposal sites.**

3. Biota and Habitat

There is currently a Michigan consumption advisory for carp due to elevated body burdens of PCBs. OMOE has also issued a fish consumption advisory for certain sizes of rock bass, freshwater drum, and walleye for mercury, and carp for PCBs. PCBs were found in young-of-the-year spottail shiners at highest concentrations in the lower, western reach of the river (Trenton Channel and below) and near Grassy Island (by the Ecorse River), indicating localized Michigan inputs.

Objective 15: **Reduction of contaminant concentrations in Detroit River fish tissue to eliminate all fish consumption advisories.**

Objective 16: **Reduction, with the goal of virtual elimination, of industrial and municipal point sources of contaminants to the Detroit River which are bioaccumulative in aquatic biota, and have or may result in fish consumption advisories.**

Objective 17: **Elimination of nonpoint sources of PCB, mercury and other persistent, bioaccumulative compounds to the Detroit River which have or may result in fish consumption advisories.**

Caged and native clams in the Detroit River contained elevated concentrations of several contaminants: PAHs, HCB, OCS, lead and cadmium. No consumption advisories or other guidelines exist for these chemicals in aquatic biota tissue, except for lead (Ontario). Although Detroit River clams are not a common food source for humans, they are for certain wildlife.

Objective 18: **Determination of the importance of clams as a wildlife food source and the impact of contaminants contained in clam tissue on wildlife health.**

Serious impacts to waterfowl, wildlife and fish, and their habitats, have occurred in the Detroit River. Waterfowl, some tern species, and their eggs contain high concentrations of persistent compounds (PCB, DDT and other organochlorine compounds), affecting organism health, reproduction and survival. Oral/dermal tumors and liver tumors are present in brown bullhead, walleye, white sucker and other species in the lower Detroit River.

Objective 19: **Identification of the chemicals responsible for such impacts on fish, wildlife and aquatic life, and the virtual elimination of point and nonpoint source inputs of these contaminants.**

Objective 20: **Development of consumption advisories for waterfowl and wildlife to protect human consumers of these organisms.**

Bulkheading and/or backfilling of wetlands, littoral zones, bayous and small embayments in the Detroit River, especially in the Trenton Channel, have resulted in extensive losses of spawning grounds and nursery areas for desirable fish, and has prevented use by waterfowl, aquatic mammals and other aquatic organisms. The fish community has changed over time resulting in losses of coldwater species. Channel dredging near the turn of the century destroyed whitefish spawning habitat near the mouth of the Ecorse River. In addition to providing habitat, wetlands also serve to remove contaminants by natural filtering.

Objective 21: **Preservation and enhancement of existing fish and wildlife habitats, and development of new habitats. Maintenance of the Wyandotte National Wildlife Refuge and protection of Grassy Island need to be enhanced to encourage wildlife, especially waterfowl.**

4. Other Issues

The contribution made by atmospheric deposition of contaminants to the Detroit River system was not examined by this study. Certain contaminants affecting the Detroit River system may be contributed, in part, through atmospheric deposition, such as lead (auto exhaust) and cadmium (steel industries). Loadings of these contaminants were often relatively high for rural and urban runoff, suggesting a diffuse source.

Objective 22: **Determine the significance of atmospheric deposition as a contaminant input mechanism in the Detroit River system, identification of contaminant origins and reduction of such input to its lowest achievable level.**

G. ADEQUACY OF EXISTING PROGRAMS AND REMEDIAL OPTIONS

1. Projection of Ecosystem Quality Based on Present Control Programs

Trend Analysis

The general media quality and aesthetics of the Detroit River have improved over recent years. However, a number of particular concerns remain.

Generally, water in the Detroit River is of a higher quality than in the recent past. However, in the present survey, concentrations of a number of contaminants and conventional pollutants increased from the head to the mouth of the Detroit River, although the statistical significance of these increases is not known. Other conventional water quality parameters, including ammonia and phenols, were found to have declining trends. Ammonia concentrations have decreased by approximately 50% between 1969 and 1981. Data on chloride concentration in the river indicate that although sources still exist on both sides, especially in the lower river, concentrations and loadings have declined from 1969 to 1981 (30).

Sediment contamination in the Detroit River is continuous along the Michigan shoreline and appears to be localized near known sources along the Ontario shoreline (39). Trend data from 1970 to 1980 indicate levels of mercury in sediments have decreased, in part a result of improvements in industrial treatment facilities (e.g. replacement of mercury cells by diaphragm cells at chlor-alkali plants at Wyandotte) (39). Results of two sediment studies indicated that mercury contamination is higher in surficial sediments than in the deeper layers, suggesting that there may still be active sources (76). Significant increases in sediment levels of cadmium, chromium, copper, lead, nickel, and zinc were noted near the mouth of the Rouge River from 1970 to 1980, suggesting recent inputs.

Data on contaminant levels in fish from the Detroit River is insufficient to determine trends for many chemicals; however, some research has been done with young-of-the-year spottail shiners, which are sensitive biomonitors for organochlorine compounds. High PCB residue accumulations were found in spottail shiners along the Michigan shoreline in the lower Detroit River, suggesting the continuing presence of inputs of biologically available PCBs to the river. DDT residues were found, but consisted of metabolites only, indicating that use restrictions have effectively reduced DDT inputs to the river. Chlordane residues were elevated in all spottail shiner samples from urban areas compared to rural collections (45).

Fish consumption advisories are currently in effect for rock bass, freshwater drum, walleye and carp due to mercury or PCB contamination (46,47). Population studies of bottom fauna have shown organisms characteristic of higher water quality are increasing in some areas, but degraded benthic macroinvertebrate populations are present especially on the Michigan side of the river (39).

2. Assessment of Technical Adequacy of Control Programs

Adequacy of Present Technology

i) Municipal Wastewater Treatment Facilities

There are five municipal waste water treatment plants in Ontario and six in Michigan which discharge into the Detroit River. The levels of treatment vary, but all have phosphorus removal. The facilities which provided inputs of contaminants of concern are discussed below.

The Detroit WWTP provides secondary treatment (activated sludge) for up to 3,047 x 10^3 m^3/day of wastes tributary to the combined sewer system. During wet weather periods, incremental flows above 3,047 x 10^3 m^3/day are provided primary treatment and disinfection prior to discharge to the Detroit River. Secondary effluent is combined with any primary effluent and discharged to the Detroit River at a rate determined by river elevation and the portion of flow receiving secondary treatment. Combined sewers discharge directly to the Rouge and Detroit rivers when the hydraulic capacity of the system is exceeded. About 284 x 10^3 m^3/day of wastewater flow is generated by industrial indirect dischargers. Presently, there are no data available on the percentage of industries which are in compliance with the Industrial Pretreatment Program since the program is new. The Detroit WWTP facility was generally in compliance with its NPDES permit during 1986, which was confirmed by 1986 wastewater survey. The present technology is adequate to control the facility's regulated and monitored parameters based on existing water quality criteria. The Detroit WWTP's permit is scheduled for reissuance in 1989 and some facility upgrading may be required.

The Wayne County-Wyandotte WWTP is a pure oxygen, activated sludge facility with a design capacity of 375 x 10^3 m^3/day. The Wayne County-Wyandotte WWTP and the South Huron Valley WWTP (which discharges into Lake Erie) jointly have an Industrial Pretreatment Program. In 1986, the facility exceeded its NPDES monthly average permit limitation for total suspended solids (4 of 12 months), and exceeded its fecal coliform monthly average limitation for all 12 months of the year. A 1986 wastewater survey indicated the facility was in compliance with NPDES permit at the time of the survey. For the purposes of controlling the facility's regulated parameters, the present technology is not adequate, since exceedences of permit limitations have occurred. As of December 1988, this facility is being sued in federal court for permit and schedule violations. A consent decree is being negotiated. The facility has begun construction on two new clarifiers in its treatment system and is planning additional repairs.

The Wayne County-Trenton WWTP is operated as a primary treatment facility with a design capacity of 13 x 10^3 m^3/day. Treated wastewater was discharged to the Elizabeth Park Canal, a tributary of the Trenton Channel. This facility served a separate sewer system, with no combined sewer discharges to the Detroit River. This facility was in significant noncompliance with its total suspended solids monthly average loading limitation (5 of 12 months), total phosphorus monthly average concentration limit (6 of 12 months) and fecal coliform monthly average concentration limit (8 of 12 months) during 1986. The 1986 wastewater survey indicated the facility met the NPDES final effluent limitations at the time of the survey. For the purposes of controlling the facility's regulated parameters, the technology was not adequate. This facility has been decommissioned (as of December 1988). Flows are being directed to the new South Huron Valley WWTP, which discharges directly into Lake Erie.

The City of Trenton WWTP is an activated sludge secondary treatment system with an average daily flow of 22 x 10^3 m^3/day, and is discharged to the Elizabeth Park Canal. The City of Trenton has an approved Industrial Pretreatment Program with 9 major participants. Wastewater flow generated by these industries is approximately 5.3 x 10^3 m^3/day. In 1986, this facility was in noncompliance for BOD concentration and loading limits (5 of 12 months), total suspended solids concentration and loading limits (5 of 12 months), total phosphorus monthly average concentration (5 of 12 months), and dissolved oxygen minimum concentration (8 of 12 months). A wastewater survey conducted in 1987 showed this facility to be in noncompliance with its NPDES permit limitations for dissolved oxygen, and concentrations of other parameters (BOD_5, phosphorus, suspended solids and fecal coliforms) were higher than would be desired (the permit does not have daily maximum limits for these parameters, so noncompliance cannot be construed). For the purposes of controlling the facility's regulated parameters, the present technology is not adequate, since exceedences of effluent limitations have occurred. No federal action has been taken against this facility, as of December 1988, however, the state has notified the facility of its noncompliance status.

The West Windsor WWTP currently uses a physical-chemical treatment process with a capacity of 160 x 10^3 m^3/day. The Windsor catchments receive a large quantity of industrial wastewater. However, sampling data indicate concentrations compare favorably with concentrations in less industrialized catchments. This facility was in compliance with its effluent requirements for BOD_5 and suspended solids during 1985 and 1986.

ii) Industrial Point Sources

The UGLCCS Point Source Workgroup identified seventeen Michigan and four Ontario industries as major point source dischargers into the Detroit River (directly or indirectly). These industries include automotive, chemical, cement and steel, and were presented in Table IX-4.

It is not practicable to discuss the technology used at each industrial facility. The Point Source Workgroup Report (6) should be consulted for such detail. However, the attainment (or lack) of effluent limitations provides insight into the adequacy of the technology used. Eleven of the Michigan facilities were in general compliance with their 1986 NPDES Permits (Table IX-4), one facility did not have a permit (Ford-Wayne Assembly Plant; but institution of one is being considered), and another facility began discharging to a sanitary sewer as a result of problems meeting its permit effluent limits (Chrysler-Trenton Engine Plant). For the purposes of controlling contaminants at regulated levels, the technology employed at most Michigan industrial facilities appear to be adequate.

Of the three Ontario industrial facilities surveyed, only one fully met the Ontario Industrial Effluent Objectives during 1985 and 1986. Ford Canada exceeded total suspended solids and phenol objectives, and Wickes Manufacturing exceeded total suspended solids and nickel objectives. The present technology at Wickes Manufacturing and Ford Canada does not appear to be adequate to control certain parameters with industrial effluent objectives.

Adequacy of Best Available Technology

The best available technology economically achievable (BAT) for every industrial and municipal sector has not yet been defined, although some U.S.industries have BAT in place. The U.S.EPA and the OMOE (through its MISA program) are currently developing BAT for various sectors.

3. Assessment of Regulatory Adequacy

Adequacy of Present Laws and Regulations

Existing legislation in the United States, Canada, Michigan and Ontario addressing ecosystem quality of the Detroit River has been discussed elsewhere in this report (Chapter III). Many acts, regulations and programs are currently in place, addressing the control of point and nonpoint sources of contaminants, management of solid and hazardous waste, acceptable contaminant concentrations in various media, and other environmental concerns. Despite the considerable, and often complex, collection of laws and regulations, serious contamination is apparent in the Detroit River system, and exceedences of requirements and guidelines have been documented. This may indicate that the existing legislation is inadequate, or is not properly enforced.

Michigan industrial and municipal point source dischargers in the Detroit River area are generally meeting the effluent limitations set by the state government. Michigan effluent limits address conventional pollutants, such as total suspended solids, and nonconventional or toxic parameters. Unless the facility is out of compliance with effluent limits, contaminants are discharged at concentrations within discharge limits. However, the large volume of effluents results in very large total loadings of contaminants to the river. NPDES permits are reviewed every five years, providing the opportunity to address specific concerns highlighted by the UGLCC Study.

All Michigan municipal facilities impacting the Detroit River receive waste water from industrial facilities. All have some regulatory mechanism for controlling the input of contaminants from industries (the Industrial Pretreatment Program - IPP). However, pretreatment requirements may have not been addressing all contaminants being introduced to the municipal facility, or controlling them adequately, as evidenced by the large loadings of some parameters by the municipal facility. From a practical viewpoint, controlling the influx of contaminants to the municipal facility from industrial facilities is the most effective method of preventing ultimate discharge. The IPP program at each Michigan facility needs to be examined for adequacy and compliance.

Only one Ontario industrial facility studied in the Detroit River area has effluent requirements (General Chemical); the others are encouraged to attain Provincial Industrial Effluent Objectives. The Objectives are nonenforceable goals in and of themselves, although they can be made enforceable through incorporation into Control Orders or Certificates of Approval. Effluent objectives are not consistently being met by all Ontario industrial facilities. In other instances, these Objectives were met, yet impacts in media were seen. For example, General Chemical, Amherstburg was identified as a major contributor of copper to the Detroit River, yet discharged copper at concentrations below the Provincial Industrial Effluent Objective of 1 mg/L. However, high copper concentrations, exceeding dredging guidelines, were found in sediments along the Amherstburg shoreline. This suggests that the Objectives may not be stringent enough, particularly for compounds with sediment binding capabilities.

The West Windsor WWTP was the only Ontario municipal facility identified as a major discharger of contaminants to the Detroit River (total phosphorus). This facility receives industrial waste water, and adheres to the Windsor By-Law (#8319) which regulates the discharge of conventional pollutants, metals and total phenolics to sanitary sewers. Since its total phosphorus discharge was less than 1 mg/L (annual average) in 1985 and 1986, it appears that the By-Law regulations are adequate and effective, in the context of this study.

The new MISA program being implemented by Ontario should improve discharge regulations in the province. Identification of effluent contaminants in specific municipal and industrial sectors will enable the instatement of limits for all potentially harmful contaminants. To be effective, it is necessary for sector requirements to contain both concentration and mass loading limits. Customizing of regulations to fit the industrial sectors should reduce treatment costs and the associated analytical costs for monitoring.

Present regulations and guidelines, particularly in Ontario, are media-specific in scope and do not offer the flexibility needed to address multimedia contamination, as found in the Detroit River system.

Adequacy of Enforcement Authority and Programs

Michigan and Ontario programs which regulate discharges require monitoring and reporting. Facilities are required to inform the regulating agency of all effluent limit exceedences. In addition, audit samples may be obtained by the regulating agency, often with the facility's pre-knowledge. Violations of effluent limitations can be handled in a variety of fashions, ranging from monetary fines to criminal prosecution. Criminal prosecution rarely occurs. Civil and administrative enforcement actions, often involving negotiations between the facility and the regulating agency, are undertaken to ensure future compliance. Adequate enforcement authority for point sources appears to exist; however, strengthening of penalties and an increase in self-monitoring and auditing actions may prevent or hinder exceedences which are occurring.

In the Detroit River, the majority of point source dischargers are in compliance with effluent limitations. The weakness, therefore, does not lie with the authority of the regulatory agencies to enforce effluent limitations. It is more the result of the traditional reliance on concentration based water quality guidelines rather than on total loadings as well as, in many cases, the limited number of parameters with which each facility is legally bound to comply or monitor.

Some Ontario industrial point sources are experiencing exceedences of the Provincial Industrial Effluent Objectives, which are nonenforceable goals for the industrial facilities. Requiring the attainment of the Objectives (or a more stringent value) is a mechanism by which to gain more control over the discharges. The new MISA program will establish effluent requirements which are specific to each industrial sector. Until these become effective, regulation through requirement of effluent objectives appears needed.

Regulations and enforcement authorities are limited or absent for contamination resulting from nonpoint sources.

Adequacy of Governmental and Institutional Authority and Jurisdictions

Federal, state, provincial, and municipal governments have the authority to regulate chemical discharges to the Detroit River. Thus, the lack of authority is not the problem. Ongoing environmental concerns related to chemical contaminants result, in part, from a fragmented approach to controlling discharges. Different priorities among agencies result in a lack of co-ordination and proper long-term planning.

H. RECOMMENDATIONS:

Actions which can result in improvements in ecosystem quality in the Detroit River system are many and varied. Generally, recommendations made for the Detroit River are in four forms: recommendations directed at specific sources which can be implemented with existing regulatory authorities, recommendations which may require process or treatment changes, management issues and applications or other voluntary (as opposed to regulatory) measures, and recommendations which identify further needed research and study.

A. Industrial and Municipal Point Source Remedial Recommendations

1. Ontario and Michigan should incorporate the Great Lakes Water Quality Agreement's goal of the virtual elimination of all persistent toxic substances into their respective regulatory programs.

2. The Detroit WWTP was a major discharger of numerous compounds which impact water, sediment and biota quality in the Detroit River. Contaminant loadings from this facility should be evaluated to ensure compliance with Michigan water quality standards.

   a) In general, contaminant concentrations in the effluent of the Detroit WWTP are low; major loadings result from the large volume and rate of effluent discharged. Control of contaminants may be obtained through the Industrial Pretreatment Program (IPP). The IPP of the Detroit WWTP should be examined and compliance of contributors of industrial waste water should be determined. The adequacy of the pretreatment requirements should be assessed. Pretreatment requirements should be assessed to determine if parameters of concern in the Detroit River system are adequately regulated. A notice of violation was issued (September 1988) to the Detroit WWTP for problems found in its IPP program.

   b) The Detroit WWTP currently performs secondary treatment on a large portion of its effluent. During wet weather flow, some effluent receives only primary treatment prior to being mixed with secondary treated effluent and discharged. Metals and organics which may be contained on suspended solids not removed in primary treatment are of concern. The City of Detroit should complete its studies of treatment plant capacities started in 1985 and upgrade its treatment process to provide secondary treatment for all effluent.

   c) The effluent limitations contained in the Detroit WWTP NPDES permit should be re-examined in light of the findings of this study to ensure compliance with Michigan water quality standards. Consideration should be given to increasing the number of parameters monitored by the permit. All effluent limitations should be the lowest technically feasible. Bioassays of the effluent to determine both acute and chronic impacts to aquatic organisms should be considered as a condition of the permit. The Detroit WWTP NPDES permit is scheduled for reissuance in 1989.

3. **The Wayne County-Wyandotte WWTP was a major discharger of** numerous compounds which impact water, sediment and biota quality in the Detroit River. Although the facility was generally in compliance with its effluent limitations, the NPDES permit monitors very few parameters found to be of concern in the Detroit River.

   In general, contaminant concentrations in the effluent of the Wayne County-Wyandotte WWTP are low; major loadings result from the large volume and rate of effluent discharged. Control of contaminants may be obtained through the Industrial Pretreatment Program (IPP). The IPP of the Wayne County-Wyandotte WWTP should be examined. The compliance of industrial contributors should be determined, and the adequacy of the pretreatment requirements should be assessed. Pretreatment requirements should be considered for all parameters of concern in the Detroit River system which are being discharged by the industrial dischargers. Contaminant loadings from this facility should be evaluated to ensure compliance with Michigan water quality standards and BAT requirements.

4. **The City of Trenton WWTP exceeded its permit limitations for** regulated parameters. The treatment provided by this facility should be examined and upgraded to ensure compliance with effluent requirements.

5. **Several industrial facilities were identified as major dis**chargers of parameters that impact media quality in the Detroit River. These facilities are presented below with a discussion of facility-specific issues.

   a) Rouge Steel was a major contributor of total iron, total copper, total lead, total zinc, and oil and grease to the Detroit River, chemicals which were present in the sediments at concentrations exceeding dredging guidelines. Rouge Steel was the major contributor of total PAHs and a source of total phenols which were found in sediments, but have no sediment dredging or quality guidelines. Rouge Steel's NPDES permits do not regulate total PAHs nor monitor iron or copper. The discharge of these 3 parameters should be evaluated to ensure compliance with Michigan water quality standards and BAT requirements. Rouge Steel was in compliance with its permit limitations for total lead (applicable at 3 of 11 outfalls), total zinc (applicable at 3 outfalls), total phenols (applicable at one outfall) and oil and grease (applicable at two outfalls). Considerable amounts of phenol were discharged from outfalls not monitored for phenol, and oil and grease were also discharged from nonregulated outfalls. Discharge of total phenols and oil and grease from all outfalls should be reduced to ensure compliance with Michigan water quality standards and BAT requirements.

b) Ford Canada was a major contributor of total lead, total zinc, PCBs and total phenols, chemicals which impact the Detroit River system. The stretch of river downstream of Ford Canada (sediment subarea 2) had the highest average sediment concentration of PCBs. Sources other than Ford Canada were suggested, but Ford Canada cannot be ruled out as a source. All sources of PCBs should be identified and eliminated. High total phenol, total lead and total zinc concentrations in sediments were also found in subarea 2. This facility met the Ontario Industrial Effluent Objective for lead and zinc of 1 mg/L, but exceeded the Ontario Industrial Effluent Objective of 20 ug/L for total phenols by a substantial amount during the survey (almost two orders of magnitude). Discharge of total phenols should be reduced to ensure compliance with the Ontario Industrial Effluent Objective. Discharges of PCBs should be reduced to the lowest level technologically achievable.

c) Wickes Manufacturing was a major contributor of chromium to the Detroit River, and discharged nickel, as well. High bottom and suspended sediment concentrations of chromium were found in Little River, to which Wickes Manufacturing discharges. Wickes Manufacturing did not meet the Ontario Industrial Effluent Objective for chromium during the survey. Nickel impacted Detroit River sediments in the upper (as well as lower) Detroit River. High water concentrations of nickel were also found in the Little River. Wickes Manufacturing did not achieve the effluent objective for nickel eight times during 1985 and 1986, in addition to exceeding it during the survey. Discharges of chromium and nickel should be reduced to ensure consistent attainment of the Ontario Industrial Effluent Objective. An effluent requirement should be developed for Wickes Manufacturing at the lowest level technologically feasible.

d) McLouth Steel-Trenton was a major contributor of zinc, iron, HCB and oil and grease, chemicals which impact the Detroit River system. Of these, McLouth Steel-Trenton has an effluent limitation for oil and grease, with which it was in compliance. This facility has no effluent monitoring requirements for zinc, iron or HCB. Such effluent monitoring should be considered for McLouth Steel-Trenton.

e) General Chemical, Amherstburg was a major discharger of copper to the Detroit River. High copper sediment concentrations were found adjacent to Amherstburg. Since the time of the point source survey, General Chemical has split into two distinct companies, Allied Chemical and General Chemical. The two new companies should be surveyed to determine the extent of present day copper discharge, and contingent upon the results, remedial action taken. General Chemical was also a major source of chlorides to the Detroit River; however, the lower Detroit River transect measuring water quality was upstream of General Chemical and did not reflect the facility's impact on water quality. Although no impacts due to elevated concentrations of chlorides were noted during this study, the potential for an increase in halophilic organisms exists. Additional surveys downstream of the General Chemical complex outfalls should be performed to determine if such a shift in organisms has occurred.

f) Great Lakes Steel-Ecorse and Great Lakes Steel-80" Mill both contributed large loadings of oil and grease to the Detroit River, pollutants found to be impacting sediments in the Detroit River. Both facilities have effluent limitations for oil and grease; both were in compliance with these limits in 1986. Consideration should be given to instituting more stringent effluent limitations for oil and grease at these facilities.

B. Nonpoint Source Remedial Recommendations

6. The extent of contaminant input to the Detroit River system resulting from Detroit WWTP combined sewer overflows is largely unknown, although some estimates have been made. Information available suggests that contaminant inputs may be substantial. The required study on the Detroit WWTP CSOs (order issued September 1988) should be expedited, and an area-wide remediation plan should be developed. Upgrading of the Detroit sewer system by increasing treatment capacities of the facility and eventually separating storm and sanitary sewer to eliminate CSOs should be undertaken.

7. Due to the significance of the Rouge River as a source of loadings of organic and inorganic substances to the Detroit River, the Rouge River Remedial Action Plan should be developed and implemented as expeditiously as possible. The implementation of recommendations for the Clinton and St. Clair Rivers' RAPs will also assist remediation efforts for the Detroit River.

8. Confirmed or possible groundwater contamination sites within the Detroit River discharge area were identified for this

study. Extensive recommendations were made for these sites by the Nonpoint Source Workgroup. The main focus of the Workgroup's recommendations are:

a) Zug Island Great Lakes Steel: MDNR should perform a site visit to clarify the facilities' proper RCRA status, to perform sampling of monitoring wells, to determine the contaminant release to groundwater and to provide information for rescoring of the site for the National Priorities List (NPL) using the new Hazard Ranking System (HRS).

b) Federal Marine Terminal Properties: U.S.EPA should monitor site closure to assess closure impacts and to study groundwater discharge to surface water.

c) Industrial Landfill (Firestone): This site should be rescored for the NPL using data generated by the UGLCC Study and other current studies.

d) Michigan Consolidated Gas-Riverside Park: Remedial action proposed by the company should be reviewed to assess its adequacy in controlling groundwater discharge to surface water.

e) BASF/Wyandotte South Works and Chrysler-Trenton: Prompt assessment of site waste operations should be performed by MDNR. Determination of any contaminant releases to groundwater and/or surface water should be made.

f) BASF/Wyandotte North Works, Monsanto Company, Huron Valley Steel Corp and Jones Chemical: Prompt performance of a RCRA Facility Assessment should be undertaken by the U.S.EPA, utilizing data generated by the UGLCC Study and other current studies.

g) Edward C. Levy Co, Trenton Plant and Plant #3: The U.S.EPA should monitor the Consent Agreement and Final Order signed by the facility to ensure compliance. Data generated for the UGLCC Study should be used in the evaluation of the recently performed RCRA Facility Assessment.

h) Pennwalt and Petrochemical Processing: Data generated for the UGLCC Study should be used in the evaluation of the recently performed RCRA Facility Assessment.

9. The integrity of the abandoned underground injection wells at Pennwalt and BASF/Wyandotte should be evaluated through a U.S.EPA inspection to determine if injection of spent waste into caverns at Grosse Ile has led to releases.

10. Michigan and Ontario should develop a five year strategy aimed at reducing spill occurrences and improving spill

responses within their jurisdictions. Spill reports from the Michigan Pollution Emergency Alerting System (PEAS), the Ontario Spills Action Centre (SAC) and other agencies should be enhanced to provide accurate information on spill volume and composition, recovery and resolution. Facilities which experience frequent spills should be required to develop stricter spill management plans. Michigan and Ontario should prepare a yearly spill report for public release and for submission to the IJC, to stimulate interaction and follow-up, and to ensure appropriate enforcement and preventive measures.

11. Use of phosphorus and nitrogen fertilizers on agricultural lands and handling of livestock manure in both Ontario and Michigan need to be conservatively managed. Federal, state and provincial environmental and agricultural agencies need to collaborate to develop a comprehensive soil and water management system to reduce impacts on ecosystem quality from these activities. Education on the proper use and application of fertilizers should be provided to farmers, and measures, such as conservation tillage and proper livestock waste management, should be encouraged to ensure minimal loss of phosphorus, nitrogen and other associated chemicals from agricultural lands.

12. The extent of required dredging and remediation of sediments in the Detroit River and its tributaries should be planned and prioritized. To do this, estimations of the volume of sediments required to be removed should be made, and an overall plan for handling these materials should be developed. Financial requirements for such plans should be analyzed, and incorporated into future agency commitments.

C. Surveys, Research and Development

13. Tributaries to the Detroit River were found to provide major loadings of several contaminants, particularly metals and total phosphorus (not all UGLCC Study parameters were analyzed). A thorough investigation of the Rouge, Little, Canard and Ecorse Rivers, Turkey and Monguagon Creeks, and the Frank and Poet Drain, if not presently being performed, should be undertaken. An inventory of all point source dischargers to the tributaries, and an assessment of all nonpoint contaminant inputs (urban and rural runoff, waste sites/contaminated groundwater, spills, CSOs, etc.) should be performed. Water, sediment and biota quality in these tributaries should be determined for the full stretch of the tributary. For tributaries where extensive investigation is presently being undertaken, information provided by this study should be used to supplement ongoing work.

14. A study of the significance of atmospheric deposition of contaminants as a contaminant input mechanism should be undertaken, in conjunction with a survey and evaluation of point sources of atmospheric emissions to the Great Lakes basin.

15. Ambient water quality guidelines for total PAHs need to be developed and adopted, along with guidelines for specific PAH compounds (e.g., benzo[a]pyrene) known to be of importance. Further research on the effects of individual and total PAHs in water on a variety of aquatic species is needed for guideline development.

16. The importance of clams as a food source for wildlife and waterfowl, and the effect of clam flesh contaminants on such wildlife should be studied.

17. Consumption advisories for waterfowl and wildlife should be developed as necessary by federal, state and provincial public health agencies, for the protection of human consumers of these animals.

18. Contaminant concentrations in other biota, such as muskrats which are consumed by native populations, should be determined, and the need for consumption advisories considered.

19. Studies to determine the cause/effect linkages of Detroit River contaminants to waterfowl and fish need to be performed.

20. Fish and wildlife habitats along the Detroit River should be protected to the greatest extent possible. The extent of filling or bulkheading of wetlands should be reduced. Remedial plans should be developed for those habitats which are severely impacted, and/or alternative habitats developed to accommodate displaced wildlife.

21. Sediment bioassays should be used to make site-specific determinations of sediment quality. Dischargers responsible for contaminated sediments should be required to conduct bioassays of these contaminated sediments to determine possible impacts. The need for acute and chronic bioassays on the effluent should be considered for all point source discharges to the Detroit River.

22. Development of sediment criteria for organic contaminants found in Detroit River sediments, specifically total phenols and total PAHs, is needed to assess the level of sediment contamination. The U.S.EPA is intending to develop such criteria; such development should be expedited.

23. A study of the significance and impact of urban runoff from Michigan municipalities should be performed. The study should be performed in a manner similar to that of the Ontario study, for comparability purposes. Contingent on the results, remedial and management action may be necessary.

24. The role played by sinkholes and carbonate solution channels on Point Hennepin in the transport of contaminants from these disposal sites should be investigated.

D. Management Strategy for Remedial Programs

25. Further regulatory actions in this Area of Concern must be co-ordinated among the various agencies and governments responsible. They should also be developed utilizing a long-term planning framework.

26. Regulatory actions must take multi-media and synergistic concerns into account with regard to contaminant management.

The correction of long-term contamination requires that contaminant sources be significantly controlled by requiring a reduction in the use of hazardous materials, or by ceasing to use hazardous materials altogether. However, limited control provided by regulation over many of the sources of contamination prevents this encompassing approach. Although regulations provide limited control over permitted discharges of industrial process and cooling water, minimum or no legal control over sources such as stormwater, combined sewer overflows, tributary loadings, contaminated groundwater, atmospheric deposition, contaminated sediments, spills from vessels, "midnight dumpers", hidden outfalls and others, is provided.

In the past, attempts to control most contaminants originating from point sources have relied upon NPDES permits, Certificates of Approval, control orders, notices of noncompliance or court orders, and have partially succeeded. For other chemicals, elimination or restrictions on production, use or sales (e.g., PCBs, DDT) have been implemented. These control methods have resulted in varying degrees of reduction of these chemicals in the environment. Once persistent and bioaccumulative chemicals are in the environment, options for control are limited to remediation or isolation of the contaminated medium, and monitoring of the environmental effects.

For the Detroit River and its tributaries, loading data dictate that the highest priority for contaminant source control is the direct regulation of point sources through NPDES permits and the MISA program. More stringent and extensive effluent limits need to be placed upon those facilities impacting the Detroit River system, to reduce the discharge of toxic chemicals, and should be expressed in terms of both concentrations and mass loadings.

The second priority is urban combined sewer overflow (CSO) control, as CSOs discharge untreated industrial and sanitary waste directly to sensitive areas of the river. Combined sewer systems in the Detroit River area receiving industrial process wastewater need to be controlled so that contaminants do not reach the river untreated.

Containing, purging and treating contaminated groundwater before discharge to the Detroit River or its tributaries is the third priority. Groundwater contaminant loadings to the river were not determined, but based on the number of Michigan contaminated groundwater sites along the Detroit River and its tributaries, Michigan is likely a major source of contaminants through groundwater inputs. A plan must be developed to identify, isolate and treat these contaminated groundwater discharges.

The fourth priority is identification and reduction of atmospheric loadings of contaminants from all sources.

The remaining sources mentioned above (other than sediments) are more difficult to control, since they are generally nonpoint in origin, and are less amenable to immediate, regulatory control. However, control of nonpoint sources of contaminants is an equal priority.

The extent of contaminant transfer from sediments to the water column and biota is unknown, since complex chemical, physical and biological factors influence these interactions. However, adverse impacts on biota have been shown. Remediation of contaminated Detroit River sediments is a difficult task. Detroit River depositional sediments have a pudding-like consistency and are not amenable to burial or coverage. Solidification and chemical treatment are also not practical alternatives for in-place sediment control. Although expensive and having the potential to release contaminants to the environment during the process, dredging of severely contaminated sediments may be the only method to reduce sediment contaminant loadings to the water column and biota and to restore impaired uses in the Detroit River.

I. LONG TERM MONITORING

1. Purposes for Monitoring and Relationships Between UGLCCS and Other Monitoring Programs.

The purposes for monitoring and surveillance are included under Annex 11 of the GLWQA, and considerations are found in Chapter 7 of the Report of the Niagara River Toxics Committee (91). The focus of the UGLCC Study was to determine where problems in the ecosystem exist and how to remedy the problem. Long term monitoring recommendations focus on trends in environmental quality to assess the effectiveness of remedial actions. Monitoring should be sufficient to 1) detect system-wide trends noted by the UGLCCS, and 2) detect changes resulting from specific remedial actions.

The Great Lakes International Surveillance Plan (GLISP) and the Remedial Action Plans (RAPs) also contain plans for long term monitoring. The GLISP for the Upper Great Lakes Connecting Channels is incomplete, pending results of the UGLCC Study. The Detroit River RAP being developed jointly by Michigan and Ontario will list impaired uses, sources of contaminants, specific remedial actions, schedules for implementation, resources permitted by Michigan and Ontario, target cleanup levels and monitoring requirements. Results from this study will be incorporated into the RAP, and will influence state and provincial Detroit River programs.

2. System Monitoring for Contaminants

Water

The principal Detroit River contaminants indicate general trends, exposure levels and contaminant impacts on biota. Parameters to be monitored include PCBs, chlorobenzenes (HCB), PAHs, oil and grease, total phenols, total volatiles, mercury, cadmium, chromium, cobalt, copper, iron, nickel, lead, zinc, total phosphorus, ammonia, suspended solids and chlorides. Monitoring stations should be located where elevated concentrations are known or predicted, including downstream of the Detroit WWTP, and Rouge River, Little River, Turkey Creek, Canard River, Ecorse River and within the Trenton Channel. Sampling locations may include horizontal and vertical distributions. Sampling frequency should bracket contaminant variability and flow fluctuations.

A mass balance approach will help identify changes in the contaminant masses over time, and target future remedial actions. It should be conducted about once every five years, assuming remedial actions have been implemented. Locations to be measured should include:

1) Head and mouth transects. The dissolved and particulate fractions and quantity of suspended sediment flux should be measured. Chemical water monitoring locations in the Detroit River should be expanded as needed for conventional pollutants, to isolate localized significant sources. Metals and organic contaminants should be added to the list of parameters measured, and appropriately low detection levels should be used. Detroit River shorelines, beaches and marinas should be monitored for evidence of human sanitary waste. The present human health sanitary waste indicator is fecal coliform bacteria, but development of a better indicator of human health wastes is needed.

2) Municipal and industrial point sources. Monitor frequently enough to calculate accurate loadings from the major point sources, including the Detroit WWTP, Wayne County-Wyandotte WWTP, McLouth Steel, Rouge Steel, Ford Canada, General Chemical, West Windsor WWTP, and Wickes Manufacturing.

3) Tributary monitoring efforts should focus on seasonal and storm event loadings from the Ecorse, Rouge, Canard and Little Rivers and Turkey Creek for dissolved and sediment associated contaminants. Best management practices should be initiated in the Detroit River tributary watersheds to more effectively manage flow, contaminants and sediment sources.

4) CSOs and urban runoff. Estimates of CSOs and contaminant loadings from Detroit and Windsor urban runoff should be repeated. Contaminant loadings should be estimated for the Riverview and Trenton storm sewers. Sewer sediments should be monitored to locate significant PCB sources to the Detroit WWTP and CSOs. Track PCBs upstream within the sewer system to isolate areas or facilities contributing PCBs. Monitor outfalls and overflows to determine loading reductions.

5) The quantity and quality of groundwater inflow from waste disposal sites adjacent to the Detroit River and its tributaries should be determined. The well drilling initiated during the UGLCCS should be expanded to determine the amount and severity of contaminated groundwater entering the Detroit River from identified CERCLA and 307 sites. The study should be designed to measure contaminated groundwater entering the river without requiring access to the shoreline property. Studies should be initiated to determine the types and amounts of materials disposed of in the Point Hennepin and Fighting Island sites, and their effects on the Detroit River. Eliminate (excavate and/or secure) the sources of ground and surface water contamination in these landfills.

6) Studies indicate that bed load sediments carry contaminant masses similar to other sources, and that mass flux should be quantified. The quantity of contaminants being desorbed from sediments should also be quantified.

7) Direct atmospheric deposition to the Detroit River is minor, but deposition within the drainage basin could be an important source of wet and dry contaminants, and estimates should be made. Expand and enforce local air monitoring efforts in the Detroit RIver watershed to isolate local sources.

Sediments

Sediment monitoring should be conducted every five years in conjunction with the biota survey to assess trends and movement of contaminants within the river. Analyses should include bulk chemistry for organic and inorganic contaminants and particle size distribution. Particular attention should be given to PCBs, PAHs, phenols, phthalates, oil and grease, and heavy metals. Sediment stations at tributary mouths should be monitored for organic and inorganic contaminants on a biannual basis if remedial actions occur. A suite of bioassays should be performed in conjunction with these chemical analyses to determine the impact these sediments are having on Detroit River biota. A map of the areal extent of Detroit River sediment contamination and one characterizing areas that are or may be toxic to aquatic life need to be developed. These maps will allow identification of areas needing to be dredged.

Biota

Long term monitoring of contaminants in biota will track contaminants in representative organisms. Three programs already exist in the Detroit River:

i) Sport fish monitoring

This program should focus on persistent, bioaccumulative chemicals, such as PCBs, mercury and other contaminants (e.g. dioxins and dibenzofurans) known or suspected of being human health hazards. Important sport species that have an extended river residence time should be sampled. Monitoring should continue beyond the point that action levels are met. Monitoring of chemical contaminants in fish livers and recording of tumors and other deformities should be done while making fish community and chemical contaminant assessments. Studies to determine the causes of tumors and reproductive problems need to be initiated for the Detroit River.

ii) Spottail shiner monitoring

This program is designed to identify local sources of bioavailable contaminants. Where spottail shiners contained elevated levels of contaminants, sources of the contaminants should be identified. Spottails should also be used to demonstrate results of remedial actions.

iii) Caged clams monitoring.

Caged clams should be used to monitor results of remedial actions. Clams may be located at tributary mouths and downstream of suspected source areas. Repeated assays at the same locations should confirm the results. A series of caged fish or clams should be placed along the Detroit River to identify inputs of persistent, bioaccumulative contaminants.

iv) Benthic Macroinvertebrate Community

The Detroit River benthic community should be quantitatively assessed every five years to monitor results of remedial actions. Sampling should be based on grid or sediment type patterns to be consistent between years. Selected persistent compound levels in benthic organisms should be monitored.

v) Waterfowl and Wildlife

Waterfowl and wildlife communities should be monitored for lowered reproduction rates, tumors and other deformities. The causes of any deformities or tumors need to be determined. Contaminant levels in flesh, livers, eggs and/or young should be determined.

vi) Ecological Significance and Interaction

Biological surveys should be designed within each tributary watershed or ecoregion to determine if there are ecosystem problems. Biological monitoring should be performed to isolate problem areas within the ecoregion, and efforts should be focused where problems have been identified. Studies should be designed to determine fish and wildlife species composition, life history, habitat requirements, movement, and spawning and nesting sites for fish and wildlife in the Detroit River ecosystem, and interactions and interdependency among these communities should be defined.

3. Habitat Monitoring

Habitat monitoring should detect and describe changes in the Detroit River ecological characteristics through periodic analysis of key ecosystem elements. The following items are recommended:

a) The abundance and distribution of Hexagenia should be determined every five years. The U.S. Fish and Wildlife Service grid used during 1985 would be appropriate. Bulk sediment chemistry, organic and inorganic contaminants, particle size analyses and a suite of bioassays should be conducted on samples taken concurrently with the Hexagenia survey.

b) Quantification of the extent of Detroit River wetlands should be conducted every five years, along with the Hexagenia survey. Aerial photography or remote sensing could discern emergent and submergent macrophyte beds important to larval fish and wildlife. Verification of aerial data should be conducted by inspection of selected transects for plant species identification and abundance. Changes in wetlands should be correlated with water level fluctuations and other natural documentable influences so that long term alterations in wetlands can be tracked and causes identified.

4. Sources Monitoring for Results of Specific Remedial Actions

Remedial actions intended to reduce contaminants from point sources require compliance monitoring. Attention must be given to sampling schedules and analytical methods. Nearfield monitoring should be conducted regularly to document contaminant reductions and recovery of impaired communities. Monitoring may be required for a "long time" in a limited area, depending on impact severity and degree of contaminant reduction that is achieved.

The following ten specific sources are recommended for contaminant monitoring:

- Detroit WWTP (PCBs, heavy metals, volatile organics, phenols, ammonia, oil and grease, cyanide, total phosphorus)
- Wayne County-Wyandotte WWTP (PCBs, heavy metals, volatile organics, ammonia, total phosphorus, total suspended solids, fecal coliform bacteria)
- City of Trenton WWTP (suspended solids, BOD, total phosphorus, dissolved oxygen)
- West Windsor WWTP (total phosphorus)
- McLouth Steel-Trenton (oil and grease, zinc, phenol, iron)
- Great Lakes Steel-Ecorse Mill (oil and grease)
- Ford Canada (phenols, heavy metals, PCBs)

- Wickes Manufacturing (chromium, nickel)
- General Chemical (chloride, copper)
- Rouge Steel (heavy metals, PAHs, phenols, oil and grease)

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APPENDIX 1

Lists of Committee, Workgroup, Task Force and Area Synthesis Team Members

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1984 to 1988

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++ St. Clair River (level 3) geographic report was written by B. G. Oliver and W. R. Swain, Eco Logic Inc.

APPENDIX II

GLOSSARY AND UNITS OF MEASURE

MEASUREMENTS & UNITS

mg/L = milligram per liter = part per million (ppm)*

ug/L = microgram per liter = part per billion (ppb)*

ng/L = nanogram per liter = part per trillion (ppt)*
(one trillenth part of a gram)

pg/L = picograms per litre = part per quadrillion (ppq)

ug/g = microgram per gram = part per million (ppm)

mg/kg = milligram per kilogram = part per million (ppm)

ug/kg = microgram per kilogram = part per billion (ppb)

ng/kg = nanogram per kilogram = part per trillion (ppt)

L/d = liter per day

m^3/d = cubic meters per day

mgd = millions of gallons per day

cfs = cubic feet per second

m^3/s = cubic meters per second

kg/d = kilograms per day

lbs/d = pounds per day

kg/yr = kilograms per year

t/yr = tonnes per year

uS/cm = microsiemens per centimeter (conductivity)

EQUIVALENT UNITS

meter = m 1m = 3.281 feet

kilometer = km 1 km = 0.621 miles

gram = g 1000 g = 1 kg = 2.205 pounds

tonne = t 1 t = 2,205 pounds

liter = L 1 L = 0.2642 gal (U.S.) = 0.2200 gal (Can.)

CONVERSION TABLES

To Convert	Multiply By	To Obtain
acres	4.047×10^{-1}	hectares
acres	4.047×10^{3}	sq. meters
centimeters	3.937×10^{-1}	inches
centimeters	1.094×10^{-2}	yards
feet	3.048×10^{-1}	meters
gallons (Imp.)	1.20095	gallons (U.S.)
gallons (U.S.)	8.3267×10^{-1}	gallons (Imp.)
gallons (U.S.)	3.785	liters
gallons (Imp.)	4.542	liters
grams	1.0×10^{-3}	kilograms
grams	3.527×10^{-2}	ounces
grams	2.205×10^{3}	pounds
hectares	2.471	acres
inches	2.540	centimeters
kilograms	1.0×10^{3}	grams
kilograms	2.2046	pounds
kilograms	3.5274×10^{1}	ounces
kilometers	6.214×10^{-1}	miles
kilometers	1.0936×10^{3}	yards
kilometers	3.2808×10^{3}	feet

To Convert	Multiply By	To Obtain
liters (U.S.liquid)	2.642×10^{-1}	gallons
liters	2.201×10^{-1}	gallons (Imp)
meters	3.281	feet
meters	6.214×10^{-4}	miles
meters	1.094	yards
miles	1.609	kilometers
milligrams/liter	1.0	parts/million
ounces	2.8349×10^{1}	grams
ounces (fluid)	2.957×10^{-2}	liters
parts/million gal.	8.354	pounds/million
pounds	4.5359×10^{2}	grams
pounds	4.536×10^{-1}	kilograms
square feet	9.29×10^{-2}	sq. meters
square inches	6.452×10^{2}	sq millimeters
square kilometers	2.471×10^{2}	acres
square kilometers	1.076×10^{7}	sq. ft.
square kilometers	3.861×10^{-1}	sq. miles
square meters	2.471×10^{-4}	acres
temperature ^{o}C	$(^{o}C \times 9/5)+32$	temperature ^{o}F
temperature ^{o}F	$(^{o}F-32) \times 5/9$	temperature ^{o}C
yards	9.144×10^{1}	centimeters
yards	9.144×10^{-4}	kilometers
yards	9.144×10^{-1}	meters

ACRONYMS

ADI	Acceptable Daily Intake: The dose that is anticipated to be without risk to humans when taken daily. It is not assumed that this dose guarantees absolute safety. The determination of the ADI is often based on the application of laboratory animal toxicity data concerning chronic (long-term) doses to the environmental doses to which humans are exposed.
AOC(s)	Areas of Concern: Geographic locations recognized by the International Joint Commission where water, sediment or fish quality are degraded, and the objectives of the Great Lakes Water Quality Agreement of local environmental standards are not being achieved.
BaP	Benzo-a-Pyrene
BAT	Best Available Technology/Treatment
BATEA	Best Available Technology/Treatment Economically Achievable
BCF	Bioconcentration Factor; the ratio of the concentration of a particular substance in an organism to concentration in water.
BCT	Best Conventional Technology.
BEJ	Best Engineering Judgement.
BHC	Benzene Hexachloride or Hexachlorocyclohexane. There are three isomers; alpha, beta, and gamma. Gamma-BHC is the insecticide lindane.
BOD	Biochemical Oxygen Demand: The amount of dissolved oxygen consumed during the decomposition of organic nutrients in water during a controlled period and temperature.
COA	Canada-Ontario Agreement Respecting Water Quality in the Great Lakes.
COD	Chemical Oxygen Demand: The amount of oxygen required to oxidize completely by chemical reagents the oxidizable compounds in an environmental sample.
CofA	Certificate of Approval

CSO	Combined Sewer Overflow; combined storm and sanitary sewer systems.
DCB	Dichlorobenzene
DDD	A natural breakdown product of DDT.
DDE	Dichlorodiphenyldichloroethylene. A natural breakdown product DDT.
DDT	Dichlorodiphenyltrichloroethane: A widely used, very persistent chlorinated pesticide (now banned from production and use in many countries).
DFO	Department of Fisheries and Oceans (Canada)
DOA	Department of Agriculture (Canada)
DOE/EC	Department of Environment/Environment Canada
EC-50	Effective concentration of a substance producing a defined response in 50% of a test population. The higher the EC-50, the less effective the substance is because it requires more material to elicit the desired response.
EP/OR	Environmental Protection, Ontario Region, Environment Canada
EPA	United States Environmental Protection Agency
GLISP	Great Lakes International Surveillance Plan. It provides monitoring and surveillance guidance to U.S. and Canadian agencies responsible for implementing the provisions of the GLWQA that include general surveillance and research needs as well as monitoring for results of remedial actions.
GLWQA	Great Lakes Water Quality Agreement
HCB	Hexachlorobenzene
HCBD	Hexachlorobutadiene
HCE	Hexachloroethane
IJC	International Joint Commission: A binational organization established in 1909 by the Boundary Waters Treaty. Through the IJC, Canada and the United States cooperatively resolve problems along their common border, including water and air pollution, lake levels, power generation and other issues of mutual concern.

LC_{50}	Lethal concentration (by volume) of a toxicant or effluent which is lethal to 50% of the test organism over a specified time period. The higher the LC_{50}, the less toxic it is because it takes more toxicant to elicit the same response.
LD_{50}	Lethal dose which is lethal to 50% of the test organism over a specified time period. The higher the LD_{50}, the less toxic it is because it takes more toxicant to elicit the same response.
MDNR	Michigan Department of Natural Resources
MISA	Municipal-Industrial Strategy for Abatement: The principal goal of this program is the virtual elimination of toxics discharged from point sources to surface waters in Ontario.
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System; a permit system limiting municipal and industrial discharges, administered by U.S.EPA and the states.
NTU	Nephelometric Turbidity Unit
OCS	Octachlorostyrene
OMNR	Ontario Ministry of Natural Resources
OMOE	Ontario Ministry of the Environment/Environment Ontario
PAH	Polynuclear Aromatic Hydrocarbons, also known as Polycyclic Aromatic Hydrocarbons or Polyaromatic Hydrocarbons. Aromatic Hydrocarbons composed of at least 2 fused benzene rings, many of which are potential or suspected carcinogens.
PBB	Polybromated biphenyl; used primarily as a fire retardant.
PCB	Polychlorinated biphenyls; a class of persistent organic chemicals with a potential to bioaccumulate and suspected carcinogens; a family of chemically inert compounds, having the properties of low flammability and volatility and high electric insulation quality. Past applications include use as hydraulic fluids, heat exchange and dielectric fluids; plastisizers for plastics.

pH	The negative power to the base 10 of the hydrogen ion concentration. A measure of acidity or alkalinity of water on a scale from 0 to 14; 7 is neutral; low numbers indicate acidic conditions, high numbers, alkaline.
QCB	Pentachlorobenzene
POTW	Publicly Owned Treatment Works
PTS	Persistent Toxic Substance: Any toxic substance with a half-life in water of greater than eight weeks.
RAP	Remedial Action Plan: This is a plan to be developed with citizen involvement to restore and protect water quality at each of the 42 Areas of Concern in the Great Lakes Basin. The RAP will identify impaired uses, sources of contaminants, desired use goals, target clean-up levels, specific remedial options, schedules for implementation, resource commitments by Michigan and Ontario as well as by the federal governments, municipalities and industries, and monitoring requirements to assess the effectiveness of the remedial options implemented.
SPDES	State Pollutant Discharge Elimination System; a state administered permit limiting municipal and industrial dischargers.
STP	Sewage Treatment Plant
TCB	Trichlorobenzene
TCDD	Tetrachlorodiebenzo-p-dioxins
TCDF	Tetrachlorodibenzofurans
TOTAL DDT	Sum of DDT isomers and metabolites
UGLCCS	Upper Great Lakes Connecting Channels Study
U.S.EPA	United States Environmental Protection Agency
WHO	World Health Organization
WPCP	Water Pollution Control Plant
WTP	Water Treatment Plant (for drinking water)
WWTP	Waste Water Treatment Plan

TERMINOLOGY

ABSORPTION	Penetration of one substance into the body of another.
ACCLIMATION	Physiological and behavioural adjustments of an organism in response to a change in environment. See also Adaptation.
ACCLIMATIZATION	Acclimation of a particular species over several generations in response to marked environmental changes.
ACCUMULATION	Storage and concentration of a chemical in tissue to an amount higher than intake of the chemical. May also apply to the storage and concentration of a chemical in aquatic sediments to levels above those that are present in the water column.
ACUTE	Involving a stimulus severe enough to rapidly induce a response; in bioassay tests, a response observed within 96 hours is typically considered an acute one.
ACUTE TOXICITY	Mortality that is produced within a short period of time, usually 24 to 96 hours.
ADAPTATION	Change in the structure forms or habits of an organism to better fit changed or existing environmental conditions. See also Acclimation.
ADSORPTION	The taking up of one substance at the surface of another.
AEROBIC	The condition associated with the presence of free oxygen in the environment.
ALGA(E)	Simple one celled or many celled micro-organisms, usually free floating, capable of carrying on photosynthesis in aquatic ecosystems.
ALGICIDE	A specific chemical highly toxic to algae. Algicides are often applied to water to control nuisance algal blooms.
ALKALINITY	A measurement of acid neutralization or buffering capability of a solution (See pH).
AMBIENT	An encompassing atmosphere.
AMBIENT WATER	The water column or surface water as opposed to groundwaters or sediments.

AMPULES	A sealed glass container of a know concentration of a substance.
ANADROMOUS	Species which migrate from salt water to fresh water to breed.
ANAEROBE	An organism for whose life processes a complete or nearly complete absence of oxygen is essential.
ANOXIA	The absence of oxygen necessary for sustaining most life. In aquatic ecosystems this refers to the absence of dissolved oxygen in water.
ANTAGONISM	Reduction of the effect of one substance because of the introduction or presence of another substance; e.g. one substance may hinder, or counteract, the toxic influence of another. See also Synergism.
APPLICATION FACTOR	A factor applied to a short-term or acute toxicity test to estimate a concentration of waste that would be safe in a receiving water.
AQUATIC	Living in water.
ASSIMILATION	The absorption, transfer and incorporation of substances (e.g. nutrients by an organism or ecosystem).
ASSIMILATIVE CAPACITY	The ability of a waterbody to transform and/or incorporate substances (e.g. nutrients) by the ecosystem, such that the water quality does not degrade below a predetermined level.
BENTHIC	Of or living on or in the bottom of a water body; benthic region, benthos.
BENTHOS	Bottom dwelling organisms, the benthos comprise: 1) sessile animals such as sponges, some of the worms and many attached algae; 2) creeping forms such as snails and flatworms, and 3) burrowing forms which include most clams and worms, mayflies and midges.
BIOACCUMULATION	Uptake and retention of environmental substances by an organism from both its environment (i.e. directly from the water) and its food.
BIOASSAY	A determination of the concentration or dose of a given material necessary to affect a test organism under stated conditions.

BIOCONCENTRATION	The ability of an organism to concentrate substances within its body at concentrations greater than in its surrounding environment or food.
BIOCONCENTRATION FACTOR	The ratio of the measured residue within an organism compared to the residue of the substance in the ambient air, water or soil environment of the organism.
BIOLOGICAL MAGNIFICATION	The concentration of a chemical up the food chain.
BIOMASS	Total dry weight of all organisms in a given area or volume.
BIOMONITORING	The use of organisms to test the toxic effects of substances in effluent discharges as well as the chronic toxicity of low level pollutants in the ambient aquatic environment.
BIOTA	Species of all the plants and animals occurring within a certain area or region.
CARCINOGEN	Cancer causing chemicals or substances.
CHIRONOMID	Any of a family of midges that lack piercing mouth parts.
CHRONIC	Involving a stimulus that lingers or continues for a long period of time, often one/tenth of the life span or more.
CHRONIC TOXICITY	Toxicity marked by a long duration, that produces an adverse effect on organisms. The end result of chronic toxicity can be death although the usual effects are sublethal; e.g. inhibits reproduction or growth. These effects are reflected by changes in the productivity and population structure of the community. See also Acute Toxicity.
COMMUNITY	Group of populations of plants and animals in a given place; ecological unit used in a broad sense to include groups of various sizes and degrees of integration.
CONGENER	A member of the same taxonomic genus as another plant or animal: Also a different configuration or mixture of a specific chemical usually having radical groups attached in numerous potential locations.

CONTAMINANT	A substance foreign to a natural system or present at unnatural concentrations.
CONTAMINATION	The introduction of pathogenic or undesirable micro-organisms, toxic and other deleterious substances which renders potable water, air, soils, or biota unfit for use.
CONTROL ORDER/REQUIREMENT AND DIRECTION ORDER	Enforceable orders in Ontario.
CONVENTIONAL POLLUTANT	A term which includes nutrients, substances which pollutant consume oxygen upon decomposition, materials which produce an oily sludge deposit, and bacteria. Conventional pollutants include phosphorous, nitrogen, chemical oxygen demand, biochemical oxygen demand, oil and grease, volatile solids, and total and fecal coliform, chlorides, etc.
CRITERIA	Numerical limits of pollutants established to protect specific water uses.
CRITERION, WATER QUALITY	A designated concentration of a constituent based on scientific judgments, that, when not exceeded will protect an organism, a community of organisms, or a prescribed water use with an adequate degree of safety.
CRITICAL LEVEL	See Threshold.
CRITICAL RANGE	In bioassays the range of magnitude of any factor between the maximum level of concentration at which no organisms responds (frequently mortality) to the minimum level or concentration at which all organisms respond under a given set of conditions.
CUMULATIVE	Brought about or increased in strength by successive additions.
CUMULATIVE ACTION	Increasingly severe effects due to either storage or concentration of a substance within the organism.
DENSITY	Number of individuals in relation to the space.
DETRITUS	A product of disintegration, defecation, destruction, or wearing away.
DIATOM	Any of a class of minute planktonic unicellular or colonial algae with silicified skeletons.

DIOXIN	A group of approximately 75 chemicals of the chlorinated dibenzodioxin family, including 2, 3, 7, 8 - tetrachlorodibenzo-para-dioxin (2,3,7,8 - TCDD) which is generally considered the most toxic form.
DISSOLVED OXYGEN	The amount of oxygen dissolved in water.
DRAINAGE BASIN	A waterway and the land area drained by it.
DREDGE SPOILS	The material removed from the river, lake, or harbour bottom during dredging operations.
DREDGING GUIDELINES	Procedural directions designed to minimize the adverse effects of shoreline and underwater excavation with primary emphasis on the concentrations of toxic materials within the dredge spoils.
ECOSYSTEM	The interacting complex of living organisms and their non-living environment; the biotic community and its abiotic environment.
EFFLUENT	Contaminated waters discharged from facilities to either wastewater sewers or to surface waters.
ENVIRONMENT	All the biotic and abiotic factors that actually affect an individual organism at any point in its life cycle.
EPHEMERAL	A plant that grows, flowers, and dies in a few days.
EPHEMERA	Invertebrates (mayflies) that live as adults only a very short time.
EPILIMNION	The warm, upper layer of water in a lake that occurs during summer stratification.
EROSION	The wearing away and transportation of soils, rocks and dissolved minerals from the land surface, shorelines, or river bottom by rainfall, running water, wave and current action.
EUTROPHICATION	The process of nutrient enrichment that causes high productivity and biomass in an aquatic ecosystem. Eutrophication can be a natural process so it can be a cultural process accelerated by an increase of nutrient loading to a waterbody by human activity.

<u>EXOTIC SPECIES</u>	Species that are not native to the Great Lakes and have been intentionally or inadvertently introduced into the system.
<u>FACULTATIVE</u>	Exhibiting a broad lifestyle which allows it to survive under a broad range of environmental conditions.
<u>FOODCHAIN</u>	The process by which organisms in higher trophic levels gain energy by consuming organisms at lower trophic levels; the dependence for food of organisms upon others in a series, beginning with plants and ending with the largest carnivores.
<u>GOAL</u>	An aim or objective towards which to strive; it may represent an ideal condition that is difficult, if not impossible to attain economically.
<u>GREAT LAKES BASIN ECOSYSTEM</u>	The interacting components of air, land, water and living organisms, including man, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States (from Article 1 of the 1978 GLWQ Agreement).
<u>GREAT LAKES WATER QUALITY AGREEMENT</u>	(GLWQA) A joint agreement between Canada and the United States which commits the two countries to develop and implement a plan to restore and maintain the many desirable uses of the waters in the Great Lakes Basin. Originally signed in 1978, the Agreement was amended in 1987.
<u>GROUNDWATER</u>	Water entrained and flowing below the surface which may supply water to wells and springs.
<u>GUIDELINES</u>	Any suggestion or rule that guides or directs; i.e. suggested criteria for programs or effluent limitations.
<u>HALF-LIFE</u>	The period of time in which a substance loses half of its active characteristics (used specifically in radiological work); the amount of time required for the concentration of a pollutant to decrease to half of the original value through natural decay or decomposition.
<u>HAZARDOUS SUBSTANCES</u>	Chemicals considered to be a threat to man in the environment, including substances which (individually or in combination with other substances) can cause death, disease (including

cancer), behavioural abnormalities, genetic mutations, physiological malfunctions or physical deformities.

HYDROLOGIC CYCLE	The natural cycle of water on earth, including precipitation as rain and snow, runoff from land, storage in groundwaters, lakes, streams, and oceans, and evaporation and transpiration (from plants) into the atmosphere to complete the cycle.
HYPOLIMNION	The cold, dense, lower layer of water in a lake that occurs during summer stratification.
ICHTHYOLOGY	A branch of zoology that deals with fishes.
INCIPIENT LC_{50}	The level of the toxicant which is lethal for 50% of individuals exposed for periods sufficiently long that acute lethal action has ceased. Synonymous with lethal threshold concentration.
INCIPIENT LETHAL LEVEL	That concentration of a contaminant beyond which an organism could no longer survive for an indefinite period of time.
INSECTICIDE	Substances or a mixture of substances intended to prevent, destroy or repel insects.
LACUSTRINE	Formed in, or growing in lakes.
LEACHATE	Materials dissolved or suspended in water that percolate through solids such as soils, solid wastes and rock layers.
LETHAL	Involving a stimulus or effect directly causing death.
LIPOPHILIC	Having an affinity for fats or other lipids.
LITTORAL	Productive shallow water zone of lakes, rivers or the seas, with light penetration to the bottom; often occupied by rooted aquatic plants.
LOADINGS	Total mass of pollutant to a water body over a specified time; e.g. tonnes per year of phosphorus.
MACROPHYTE	A member of the macroscopic plant life (i.e. larger than algae) especially of a body of water.
MACROZOOBENTHOS	The distribution of macrozoobenthos in an aquatic ecosystem is often used as an index of the impacts of contamination on the system.

MALIGNANT	Resistent to treatment, occurring in severe form and frequently fatal.
MASS BALANCE	An approach to evaluating the sources, transport and fate of contaminants entering a water system, as well as their effects on water quality. In a mass balance budget, the amounts of a contaminant entering the system less the amount leaving the system. If inputs exceed outputs, pollutants are accumulating and contaminant levels are rising. Once a mass balance budget has been established for a pollutant of concern, the long-term effects on water quality can be simulated by mathematical modelling and priorities can be set for research and remedial action.
MUTAGEN	Any substance or effect which alters genetic characteristics or produces an inheritable change in the genetic material.
MUTAGENICITY	The ability of a substance to induce a detectable change in genetic material which can be transmitted to progeny, or from one cell generation to another within an individual.
NONPOINT SOURCE	Source of pollution in which pollutants are discharged over a widespread area or from a number of small inputs rather than from distinct, identifiable sources.
NUTRIENT	A chemical that is an essential raw material for the growth and development of organisms.
ORGANOCHLORINE	Chlorinated hydrocarbon pesticides.
PATHOGEN	A disease causing agent such as bacteria, viruses, and parasites.
PERIPHYTON	Organisms that live attached to underwater surfaces.
PERSISTENT TOXIC SUBSTANCES	Any toxic substance with a half-life in water and greater than eight weeks.
PESTICIDE	Any substance used to kill plants, insects, algae, fungi or other organisms; includes herbicides, insecticides, algicides, fungicides.
PHENOLICS	Any of a number of compounds with the basic structure of phenol but with substitutions made onto this structure. Phenolics are produced during the coking of coal, the distillation of

	wood, the operation of gas works and oil refineries, from human and animal wastes, and the microbiological decomposition of organic matter.
PHOTOSYNTHESIS	A process occurring in the cells of green plants and some micro-organisms in which solar energy is transformed into stored chemical energy.
PHYTOPHAGOUS	Feeding on plants.
PHYTOPLANKTON	Minute, microscopic aquatic vegetative life; plant portion of the plankton; the plant community in marine and freshwater situations which floats free in the water and contains many species of algae and diatoms.
POINT SOURCE	A source of pollution that is distinct and identifiable, such as an outfall pipe from an industrial plant.
POLLUTION (WATER)	Anything causing or inducing objectionable conditions in any watercourse and affecting adversely the environment and use or uses to which the water thereof may be put.
POTABLE WATER	Water suitable, on the basis of both health and aesthetic considerations, for drinking or cooking purposes.
PRECAMBRIAN	The earliest era of geological history.
PRIMARY TREATMENT	Mechanical removal of floating or settable solids from wastewater.
PUBLIC	Any person, group, or organization.
RADIONUCLIDE	A radioactive material.
RAPTORS	Birds of prey.
RAW WATER	Surface or groundwater that is available as a source of drinking water, but has not received any treatment.
RESUSPENSION	(of sediment) The remixing of sediment particles and pollutants back into the water by storms, currents, organisms and human activities such as dredging.
RIPARIAN	Living or located on the bank of a natural watercourse.

SCAUP	A diving duck.
SECONDARY TREATMENT	Primary treatment plus bacterial action to remove organic parts of the waste.
SEDIMENT	The fines or soils on the bottom of the river or lake.
SEICHE	An oscillation in water level from one end of a lake to another due to wind or atmospheric pressure. Most dramatic after an intense but local weather disturbance passes over one end of a large lake.
SELENIUM	A nonmetallic element that chemically resembles sulfur and is obtained chiefly as a by-product in copper refining, and occurs in allotropic forms of which a gray stable form varies in electrical conductivity with the intensity of its illumination and is used in electronic devices.
SESSILE	An animal that is attached to an object or is fixed in place (e.g. barnacles).
SIGMOID CURVE	S-shaped curve (e.g. the logistic curve)
SLUDGE	The solids removed from waste treatment facilities.
SOLUBILITY	Capability of being dissolved.
STABILITY	Absence of fluctuations in populations; ability to withstand perturbations without large changes in composition.
STRATIFICATION	(or layering) The tendency in deep lakes for distinct layers of water to form as a result of vertical change in temperature and therefore, in the density of water.
SUBACUTE	Involving a stimulus below the level that causes death.
SUBCHRONIC	Effects from short-term multiple dosage or exposure; usually means exposure for less than three months.
SUB-LETHAL	Involving a stimulus below the level that causes death.
SUSPENDED SEDIMENTS	Particulate matter suspended in water.

SYNERGISM	The joint action of two or more substances is greater than the sum of the action of each of the individual substances. The improvement in performance is achieved because two agents are working together. See also Antagonism.
SYNERGISTIC	Interactions of two or more substances or organisms producing a result such that the total effect is greater than the sum of the individual effects.
SYNTHESIS	The production of a substance by the union of elements or simpler compounds.
TAXA	A group of similar organisms.
TAXONOMICALLY	To identify an organism by its structure.
TERATOGEN	A substance that increases the incidence of birth defects.
TERATOGENICITY	The ability of a substance to produce irreversible birth defects, or anatomical or functional disorders as a result of an effect on the developing embryo.
THERMOCLINE	A layer of water in lakes separating cool hypolimnion (lower layer) from the warm epilimnion (surface layer).
THRESHOLD	The chemical concentration or dose that must be reached before a given reaction occurs.
TOXIC SUBSTANCE	As defined in the Great Lakes Agreement, and substance that adversely affects the health or well being of any living organism.
TOXICITY	Quality, state or degree of the harmful effect resulting from alteration of an environmental factor.
TRANSLOCATION	Movement of chemicals within a plant or animal; usually refers to systemic herbicides and insecticides that are moved from the point of contact on the plant to other regions of the plant.
TROPHIC ACCUMULATION	Passing of a substance through a food chain such that each organism retains all or a portion of the amount in its food and eventually acquires a higher concentration in its flesh than in its food. See also Biological Magnification.

TROPHIC LEVEL	Functional classification of organisms in a community according to feeding relationships; the first trophic level includes green plants, the second level includes herbivores; etc.
TROPHIC STATUS	A measure of the biological productivity in a body of water. Aquatic ecosystems are characterized as oligotrophic (low productivity), mesotrophic (medium productivity) or eutrophic (high productivity).
TUBIFICID	Of aquatic oligochaete or sludge worms which is tolerant to organically enriched waters.
TURBIDITY	Deficient in clarity of water.
WATER QUALITY OBJECTIVES	Under the Great Lakes Water Quality Agreement, goals set by the Governments of the United States Agreement, goals set by the Governments of the United States and Canada for protection of the uses of the Great Lakes.
WATER QUALITY STANDARD	A criterion or objective for a specific water use standard that is incorporated into enforceable regulations.
WIND SET-UP	A local rise in water levels caused by winds pushing water to one side of a lake. (See Seiche)