Detroit River
Modelling and Management Framework

Interpretive Report

DRAFT

Prepared by the
Great Lakes Institute for Environmental Research (GLIER)
University of Windsor

for the
Detroit River Canadian Cleanup Committee

April 2002
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Several agencies and corporations in Canada and the U.S. cooperated in this study:

- The University of Windsor sponsored GLIER Post-Doctoral Fellowships, hosted workshops and conferences and supported the DREAMS (Data Retrieval; Exchange, Archival and Management System) database on university servers;
- The Essex Region Conservation Authority (ERCA) supported the database development, data distribution and tributary monitoring studies;
- The Citizens Environment Alliance (CEA) contributed to the study components and provided editorial assistance;
- The City of Windsor provided financial support for biomonitoring studies that measured water quality in the Detroit River;
- The Ontario Ministry of the Environment (MOE) provided monitoring data sets and cooperated with GLIER on sediment toxicity bioassays;
- Environment Canada contributed to acoustic studies of streambed characteristics, provided data sets on contaminants in sediment traps and assisted in assessing the degradation of benthic communities;
- The Department of Fisheries and Oceans assisted with fish collections required for validating the food web model;
- The U.S. Environmental Protection Agency (EPA) supported the development of hydraulic models by supplying code for the contaminant desorption model, contributing the UGLCCS data set, a bibliography of Detroit River studies, and reviewing GLIER proposals and study designs;
- The U.S. Army Corps of Engineers provided code for the hydraulic model (CH3D), technical support for developing hydraulic models, data sets for water flow (Acoustic Doppler Profiler data for 1996-1999) and aerial photography to define river boundaries;
- Environmental Modeling Systems, Inc, provided a modelling interface and technical support for the development of the hydraulic model;
- The National Oceanic and Atmospheric Administration (NOAA) provided data on Detroit River bathymetry and water level data;
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The Canadian Wildlife Service (Environment Canada), provided access to historical Detroit River and Lake Erie Herring Gull population monitoring databases.

The National Water Research Institute (Environment Canada) collaborated with GLIER in designing the acoustic surveys and provided access to their survey findings for use in the hydraulic model.
EXECUTIVE SUMMARY

The Detroit River Modelling and Management Framework Interpretive Report, a public document describing the status of the river, is based on surveys and analyses conducted by the Great Lakes Institute for Environmental Research (GLIER), University of Windsor on behalf of the Detroit River Canadian Cleanup Committee (DRCCC) between 1999 and 2001. The Detroit River Data, Modeling and Management Framework (DRMMF) is a critical part of a strategic management program for the Detroit River Area of Concern.

Consisting of four integrated components that link delisting criteria with ecosystem health, the DRMMF provides data and information to the DRCCC, allowing them to make timely, accurate decisions that ensure we are moving toward delisting beneficial use impairments in the Detroit River. All components were developed in partnership with relevant Canadian and U.S. agencies to include the best available tools, data and advice in the DRMMF. A summary of key DRMMF components and their future applications follow.

1.0 Ecosystem Health

Surveys of the water, sediments and biota of the Detroit River indicate pollution to be a continuing concern. Whether the river simply transports contaminants from upstream or acts as a contaminant source has been disputed. It is now evident, however, that active sources exist in the river’s watershed and affect nearshore areas of the river in both jurisdictions. Contaminants such as dieldrin, lindane and DDT were measured in water at concentrations that exceeded, or were slightly below water quality objectives. These chemicals need to be monitored more frequently in water to protect water quality.

The large quantity of contaminated sediments deposited in the system is the greatest concern in the Detroit River. Sediment quality guidelines were exceeded for a number of chemicals including PCBs, mercury, PAHs, DDT, HCB, arsenic, cadmium, nickel, copper, chromium, zinc, manganese and lead. The high concentrations of these contaminants in sediments cause restrictions to be placed on dredging activities in the
Although many organic contaminants were elevated primarily along the U.S. shoreline, high mercury concentrations were found in both Canadian and U.S. jurisdictions. Further, the elevated mercury concentrations at Canadian downstream reaches, compared with upstream sites, suggest mercury point sources commencing in the vicinity of Turkey Creek. Mercury, detected at relatively high concentrations along the U.S. nearshore downstream reaches of the river, was measured above MOE’s severe effect level in subsurface sediments. This distribution indicates that mercury, along with other contaminants elevated in the downstream reaches of the river, could enter Lake Erie during sediment disturbance events. The elevated mirex concentrations in biota at the Turkey Creek Outlet suggest a source of mirex in the vicinity of the Turkey Creek Outlet or possibly in Turkey Creek itself. Mirex concentrations in biota at this site registered below Ontario fish tissue guidelines used to establish fish consumption advisories.

Some of the contaminants (e.g. PCB congeners, hydrophobic organochlorine pesticides, methylmercury) bioaccumulate in aquatic organisms and fish. Biological surveys and modelling results indicate that aquatic organisms take up mercury and PCBs mainly from contaminated sediments. Benthic invertebrates and forage fish are most exposed to high PCB concentrations through the surficial sediments of the Trenton Channel and in the downstream U.S. reaches of the river. Further, these chemicals can bioaccumulate in sport fish tissues at concentrations requiring that governments issue consumption advisories. Currently, the governments of Michigan and Ontario have issued fish consumption advisories for 11 species in the Detroit River. The majority of these advisories are linked to PCBs and mercury. A comparison of 2000/2001 surveys with historical data sets indicates that concentrations of PCBs have not changed in animal tissues during the last 15 years. Unless remediation programs are developed to specifically address mercury and PCBs in sediments, this beneficial use will remain impaired in the Detroit River. For example, if only ten of the most frequently consumed fish species are targeted, PCB concentrations in sediment of less than 2 µg/g OC weight will protect fish consumers.
1.1 Recommendations: Ecosystem Health

Beneficial Use Impairments

- Biological studies indicate that bioaccumulated residues of mercury, PCBs and DDT threaten sport fishing and fish-eating wildlife. PCB concentrations have not changed in Detroit River biota over the last 15 years. Efforts should be made to evaluate contaminant sources and loadings and, more importantly, to identify remedial strategies for contaminated sediments.

- Surveys of contaminant residues in sport fish species should be conducted every other year to identify temporal trends. Surveys of contaminant residues in forage fish should be used to determine local environmental quality, delineate areas of the river requiring remediation, and assess the effectiveness of cleanup activities. The chemical content of fish tissue should be coordinated and linked via bioaccumulation models with the programmes monitoring the Herring Gull population in the Western Basin of Lake Erie.

- Several lines of evidence support the claim that contaminated sediments in the lower U.S. reach of the Detroit River dominate beneficial use impairments (restricted dredging activities, restrictions on fish consumption, fish tumors) throughout the river. The sediments of the lower Trenton Channel also threaten Lake Erie during sediment disturbances. This area of the river should become a high priority for future remediation.

Water Quality

- Water quality studies indicate that dieldrin, lindane and DDT occur or are likely to occur at concentrations in water that exceed water quality objectives. Monitoring programs for water quality must be established to include these chemicals as part of their routine analyses.
Prospective water quality studies should provide a river-wide assessment consistent with modelling activities as they relate to BUIs. The parameters to be addressed are dieldrin, lindane, DDT, PCBs, mercury, trace elements and nutrients. Water quality surveys should be conducted at least biennially. Selected monitoring sites should be sampled more frequently, e.g. monthly to allow agencies to promptly respond to emerging chemical concerns and appropriately adjust their monitoring strategies. Specific features of future water monitoring programs should be coordinated with management needs; the resulting designs will benefit from findings in the present study.

**Sediment Quality**

- Sediment quality studies indicate that mercury, PCBs, PAHs, HCB, DDT, cadmium, nickel, copper, arsenic, chromium, zinc, manganese and lead occur at concentrations that should restrict dredging activity. Mercury, PCBs and PAHs also threaten sport fishing and PAHs produce tumors in fish. Prospective studies must evaluate sources and loading information for these contaminants. Elevated mercury concentrations in the lower Canadian river reach, for example, indicate active sources in the vicinity of Turkey Creek. The magnitude and location of this source (or sources) require further evaluation.

- Sediment quality surveys should be re-evaluated every five years and should apply a stratified random sampling design that encompasses the entire river.

- The benefits of ongoing and prospective sediment remediation projects should be evaluated in terms of the present whole-river sediment quality baseline as established by the 1999-2001 surveys of the DRMMF.

**2.0 Hydraulic Modelling**

The CH3D model of the U.S. Army Corps of Engineers was adapted to simulate the hydraulics of the Detroit River. This model is capable of predicting the flow distribution
in the river and the associated transport of chemicals in water and by means of sediment particles. The main use of the model is to realistically assess the relative importance of water and sediment inputs to the BUlS and predicts where contaminated sediments are likely to settle. The model was applied to perform a hazard assessment of contaminant loadings entering Lake Erie during storm events. Model simulations indicated that sediments located in the downstream U.S. reach of the river are particularly sensitive to resuspension during wind-induced water setup in Lake Erie. Since these sediments contain high concentrations of mercury, PCBs, PAHs and other contaminants of concern, contaminated sediments in the lower U.S. reach of the river pose a significant threat to Lake Erie during sediment disturbances.

3.0 Bioaccumulation Modelling

Threats to human health and the toxic impacts of chemicals on fish and wildlife communities along the Detroit River led the International Joint Commission to identify the Detroit River as an Area of Concern. A food web bioaccumulation model was developed to evaluate sources of chemical exposure and determine safe levels for chemicals in fish, wildlife and human health. The model links chemical sources and fish consumption guidelines. When applied to the Detroit River ecosystem, the foodweb bioaccumulation model demonstrates that contaminated sediments are the most important factor regulating the exposure of fish and wildlife to chemicals. The current model was developed for PCBs and mercury and links contaminated sediments with restrictions on fish consumption. Model simulations assessed the hazard associated with restrictions on fish consumption caused by PCBs in the river’s water and sediments. The simulations indicated that contaminated sediments in the lower U.S. reach of the river were responsible for most fish consumption advisories (associated with PCB concentrations) throughout the system.
4.0 Data Management and Communication

The Detroit River Update Report (1999) concluded that monitoring and research data were not readily available in a common format to answer basic questions such as ‘is the river improving?’ and ‘what needs to be done to remove the remaining impairments?’ To address these shortcomings, GLIER researchers developed and currently operate a data management system with an online interface. The database, known as DREAMS, links key agencies and public interest groups, and enables data exchange, retrieval, archiving and management of activities related to the Detroit River Area of Concern. DREAMS is an archive of contaminant data on sediments, water and biota, and supporting data and information on bathymetry, water flow and shoreline geometry. The DREAMS database supports geographic lookup and analysis capability (GIS). By posting their reports and information online, agencies and citizen groups contribute to a binational information clearinghouse. The U.S Environmental Protection Agency, for example, donated the data set from the Upper Great Lakes Connecting Channels Study (UGLCCS) and a recent bibliography on Detroit River studies resides in the database. DREAMS is a valuable resource not just for environmental managers but also for those involved in shipping, shoreline planning and habitat protection.

4.1 Recommendations: Data Management and Communication

- DREAMS, an online database used to compile the most current data on the Detroit River AOC, also serves as a repository for historical data relating to the system. A coordinated binational effort involving researchers in universities, industry and government agencies as well as the appropriate financial support to continue this work is required to ensure that DREAMS is updated to include all relevant data on the river.

5.0 Future Applications of the Framework

The DRMMF will address a number of other prospective remedial actions, including:

- The benefits of controlling point sources of contaminants such as PCBs, mercury and PAHs;
• The application of habitat management plans to ameliorate historic pollution;
• The extension of the framework to produce a Huron-Erie corridor action plan as promoted by many agencies and the DRCCC; and
• The connection between remedial actions in the Detroit River and those in the Lake Erie Lakewide Management Plan (LaMP).
1.0 INTRODUCTION

The 1997 International Joint Commission’s (IJC) review of progress in remedial action plans (RAPs) for Areas of Concern (AOC) in the Great Lakes basin rated the binational Detroit River program as among the least effective along the Canadian shoreline. The review noted that although many remedial programs had been implemented, progress in meeting delisting targets for the Detroit River lagged well behind that achieved in other AOCs.

It was recognized in 1986, at the inception of the Detroit River Binational Remedial Action Plan, that the river could be restored only through an ecosystem approach, involving relevant binational agencies. The failure to complete Stage Two of the Remedial Action Plan, a serious drawback in developing such an approach, was addressed in the IJC’s subsequent review of the Detroit River RAP. The review recommended the development of a management framework to integrate information and evaluate remedial options for meeting delisting criteria.

The Detroit River Canadian Cleanup Committee (DRCCC) initiated the development of a remedial action plan for the river, noting that the plan should be community-driven and based on good science. To assess the relationship among chemical loadings, the state of the river and the delisting criteria, the DRCCC established four subcommittees: Point Sources, Non-point Sources, Combined Sewer Overflows and Contaminated Sediments. It was soon recognized that the subcommittees required a common framework to exchange information and data, and more importantly, a strategic plan to move complementary efforts in the same direction. The four subcommittees affirmed their agreement with the IJC review and reiterated to the DRCCC the need for a common management framework. The committee charged the Great Lakes Institute for Environmental Research (GLIER) at the University of Windsor with developing a modelling and management framework for the river, and in conjunction with U.S. partners, a model compatible with U.S. remedial action plans under development.
1.1 Detroit River Modelling and Management Framework (DRMMF)

The Detroit River Modelling and Management Framework (DRMMF) was developed to address delisting targets in the Remedial Action Plan. Critical components of the framework include an interactive data management system (DREAMS) and mathematical models: 1) a sediment toxicity model, based on the TRIAD approach, to assess the biological effects of contaminated sediments, 2) a hydraulic model (CH3D) to predict the transport and fate of chemicals and 3) a food web bioaccumulation model to predict chemical exposures to biota. These components allow researchers to determine the relationships among contaminant loadings, transport, fate and effects in the Detroit River ecosystem.

Using the framework, GLIER researchers produced the first comprehensive assessment of the river since the Upper Great Lakes Connecting Channels Study (UGLCCS) in the early 1980s. The importance of the new data became increasingly evident as the DRCCC initiated its review of delisting criteria. In the Detroit River Update Report (1999) the lack of coordinated research and monitoring programs was identified as a critical problem. Findings presented at independent conferences such as the binational State of the Strait (2001) also concluded that cause/effect linkages were not possible without major changes in the design and implementation of research and monitoring programs on the Detroit River. The DRCCC was designated as the appropriate group to determine the type of monitoring and research required for the wise and effective future management of the river.

During the development of the framework, GLIER researchers and their partners implemented an extensive survey of contaminants in sediment, water and biota to provide essential data for the model, update the environmental quality of the river and measure the severity and extent of beneficial use impairments. As previous monitoring and research programs had focused only on known or suspected problem areas along the river, it had been difficult to determine the overall health of the Detroit River ecosystem.
The DRMMF consists of the following key components:

- An assessment of ecosystem health, including water, sediments and biota;
- A hydraulic model to help determine contaminant transport and fate;
- A food web bioaccumulation model to link contaminants in the ecosystem with delisting criteria; and
- An interactive database (DREAMS) with online access and geographic analysis capability (GIS).

These components were implemented through partnerships with key agencies in the U.S. and Canada. The DRCCC requested that all components of the project be completed within three years of its inception in 1999. As researchers realized the impossibility of addressing all delisting criteria, the DRCCC recommended that the first phase of the DRMMF project focus on fish consumption guidelines related to PCBs and mercury.

### Assistance in Reading This Report

**Definitions**
Terms underlined in the report are defined in the glossary that appears in Appendix B.

**Recommendations**
Recommendations appear in the Executive Summary, in single-border boxes throughout the report and in chapter 10.

**Conclusions**
Conclusions are underlined in the text and appear in chapter 9.

**Tables and Figures**
Tables and figures appear at the end of each chapter.
Figure 1.1. Detroit River Modelling and Management Framework project design. Modelling activities and environmental data collection are distributed between water, sediment and biological components of the Detroit River ecosystem. Models are used to determine water flow, sediment transport and Beneficial Use Impairments of biota. Data sets on contaminant concentrations or sources/loadings are used as input parameters in models or to validate model output. Model reports and data collection reports are published on the DREAMs online database.
2.0 WATER QUALITY

2.1 Introduction

Beneficial use impairments occur when contaminant concentrations in water exceed water quality standards or objectives. Further, toxic chemicals dissolved in water indirectly affect other BUIs including restrictions on the consumption of fish and wildlife caused by chemical bioconcentration, and degraded fish and wildlife populations, fish tumors and other deformities, and degradations in phytoplankton and zooplankton populations. Knowledge of chemical concentrations in the river is essential for calculating chemical loadings entering Lake Erie and for developing pollutant bioaccumulation models for the river. Despite the importance of contaminant concentrations in water, the intensity of water quality monitoring in the Detroit River has declined in recent years (DRCCC Update Report 1999).

The most comprehensive water quality assessment of the Detroit River remains the Upper Great Lakes Connecting Channels Study (UGLCCS), compiled in 1989. The study reviewed the available information on residues of polychlorinated biphenyls (PCBs), chlorinated benzenes, organochlorine (OC) pesticides (including DDT and its metabolites, dieldrin, hexachlorocyclohexanes, chlordane, heptachlor, endosulfan, endrin, methoxychlor and octachlorostyrene), polynuclear aromatic hydrocarbons (PAHs), trace metals (copper, cadmium, manganese, nickel, zinc, mercury) and nutrients in the water column. Although the Ontario Ministry of the Environment (MOE) sampled water quality at upstream and downstream transects of the Detroit River between 1998 and 2000, data from these monitoring initiatives have not yet been released. Other information on contaminant concentrations in Detroit River water appears in the work of Froese et al. (1997), who documented PCBs in the Trenton Channel in 1995. In 1994, Metcalfe et al. (2000) measured contaminant accumulation using semi-permeable membrane devices (SPMDs) and reported concentration trends
for PCBs, PAHs and OC pesticides in water. Rossman et al. (1999) documented mercury concentrations in water from the Trenton Channel.

Comparing water chemistry data generated by different studies is difficult as researchers use different analytical methods, which may or may not include contaminant residues associated with dissolved or suspended particulates in the water column. The analytical method chosen for determining water chemistry depends on the chemical being analyzed. The choice is determined by sampling and analysis costs and the need for low detection limits as required for data interpretation of the respective study. While total contaminant concentrations in water are useful for estimating chemical loadings, freely-dissolved chemical concentrations are required for assessing the bioavailability of chemicals to aquatic organisms (Gobas and Morrison 2000). Adequately assessing the bioavailability of trace metals, including mercury, to aquatic organisms requires knowledge of freely-dissolved chemical concentration and the chemical speciation. Unfortunately, few analytical methods exist for measuring mercury (and its various chemical forms) in the water column and the link between total metal concentrations and chemical bioavailability is not as well known as it is for organic pollutants. Another consideration involves the timing of water sampling, which may be important for systems exhibiting low hydraulic residence times and/or be subject to frequent disturbance events. In the latter case, perturbations or changes in flow conditions contribute to variations in chemical loadings. Annual loadings, for example, will be underestimated if the water sampling protocol is not designed to specifically sample such events. (Froese et al. 1997).

Many hydrophobic chemicals occur in water in concentrations approaching detection limits. Although measuring these concentrations may produce large errors and uncertain results, such concentrations may nonetheless indicate chemical loadings carried by the river.
In this report, data for water chemistry analyses are taken from a series of studies conducted by GLIER and sponsored by the City of Windsor. These studies used freshwater mussels, *Elliptio complanata*, as biomonitors to estimate residues of organic contaminants in Detroit River water between 1996 and 2000. Mussels have long been used as biomonitors of pollutant residues in the waters of the Detroit River and the Huron-Erie corridor (Pugsley et al. 1985). Water residues extrapolated from mussels may differ from water concentrations determined by using direct measurement techniques, i.e. Goulder large volume extractor or XAD-resins. The lower costs and greater sensitivity of the mussel method allow for the generation of the large data sets required to interpret spatial or temporal trends in water residues.

Biomonitors involve deploying animals (caged mussels collected from a reference site) at a specific location and allowing them to filter water over an extended time (days to months). This technique can detect low-level concentrations of hydrophobic chemicals as chemical residues are concentrated in the animal’s tissues. It also reduces the probability of cross-contamination during the retrieval of samples. Biomonitors provide average water residues for the time they reside in the water, making them ideal for use in frequently disturbed systems. As *Elliptio complanata* has historically been used as a biomonitor in the Detroit River, these data sets can be directly compared with previous surveys (Pugsley et al. 1985; Russell and Gobas 1989; Gewurtz et al. 2000). The locations of the Detroit River biomonitoring sites are shown in Figure 2.1.1.

### 2.2 Temporal and Spatial Trends in Organochlorine Chemicals in Water at Biomonitoring Sites

PCB congeners were detected in all 240 mussel tissue samples analyzed between 1996 and 2000. Of the eighteen organochlorine compounds monitored, four (dieldrin, total chlordanes, HCB, DDT) were frequently detected in mussel tissues (more than 92 percent of the samples retrieved). Chemical residues in mussel
tissue were less frequently detected (5 to 38 percent detection in samples) for 1,2,3,4-TCB, 1,2,4,5-TCB, QCB, OCS, heptachlor, lindane and mirex. Data analyses focused on PCB residues and the frequently detected organochlorine pesticides. Although seasonal differences in chemical concentrations in water were occasionally noted, such trends were not duplicated at specific sites over multiple years. Consequently, all data are presented as average chemical concentrations for each year of the study. Temporal trends in water concentrations for organochlorine pesticides (dieldrin, total chlordane, HCB and DDT) appear in Figure 2.2.1.

2.2.1 Dieldrin

Dieldrin, a pesticide banned in both Canada and the U.S., was detected in mussel tissues in 93 percent of the samples. The IJC recommended that dieldrin concentrations in water not exceed a concentration of 1 ng/L (IJC 1976). In the current study, dieldrin had concentrations that ranged from non-detection to 2.48 ng/L. The average concentration for dieldrin in the river was 0.10 ng/L. Although the average dieldrin concentration in water was lower than the water quality objective of 1 ng/L, the objective was exceeded in 43 cases. Trends in dieldrin concentrations (Figure 2.2.1) indicate a pronounced spike in water in 1998 at four out of six deployment sites. The elevated water concentrations were noted throughout the year.

Since dieldrin concentrations in water have exceeded water quality objectives, prospective monitoring programs should routinely include dieldrin residues.

2.2.2 Chlordane

Chlordane was detected in 98 percent of the samples analyzed. The IJC water quality objective for chlordane is 60 ng/L (IJC 1976); the U.S. EPA maximum allowable level in drinking water, 2000 ng/L (U.S. EPA 2000); and the Ontario maximum acceptable concentration of chlordane, 7000 ng/L. In the current study,
Chlordane concentrations registered below water quality objectives for this chemical; they ranged from non-detection to 1.79 ng/L and averaged 0.11 ng/L. Chlordane concentrations were generally stable among sites and years, with the exception of elevated concentrations at GLIER and downstream of the West Windsor Treatment Plant in 2000. At the latter sites, total chlordane residues were three to five times higher than the river-wide average concentration, although the elevated water concentrations at these sites still registered below water quality objectives for this chemical.

2.2.3 Hexachlorobenzene

Hexachlorobenzene (HCB) was detected in 98 percent of the samples analyzed. The Canadian Water Quality Guideline established for HCB for the protection of livestock watering is 520 ng/L and the U.S. EPA maximum contaminant level in drinking water is 1000 ng/L. In the current study, HCB concentrations in water ranged from non-detection to 0.180 ng/L and averaged 0.034 ng/L. These concentrations were lower than those reported for the Detroit River in the UGLCCs study (0.24 – 0.39 ng/L), but similar to levels reported for the St. Clair River in 1986 (0.041 – 0.051 ng/L). No spatial or temporal trends were evident for this chemical.

2.2.4 DDT

DDT, a banned pesticide, was historically applied to crops in Canada and the U.S. DDT residues were detected in all samples analyzed in the current study. IJC established a DDT water quality objective of 3 ng/L for the protection of aquatic life. The Ontario maximum acceptable concentration of DDT in drinking water is 30,000 ng/L. In the current study, DDT ranged from 0.01 to 1.36 ng/L and averaged 0.10 ng/L. The highest concentrations of DDT in water approached the IJC water quality objective and were associated with the upstream Lake St. Clair site where average DDT concentrations were from 1.5 to 7 times higher than other
sites. These data support the conclusion in the UGLCCS study that DDT sources most likely occur upstream of the Detroit River. No definitive temporal trends emerged for DDT at the individual sites.

As with dieldrin, DDT residues in water approach existing water quality objectives and should be included in prospective water quality monitoring programs.

2.2.5 Other organochlorine pesticides

The other monitored organochlorine pesticides were less often detected in samples. Only lindane had water concentrations that approached water quality guidelines. The recommended IJC water quality objective and the Canadian Water Quality Guideline for the Protection of Aquatic Life are 10 ng/L; the U.S. EPA maximum contaminant level in drinking water is 200 ng/L (U.S. EPA 2000). Lindane concentrations in water ranged from non-detection to 4.78 ng/L and averaged 0.37 ng/L. The highest lindane concentrations were found at the West Windsor Treatment Plant and downstream of this site, suggesting that lindane is being released with effluents from sewage treatment plants.

Lindane concentrations in water approached water quality objectives and should be included in prospective monitoring programs.

2.2.6 Polychlorinated biphenyls

Polychlorinated biphenyls (PCBs) have been banned in both Canada and the U.S. Along with mercury, PCBs are designated as critical pollutants for priority action in the Lake Erie LaMP. PCBs were detected in all samples analyzed in the current study. PCB concentrations in water ranged from 0.01 to 1.0 ng/L and averaged 0.16 ng/L. Differences among PCB concentrations found at the various sites were low and remained stable over time. Trends for PCB concentrations in water are summarized in Figure 2.2.2.
In 1998 the biomonitoring study was extended to a total of ten stations in the Detroit River. Average PCB concentrations at each of these locations are summarized in Figure 2.2.3. Spatial trends among PCB water concentrations are more notable for their similarities than their differences. With the exception of a low PCB concentration near Fighting Island and elevated concentrations in the Trenton Channel, all sites showed similar concentrations. The PCB concentration in Trenton Channel waters averaged 0.72 ng/L compared with the river-wide average of 0.16 ng/L. The very low PCB concentration in the Fighting Island Channel likely reflects a plume of clean water originating in Lake Huron that follows the dredged channels. Figure 2.2.3 also includes PCB concentrations in water determined by using large volume water sampling techniques (Environment Canada data; Froese et al. 1997). These concentrations were consistent with those from the current study. Excluding the Fighting Island Channel site, the data indicate that PCB concentrations in water remain constant along the entire Canadian shore of the river and do not exhibit pronounced upstream/downstream gradients.

2.3 Key Conclusions from Water Quality Monitoring Studies

The current study used mussel biomonitors to determine water concentrations for several organochlorine chemicals in the Detroit River. The main advantages of mussel biomonitors are their low cost, their ability to concentrate low levels of chemicals present in the water column, and their ability to estimate average water concentrations during the entire deployment time. These advantages enable researchers to generate large data sets, define spatial trends, measure potential chemical sources/loadings, and determine temporal trends in chemical residues in the river. Of the organochlorine contaminants examined in the current study, dieldrin, DDT and lindane exceeded or approached water quality objectives.

These chemicals require close monitoring to ensure that concentrations remain below environmental quality standards and objectives. Such monitoring requires techniques such as biomonitors that can continuously sample water residues.
Although many of the contaminants analyzed in the current biomonitoring survey have been banned or restricted, most chemicals exhibited no decreasing trends in water from 1996 and 2000. **These findings indicate that the river is not cleaning itself up over time.**

Identifying spatial patterns of chemical concentrations requires a river-wide assessment. While PCB concentrations in water occurred at relatively uniform levels along the Canadian side of the river, elevated concentrations were identified on the U.S. side in the Trenton Channel. Low PCB concentrations appeared in the dredged shipping channels. Sources of PCBs upstream of the Trenton Channel should be further investigated to assess possible control or remedial options.
Figure 2.1.1. Locations of biomonitoring sites in the Detroit River. LSC = Lake St. Clair; RM = Riverside Marina; GLIER = Great Lakes Institute for Environmental Research Dock; WWTP = West Windsor Water Treatment Plant Outflow; DWWTP = 300 m downstream of WWTP; TC = upstream of Turkey Creek Outlet; GI = Grassy Island; FI = Fighting Island Channel; TT = Trenton Channel; MSI = Middle Sister Island, Western Lake Erie.
Figure 2.2.1. Trends in organochlorine pesticide concentrations in water of the Detroit River. Each bar represents the annual geometric mean chemical concentration for a given site. Error bars refer to the 95% confidence interval surrounding the geometric mean concentration.
Figure 2.2.2. Trends in polychlorinated biphenyl concentrations in water of the Detroit River. Each bar represents the annual geometric mean PCB concentration observed for a given site. Error bars refer to the 95% confidence interval surrounding the geometric mean concentration.
Figure 2.2.3. PCB concentrations (ng/L) in water of the Detroit River. Striped columns indicate the geometric mean concentrations (+- 95% confidence interval) in water derived from mussel biomonitoring studies. Grey columns indicate mean PCB concentrations in water derived from direct measurement studies. Direct measurements for TT were performed in 1995 using XAD columns (Froese et al. 1997). Direct measurements for DDR and MSI were performed in 1994 using Goulder extractions (Environment Canada Data).
3.0 SEDIMENT QUALITY

3.1 Introduction

Contaminated sediments are a major environmental problem in the Great Lakes (Persaud et al. 1993) and a key concern in the Detroit River (UGLCCS 1989; Detroit River Update Report 1999). Many persistent organic and inorganic compounds released into this system can bind or partition to particulate matter in the water column and settle on the riverbed (Pierce et al. 1998). Once settled, some of these chemicals might be reintroduced into the water column and transported downstream; others might accumulate in biota and biomagnify through the food web. Several beneficial use impairments (BUIs) in the Detroit River AOC are associated with toxic chemicals in sediments (Detroit River Update Report 1999).

It was thus necessary to determine the river-wide distribution of chemical residues in sediments to measure the contribution of contaminated sediments to BUIs and support management decisions leading to the delisting of the river.

3.2 Surficial Sediment Sampling Design

A river-wide surficial sediment survey consisting of one hundred and 50 primary sampling stations was conducted in 1999. This survey characterized sediment quality and measured the contribution of deposited sediments to BUIs in the river. The stations used in the 1999 survey appear in Figure 3.2.1. Sampling stations were selected according to a stratified random design to provide a representative description of sediment quality in the river. The stations were assigned to three reaches (upper, middle and lower) along the river. The upper and middle reaches of the river each contained 30 stations; the lower reach contained 90 or 60 percent of the stations. For each reach along the river, sample stations were divided evenly between U.S. and Canadian waters. The sampling strategy de-emphasized the shipping channels since these areas are less susceptible to sediment accumulation, and two-thirds of the stations were in waters shallower than or equal to the median depth of the reach. To minimize spatial clustering of the data set, the distance
between stations was at least 300 metres. The 1999 sampling initiative was complemented in 2000 by revisiting and sampling a sub-set of the 1999 stations.

Sediment samples were collected using a ponar grab sampler. As sediment characteristics varied among the different sampling locations, it was sometimes necessary to composite multiple grab samples to ensure sufficient sediment mass for physical, chemical and biological analyses. To standardize this procedure, sediments were collected at each station until a volume of 2 L was obtained, and the number of grabs required to collect the sample was recorded. Figure 3.2.2 demonstrates key sediment characteristics observed in the Detroit River. Collected sediments were sieved to ensure a constant grain size of less than 2mm. This procedure reduces variability in sediment characteristics among the sampling locations and permits more meaningful comparisons of sediment chemistry. The frozen sediment samples were submitted to the GLIER analytical laboratory and analyzed for a range of organic and inorganic parameters. The samples were also characterized for grain size distribution and organic carbon content. Analytical data from the 1999/2000 sampling surveys are published on DREAMS and described in Chapter 7.0.

3.3 Suspended Sediment Sampling Design

To estimate the sediment-associated chemical loadings entering the river at its headwaters Environment Canada placed sediment traps at nine locations in the Detroit River in 1999. Sediment traps collect particles in the water column and therefore represent mobile particles in the river. The sediment trap content was collected at monthly intervals; Figure 3.3.1 identifies the location of the sediment traps in relation to the 1999 surficial sediment sample locations. Environment Canada performed the chemical analyses of suspended sediments. There were no significant spatial or temporal trends in chemical concentrations among suspended particles collected from different traps at different times for any of the measured parameters. Both data sets were interpreted with reference to: Total Organic Carbon (TOC), sodium (Na), magnesium (Mg), aluminum (Al), potassium (K), calcium (Ca), vanadium (V), chromium (Cr),
manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), antimony (Sb), mercury (Hg), lead (Pb) and bismuth (Bi).

3.4 Spatial Trends in Surficial Sediment Contaminations

The spatial distribution of contaminated sediments provides information about areas of the river that are responsible for impairment of selected beneficial uses, problem source identification and the assessment of the type and magnitude of remedial activities required to address impairments. This chapter of the report focuses on mercury, PCBs and PAHs. These contaminants affect a number of the beneficial use impairments in the Detroit River.

3.4.1 Data analysis techniques

The geometry of the Detroit River is complex: it contains a number of islands, dredged channels and curves in the river shape. These geographic features influence water flow conditions and make it difficult to analyze spatial trends or track pollutant sources. A technique was used in the current study to statistically ‘straighten’ the Detroit River. Figure 3.4.1 demonstrates the transformation of the river geometry used to facilitate the interpretation of spatial trends in contaminated sediments. This technique provides a means for better describing sources and sediment deposition patterns in the river.

3.4.2 Mercury in surficial sediments

Past studies have indicated significant mercury contamination in sediments and aquatic animals in the Detroit River (Federal Water Quality Administration 1970; Thornley and Hamdy 1984; Fallon and Horvath 1985; Hamdy and Post 1985; Farara and Burt 1993). Recently, the risk associated with concentrations of mercury in sediments at two U.S. locations in the river – Conners Creek and Black Lagoon – was high enough for U.S. federal and state agencies to pursue dredging activities at these locations (MDEQ 1997; Ostaszewski 1997; NTH Consultants 1998; HEC Hinshon Environmental Consulting 1999). Determining the river-wide distribution of mercury is therefore necessary to
establish a database that will allow the DRCCC to evaluate the need for developing remediation programs.

Figure 3.4.2 shows the location of sediment sampling stations in the 1999 survey and indicates stations that had mercury concentrations in sediments that exceeded MOE’s **Lowest Effect Level** (LEL = 0.2 mg/kg dry weight) and **Severe Effect Level** (SEL = 2 mg/kg dry weight) sediment guidelines (Persaud *et al.* 1993). These are used in Ontario to regulate dredging activities, a listed beneficial use impairment in the Detroit River. Sediments with mercury concentrations that exceed an LEL are not suitable for open water disposal in Ontario. Sixty-nine surficial sediment stations (39 U.S. and 30 Canadian) had mercury concentrations in sediments that exceeded the MOE LEL guideline. Notably, all sediment samples collected downstream of the Trenton Channel had mercury concentrations above the LEL value, and one station (downstream of Celeron Island) had a mercury concentration above the SEL.

Figure 3.4.3 shows the relationship between mercury concentrations in surficial sediments and the distance of sampling stations from the river’s headwaters. Mercury concentrations in both Canadian and U.S. sediments increase along the river’s length. The data on mercury concentrations in suspended sediments (Section 3.4.2) were compared with data from surficial sediment surveys (Figure 3.4.3). Generally, mercury concentrations in suspended sediments were higher than in surficial sediments at the river’s headwaters. This observation suggests that the upstream population of sediment particles does not contribute to surficial sediment contamination at nearshore upstream areas of the river. Mercury concentrations in downstream Canadian and U.S. surficial sediments are often higher than concentrations in suspended sediments. This observation indicates that the suspended sediments originating in the Lake St. Clair/St. Clair River system do not contribute to elevated mercury concentrations at downstream locations on the river. Ongoing local sources of mercury both on and under the Detroit River are the only possible explanation for the mercury distribution in the sediment.
In the upper reaches of the river, sediments along the U.S. side have higher mercury concentrations than along the Canadian side. At the lower reach of the river (downstream of Turkey Creek), however, mercury concentrations in sediments are similar in both U.S. and Canadian waters. The exception occurs at the mouth of the Trenton Channel, which contains a distinct cluster of highly contaminated sediments. Definite increases in mercury concentrations in surficial sediments at approximately 20 km downstream of the headwaters on the Canadian side of the river suggest a source in the vicinity of and/or downstream from Turkey Creek.

Collectively, these data confirm the conclusion that local sources of mercury occur in the Detroit River watershed.

Figure 3.4.4 compares mercury concentrations in surficial sediments at Conners Creek and Black Lagoon with concentrations at other locations in the river. Mercury concentrations at these locations were higher than at most other areas on the river, but were not exceptional compared to other contaminated regions found in the system. Notably, the cluster of highly contaminated sediments at the mouth of the Trenton Channel exhibited mercury concentrations similar to those at Conners Creek and Black Lagoon. It is also important to note that the area of contaminated sediments at the mouth of the Trenton Channel is much greater than the combined areas of Conners Creek and Black Lagoon. The contaminated sediments at the lower U.S. river reach could introduce pollutants into Lake Erie should these sediments be mobilized during disturbance events. Therefore, the DRCCC recommends remedial action be extended to include the sediments in the lower reaches of the river.
3.4.3 PCBs in surficial sediments

Polychlorinated biphenyls (PCBs) are another major pollutant identified in the contaminated sediments of the Detroit River (Fallon and Horvath 1985; UGLCCS 1988). PCBs are responsible for at least two beneficial use impairments: restrictions on dredging activities and restrictions on fish consumption. MOE sediment quality guidelines for PCBs were exceeded at 33 stations on the river. Only six of these sites were in Canadian waters, suggesting negligible inputs along the Canadian shoreline. The locations of sediment stations with PCB concentrations higher than MOE’s PCB sediment quality guideline are shown in Figure 3.4.5.

The data on PCB concentrations in surficial sediments were analyzed using the transformed Detroit River geometry described in Section 3.4.1. Figure 3.4.6 shows the relationship between PCB concentrations in surficial sediments and sample distance from the river’s headwaters. PCB concentrations are expressed in units of µg/g organic carbon to standardize for different sediment types. With the exception of the two U.S. stations in the upper river reach with unusually high values, PCB concentrations in surficial sediments on the U.S. side increase downstream along the river’s length. Similar to mercury, PCB concentrations in surficial sediments in the lower U.S. river reach were higher than at other locations. Previous studies have identified the Rouge River and the Detroit Waste Water Treatment Plant as important PCB sources entering the Detroit River (UGLCCS). These sources may continue to contribute PCB loadings at downstream U.S. sites, although further evaluation is necessary to confirm this observation. PCB concentrations in surficial sediments along the Canadian shoreline remain low, except for small clusters of moderately elevated concentrations around Goyer’s Marina and downstream of Amherstburg. No definitive sources of PCBs on the Canadian side of the river could be identified. The large differences in PCB concentrations in surficial sediments between the U.S. and Canadian lower reaches of the river indicate little or no cross channel mixing of contaminated sediments.
3.4.4 PAHs in surficial sediments

Polynuclear aromatic hydrocarbons (PAHs) are genotoxic and responsible for tumors in benthic fish species (Bauman et al. 1992). Like PCBs, PAHs are organic contaminants with a strong affinity for the organic carbon component of sediments. The MOE sediment quality guideline for PAHs was exceeded at 53 stations (42 U.S. and 11 Canadian). Figure 3.4.7 identifies sediment stations with PAH concentrations above the MOE sediment quality guideline. As observed with PCBs, most sediment stations with PAH concentrations above the MOE guideline are in U.S. waters.

Figure 3.4.8 shows the relationship between PAH concentrations in surficial sediments and station distance from the river’s headwaters. Trends for the spatial distribution of PAHs in sediments differ from those for mercury and PCBs, with elevated concentrations along the U.S. shoreline. The lack of an upstream-downstream gradient combined with low PAH concentrations along the Canadian shoreline indicate few sources for this class of chemical in Canadian jurisdictions. On the U.S. side PAHs are currently being released along the river’s length.

3.4.5 Other contaminants in surficial sediments

Several other contaminants were found in surficial sediments at concentrations above MOE sediment quality guidelines. Trace elements: cadmium (115 sites), nickel (92 sites), copper (75 sites), arsenic (61 sites), chromium (51 sites), zinc (40 sites), manganese (25 sites) and lead (23 sites) exhibited surficial sediment concentrations above MOE guidelines. With the exception of zinc, none of these compounds were measured in biota samples from the river (Chapter 4.0). Although the concentrations of these contaminants may warrant restrictions on dredging activities, there is little evidence of toxicological stress. It is suspected that environmental conditions in the Detroit River contribute to low bioavailability of these compounds. Two organic contaminants, HCB (13 sites) and DDT (14 sites) also had surficial sediment concentrations greater than MOE sediment quality guidelines. Like PCBs, HCB and DDT were found to bioaccumulate in aquatic animals and fish tissues. The elevated contaminant concentrations in sediment of
these two chemicals were generally associated with the lower U.S. reach of the river. All stations sampled exceeded MOE’s LEL in one or more parameters, making these dredges unsuitable for open water disposal according to provincial guidelines (Persaud et al., 1993).

3.5 Comparison of Suspended Particles with Surficial Sediments

This section compares the chemistry of suspended sediment particles collected in sediment traps along the river’s length with surficial sediment chemistry. Such a comparison provides information about the origin of sediment deposits in the river and determines the importance of upstream sources on BUIs observed in the Detroit River. The chemical profiles associated with suspended particles and those of surficial sediments are used as chemical ‘fingerprints’ to trace the origin of sediment particles. These ‘fingerprints’ also provide information about the extent of cross channel mixing to evaluate if contaminant migration occurs between the Canadian and U. S. nearshore areas.

3.5.1 Comparison of TOC in suspended and surficial sediments

The total organic carbon (TOC) content of sediment particles is a key property that defines the capacity of sediments and suspended particles to absorb organic chemicals. Other pollutants such as mercury and trace elements are generally enriched in the fine grain fraction of sediments, and this portion of the sediments typically has high TOC concentrations. High TOC content is also often associated with organically rich discharges into the river such as municipal sewage, CSOs and wetlands overflows.

Figure 3.5.1 compares variations in the TOC content of suspended sediments with surficial sediments deposited on the riverbed. The TOC content of suspended sediments is much lower and less variable than the TOC of surficial sediments. No significant spatial or temporal trends appeared in the TOC of suspended sediments. Since suspended sediments reflect particles captured from the water column, the lack of variability in the
TOC of this material indicates a common source for particles in all sediment traps (Lake St. Clair/St. Clair River). In contrast, the TOC was higher for deposited surficial sediments than for suspended sediments. The TOC of surficial sediments was highly variable at different reaches of the river; the most variation occurred at the middle U.S. reach followed by the lower Canadian reach.

Some general conclusions can be drawn from the dissimilarity between the TOC of suspended and surficial sediments. First, there is limited cross-channel mixing. Second, the low TOC content of suspended solids remains unchanged between upstream to downstream regions indicates that suspended solids in the main channel, that have a low capacity for partitioning organic contaminants, will not likely represent a substantial contaminant loading to Lake Erie.

3.5.2 Comparison of chemical composition of suspended and surficial sediments

A statistical technique (Discriminant Function Analysis or DFA) was used to determine if sediment particles in the river can be separated according to their chemical signatures. The DFA analyses were clearly able to distinguish the chemical composition of suspended particles collected in sediment traps from the composition of surficial sediments (Figure 3.5.2). Differences in the chemical composition of surficial sediments among the different reaches of the river were apparent. Surficial sediments collected from the lower U.S. reach exhibited the most dramatic differences when compared with other areas in the river. Table 3.4.1 summarizes the DFA performance by comparing the ability of DFA to assign each suspended or surficial sediment sample to the correct sediment grouping on the basis of the sample’s chemical composition. The ‘% correct’ column of Table 3.4.1 indicates the proportion of samples that were correctly assigned by the analysis. Most sediment samples drawn from the middle and lower Canadian and U.S. zones were correctly allocated by the DFA. The model poorly distinguished only the upper Canadian and U.S. zones, suggesting that surficial sediments from the upper portion of the Detroit River exhibit similar chemical composition on both the Canadian and U.S sides.
The above data indicate that suspended sediments in the deep channels of the Detroit River (likely originating in Lake St. Clair/St. Clair River) are chemically different from sediments deposited along the nearshore areas of the river. Local inputs of pollutants on the Canadian and U.S. sides of the river have historically contributed and/or continue to contribute to contaminated sediments. **The data further suggest that there is limited cross channel mixing of suspended particles across the shipping channels.** Contaminated particles originating on the U.S. shoreline are not deposited along the Canadian reaches of the river and vice versa. This separation of U.S. and Canadian particle sources occurs even at the lower reaches of the river as indicated by the ability of the DFA to successfully distinguish sediment samples from the lower Canadian and U.S. sides.

**3.6 Historic Profiles of Contaminated Sediments**

The sediment coring survey allowed for an analysis of the history of chemical loadings entering the river. In essence, this portion of the study addresses the question of whether the environmental quality of the river is getting better or worse. Figure 3.6.1 identifies the locations of the sediment cores drawn from the river.

Sixteen sediment cores were collected. The cores were sectioned at 1 cm intervals within hours of collection and individual core slices were stored frozen at –20°C until chemically analyzed. Chemical analyses were conducted on the 1\(^{st}\), 2\(^{nd}\), 3\(^{rd}\), 5\(^{th}\), 10\(^{th}\), 20\(^{th}\), 30\(^{th}\) and/or 40\(^{th}\) sediment layers. At the time of this writing, chemical analyses have been completed only for mercury, but depth profiles for organic chemicals and trace elements will be completed shortly.

Figure 3.6.2 shows the vertical distribution of mercury in the analyzed sediment slices of cores collected at each station. Three individual cores were collected at coring station 4 (Celeron Island) to determine field and sampling variability. Very good agreement was demonstrated among the mercury concentrations at depth for the three cores collected at this site, confirming the integrity of the samples. Most core samples (except for those
composed of consolidated clay) were found to exceed MOE’s LEL sediment quality guideline of 0.2 µg/g for mercury. Two samples collected 10 cm below the sediment/water interface from Conners Creek and the Detroit River mouth exceeded MOE’s SEL guideline of 2 µg/g.

Mercury concentrations in core samples from Celeron Island were similar at various depths. Mercury concentration in the surficial horizons of this core was consistent with concentrations in grab samples in the surficial sediment collected near the core site.

Core samples collected at Peche Island and Goyer’s Marina show nearly constant mercury concentrations with depth. This consistent vertical structure for mercury in cores from Peche Island suggests that background mercury loadings entering the Detroit River from upstream sources are constant over time. The higher mercury concentrations in the top layer at River Canard were consistent with concentrations found in surficial sediments downstream of the River Canard Outlet, suggesting a local source of mercury in this area.

The core collected from Conners Creek had mercury concentrations in the upper 5 cm that were twice as high as those found at the nearby Peche Island site. Further, the concentrations of mercury in these sediments were considerably higher at 10 cm than in sediment slices from near the sediment surface, suggesting a recent decrease in mercury loading in this area. High mercury concentrations also appeared at the river mouth. As with Conners Creek, mercury concentrations were highest at the 5 cm and 10 cm layers at the river’s mouth. The vertical pattern of mercury distribution at these stations suggests similar sources and temporal trends of mercury loadings. Conners Creek receives direct mercury loads from the U.S. combined sewer overflows (CSOs), and reductions in mercury concentration at the surface may indicate a reduction in mercury loadings from these sources over time. These data further indicate that large changes in water flow or disturbance events in the Detroit River could uncover highly contaminated sediments, particularly at downstream locations on the U.S. shoreline.
3.7 Water-Sediment Interactions

Sediments can be both a source and a sink for chemicals depending on the process that regulates the chemical flux. The direction of chemical flux (whether sorption or desorption is taking place) is calculated by comparing the chemical pressures in sediment and water, termed the sediment/water fugacity ratio. When this ratio equals one, water and sediments are in a state of thermodynamic equilibrium. Under these conditions sediments are neither a source nor a sink. If, however, the sediment/water fugacity ratio is greater than one, sediments are a source of chemicals. If these conditions persist over time, the diffusive exchange between water and sediments must be small or negligible, compared with advective processes and ongoing chemical loadings. In the latter case, including diffusive exchanges between suspended particles and water would not be required in the hydraulic model.

Figure 3.7.1 summarizes average sediment/water fugacity ratios for PCBs determined at selected locations in the river. These ratios were calculated using data on PCB concentrations in water described in Chapter 2 and data on surficial sediments collected in the vicinity of each biomonitoring station in 1999. Peche Island had the lowest sediment/water fugacity ratios for most of the chemicals analyzed. The average PCB sediment/water fugacity ratio at this site, however, was still almost four times higher than the equilibrium prediction. The sediments at the Turkey Creek Outlet and Middle Sister Island had PCB concentrations ten times higher, while Celeron Island sediments were nearly 60 times higher than the equilibrium prediction.

These data indicate that the direction of diffusive exchange of PCBs between water and sediments occurs by desorption from sediments to water at most sites in the Detroit River. However, the magnitude of the sediment/water fugacity ratios indicate that desorption rates must be very slow. In view of the high water flows and slow desorption rates, it is unlikely that sediment desorption can contribute significantly to contaminant concentrations in the water column. This observation does not mean that contaminants are not being released from sediments into water, but rather that
these releases are small and are not responsible for beneficial use impairments in the system. On the basis of these calculations, the hydraulic model was not modified to address chemical desorption processes for PCBs. Instead, modelling initiatives focused on describing the advective movement of contaminated particles in the river.

The high sediment/water fugacity ratios suggest one of two possibilities: 1) ongoing point sources of contaminated particles (with subsequent advection of these particles to deposition zones) continue to replenish contaminated sediment deposits in the river or 2) sediment deposition zones which have been historically contaminated are highly stable during disturbance events and desorption processes are negligible. The likelihood of sediment remobilization during severe weather events is further evaluated using hydraulic model simulations as described in Chapter 5.

3.8 Benthic Community Structure

The benthic community consists of aquatic invertebrates and microfauna living in the upper layers of sediments. The respiration and burrowing activities of these communities promote a fine vertical structure in the sediments (oxygen, redox potential, sulphur, nitrogen species and organic carbon content) and microhabitats that can control the distribution and bioavailability of a wide variety of toxicants (Burton 1992). These communities also play an important role in nutrient and carbon cycling and can form the base of the aquatic food web in riverine systems. Benthic communities therefore provide an important link for chemical movement between contaminated sediments and fish communities (Morrison et al. 1997).

Past evaluations of benthic invertebrates in the Detroit River have identified some of these communities as impaired (UGLCCS 1989; Farara and Burt 1993). As part of the 1999/2000 sediment survey design, sediment samples were collected to assess benthic community structure. The samples were also drawn from selected sites in 1999 and 2000 and submitted to MOE to conduct laboratory toxicity bioassays. The sampling locations of the latter study were consistent with the surficial sediment survey and the benthic
community survey. Together, these studies form the basis of the sediment TRIAD approach, which uses field and laboratory toxicity studies in combination with chemical sediment quality guidelines to evaluate areas of degraded sediments. The sediment TRIAD approach, originally proposed by Chapman et al. (1992), is endorsed by the IJC. The aims of the survey of the benthic communities conducted in 1999/2000 were to describe the benthic community structure in the entire Detroit River and to determine the relationship between benthic community structure, contaminated sediments and sediment toxicity assays.

3.8.1 Sample collection and processing

The sampling design was similar to that described for surficial sediments in Section 3.3 and involved the same sample locations identified in Figure 3.2.1. The sediments were sieved on site using a sieve bucket with 600 µm mesh. The rinsed samples were transferred to plastic bags and preserved with Kahles solution (mixture of water, formalin and ethanol). To assist in the subsequent analyses, additional environmental parameters were collected at each sampling location. These parameters included sediment pH, water pH, water temperature, water specific conductivity, dissolved oxygen concentrations (0.5 m above the sediments), water depth and current velocity profile. Other parameters gathered from each site included sediment grain size distribution, total organic carbon content, nitrogen content and contaminant concentrations.

In the laboratory, randomly selected samples were rinsed and sieved to separate animals according to size. Organisms were identified by taxonomists using dissecting microscopes and identified to the lowest practical taxonomic level. For the majority of animals this was the species level; chironomids were identified to genus; mayflies, caddisflies and oligochaetes were identified to the family level. Following identification, organisms were preserved and archived for further identification. An independent taxonomist was used to validate animal identifications for every tenth sample analyzed.
3.8.2 Sample collection for sediment bioassays

To complement the physical, chemical and biological sediment quality evaluation, surficial sediment samples were collected at ten sampling stations in 1999. Another set of five locations was sampled in 2000. The program was designed and implemented as a collaborative effort between GLIER and the Ontario Ministry of Environment’s Standards Development Branch Aquatic Toxicity Section with the objective of measuring sediment toxicity. Figure 3.8.1 shows the location of sampling stations used for sediment bioassays each year. At MOE’s request, the sampling stations were located in Canadian waters, but were interspersed along the river. These locations were coordinated with the sampling stations used for chemical, physical and benthic invertebrate evaluations.

Sediment sampling and testing methodology followed the MOE Environment Laboratory Sediment Biological Testing Protocol (Bedard and Persaud, 1992). Sediments were collected as described in Section 3.8.2 until 6 L of sample was obtained. The samples were immediately refrigerated at 4°C and submitted to the MOE laboratory within a week of collection. The sediments were evaluated for acute and chronic laboratory toxicity using standardized mayfly, chironomid and fathead minnow bioassays. The final report on the 1999 and 2000 toxicity results has not yet been completed but will be incorporated into the sediment TRIAD assessment when available.

3.8.3 Benthic community structure and contaminated sediments

The benthic community structure is often used as an index of ecosystem health in management strategies governing aquatic systems (Reynoldson et al. 1995). As a preliminary evaluation, the relationship between community structure and contaminant concentrations in Detroit River sediments was determined. Multivariate statistical analyses (cluster analyses) indicated three main benthic communities in the river: 1) Chironomid, nematode, mayfly and oligochaete-dominated communities; 2) Oligochaete-dominated communities and 3) Zebra mussel and amphipod-dominated communities.
Figure 3.8.2 summarizes the distribution of these benthic communities in the Detroit River. Benthic community cluster #3, consisting mainly of zebra mussels, was found mostly in the upper reaches of the river along the U.S. and Canadian shorelines. Small clusters of these communities were also located in the middle and downstream reaches of the river. This community appears to be associated with high energy regions and course substrates.

Benthic community type #2, consisting mainly of oligochaetes, occurred mostly in the middle reach of the river and along the Trenton Channel. Benthic community type #1 was observed across the entire river length in both U.S. and Canadian waters. This community was notably absent in the highly contaminated Trenton Channel but was frequently observed downstream of the Trenton Channel near Celeron Island and the Detroit River/Lake Erie mixing zone. The latter area contained higher concentrations of mercury and PCBs than the Trenton Channel. **The data suggest that benthic community structure is more strongly defined by the habitat conditions of local sediments and the overlying water quality than by contaminated sediment stress.**

Correlations were not evident between the locations of different benthic communities and surficial sediments having contaminant concentrations above MOE’s SEL or LEL guidelines. Therefore, the benthic community structure of the Detroit River is apparently not related to the distribution or levels of toxic contaminants (mercury, PCBs, PAHs, HCB, DDT or trace elements identified in Sections 3.4.3 through 3.4.6). It should be noted, however, that the present study did not account for variations in contaminant bioavailability in different areas of the river.

### 3.8.4 Prospective work on benthic community structure

The analyses described in Section 3.8.3 were limited to determining whether a correlation exists between toxic contaminant concentrations in surficial sediments and benthic community structure. Other techniques allow benthic community structure at a specific location to be compared with appropriate reference sites (an area having similar environmental parameters as the sample station, but known to be pristine). Key to this
technique is the establishment of reference sites that exhibit habitat and overlying water chemistry conditions similar to the sample locations. When the benthic community structure at a specific sampling station deviates from the reference condition, the station is flagged for further study to determine if changes in community structure relate to toxic stress.

Environment Canada’s Benthic Assessment of Sediment (BEAST) is an example of such a technique (Reynoldson et al. 1995). The sampling strategy employed in the 1999 benthic community survey was designed to meet the requirements of the BEAST technique by including appropriate measures of environmental quality parameters. GLIER researchers have submitted these data sets to Environment Canada (T. Reynoldson and co-workers) to use BEAST to further evaluate degraded benthic communities. These data sets will be combined with the MOE sediment toxicity bioassays when they become available to complete the sediment TRIAD approach for the assessment of benthic communities in the Detroit River Area of Concern.
Table 3.4.1  Success rate of DFA in discriminating between sediment particle groups

<table>
<thead>
<tr>
<th>Source</th>
<th>Number of samples allocated to group</th>
<th>TOTAL</th>
<th>% CORRECT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TRAPS</td>
<td>UPCDN</td>
<td>UPUSA</td>
</tr>
<tr>
<td>TRAPS</td>
<td>42</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>UPCDN</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>UPUSA</td>
<td>0</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>MIDCDN</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>MIDUSA</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>LOWCDN</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>LOWUSA</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Figure 3.2.1 Locations of the 1999 deposited sediments sampling stations. To facilitate representative description of the sediment deposits in the system, stations were located at random locations, interspersed within the river. The sampling grid was stratified into three reaches along the river with sampling intensity equally divided between Canada and US.
Figure 3.2.2 Example of diversity of surficial sediment deposits in Detroit River. Samples collected in 1999 near Peche Island. Samples show a complex mixture of cohesive and granular material (including dead mussel shells). Most locations within the river contained more than 10% of fine-grained, cohesive material as part of the mixture.

Gravel and Stones; 7% <0.075mm; 3% Shells >4mm

Silty Clay; 33% <0.075mm; 0% Shells >4mm

Coarse Sand + Shells; 7% <0.075mm; 12% Shells >4mm

Fine to Coarse Sand; 4% <0.075mm; 0.05% Shells >4mm

**Silt and Clay Content**
- P25 = 2.7%
- Median = 11.0%
- P75 = 30.4%
- Max = 74.1%

**Effort per Sample (grabs to volume)**
- 1 grab = 45%
- 2 grabs = 23%
- 3 grabs = 10%
- Max = 11 grabs/sample
Figure 3.3.1 Locations of the deposited sediment sampling stations (1999) and suspended sediment traps in Detroit River. Deposited sediment stations were stratified according to the river reaches shown.
Figure 3.4.1 Transformation of the sediment sampling grid to account for the direction of flow (‘straightening the river’). The transformed grid is used to calculate the position of each sampling station in the grid from the river head in the downstream direction. This distance is used in data analyses and in subsequent figures in this section.
Figure 3.4.2  Mercury concentrations above MOE sediment quality guidelines (Persaud et al. 1993) in the Detroit River surficial sediment deposits 1999.
Figure 3.4.3  Distribution of mercury in surficial sediment deposits along the Detroit River as a function of the downstream distance and the national jurisdiction. The mercury concentration increases steadily along the U.S. side of the river, whereas mercury residues in Canadian sediments are low in the upper reach and begin increasing downstream of the Turkey Creek area. A spatially condensed group of elevated U.S. stations located in the mouth of Trenton Channel suggests a distinct Hg source upstream of this area.
Figure 3.4.4 The histogram of mercury distribution in Detroit River surficial sediment deposits (1999 randomized whole-river survey) contrasted with two local impacted areas (Conners Creek and Black Lagoon, target-sampled in 2000). Two populations of sites in the river (excluding Conners Creek and Black Lagoon) are evident: the background stations (95% of total stations sampled) dispersed throughout the river, and the subset of elevated stations comprising the remaining 5%. The mouth of Trenton Channel contains \( \frac{3}{4} \) of the latter group of stations. The magnitude of mercury residues found at the stations falling into the elevated subpopulation of stations is comparable with the concentrations of sediments in Conners Creek and the Black Lagoon.

Note: The histogram summarises the year 1999 whole river survey results using random stations within the river. Black Lagoon and Conners Creek sites were not sampled during this survey and are not part of the main histogram.

Ranges of Hg concentrations into which the individual stations from Black Lagoon and Conners Creek (marked) would fall if included in histogram of the whole river survey results.
Figure 3.4.5 PCB concentrations above MOE sediment quality guidelines (Persaud et al. 1993) in the Detroit River surficial sediment deposits. 1999 sediment survey results.
Figure 3.4.6. Distribution of total PCBs in the organic carbon of surficial sediment deposits along the Detroit River as a function of the downstream direction and the national jurisdiction. There is a progressive increase in PCBs along the US shore, while the sediments along the Canadian shore remain relatively constant, with the exception of a group of stations downstream of the Turkey Creek area. Elevated PCBs residue at sporadic stations along both US and Canadian shores are evident.

Note: two outlying US datapoints from in upper river reach were removed for clarity of presentation:
Station 015 at 7,900m (114,000 mg/kg OC) and
Station 030 at 12,000m (51,000 mg/kg OC)
Figure 3.4.7 PAH concentrations above MOE sediment quality guidelines (Persaud et al. 1993) in the Detroit River surficial sediment deposits. 1999 sediment survey results.
Figure 3.4.8 Distribution of total PAHs in the organic carbon of surficial sediment deposits along the Detroit River as a function of the downstream direction and the national jurisdiction. PAH compounds are ubiquitous in the river with no apparent increase along the river. PAH residues are significantly higher in the sediments near U.S. shoreline than in the sediments along the Canadian shore.
Figure 3.5.1 The distribution of organic carbon in the deposited sediment stations grouped by river reach and fluvial suspended sediments collected in sediment traps in 1999. Deposited sediments were collected at 147 stations in 6 river reaches. Fluvial suspended sediments were collected monthly at 9 sediment traps. The deposited bed sediments are organically enriched as compared with the suspended sediments carried by the river flow at all locations.
Figure 3.5.2 Chemical signatures of sediment particle populations in Detroit River using Discriminant Function Analysis. Sediment ‘fingerprints’ are based on concentrations of 19 metals common to all the suspended and deposited sediment samples. Deposited sediments were collected at 147 stations from 6 strata/river reaches (1999). Suspended sediments were collected monthly at 8 sediment traps (1999).
Figure 3.6.1 Locations of sediment coring stations sampled by GLIER in April 2001.
Figure 3.6.2. Vertical subsurface distribution of mercury at the coring locations (mg/kg, dry weight). Three individual cores at the Station #4 are shown individually (field replicated station). Standard error calculated using Station 4 samples is assumed to apply to other stations and was used to construct error bars in the rest of the plots.
Figure 3.7.1. Sediment/water PCB fugacity ratios at three locations in the Detroit River and one location in Western Lake Erie. Columns indicate the average PCB fugacity ratio for all PCB congeners. Error bars refer to the standard error of the estimate.
Figure 3.8.1 Locations of the 1999 and 2000 sediment sampling sites for toxicity bioassays. A set of 10 sites was sampled in November 1999, 5 sites were sampled in November 2000. Sediment samples were submitted to the MOE Toxicology Labs for evaluation using standard laboratory sediment biological testing protocol.
Figure 3.8.2 Distribution of benthic communities in Detroit River. There are three general clusters of surficial sediment deposits characterized by the structure of aquatic invertebrates that inhabit them.
4.0 CONTAMINANTS IN FISH AND BIOTA

4.1 Fish Consumption Advisories in Michigan and Ontario

Elevated contaminant concentrations in sport fish species in the Detroit River result in government advisories on the amount of fish that can safely be consumed. Sport fishing in the Detroit River and the associated Huron-Erie corridor is a multi-million dollar industry that is constrained by fish consumption advisories. Eighteen percent of fishermen interviewed along the Canadian shoreline in a recent survey were concerned about contaminant levels in fish and 42 percent had concerns about the water quality of the river (Fish and Wildlife Nutrition Project 2000).

Fish consumption advisories constitute an impairment of a beneficial use. Further, the lifting of fish consumption advisories in an Area of Concern is used as a benchmark for evaluating the success of management activities (IJC 1991). Different contaminant concentrations drive fish consumption advisories in different jurisdictions. The number of fish consumption advisories, the species considered in different sampling programs, and the size ranges for specific advisories differ between Ontario and Michigan. This report addresses fish consumption advisories for both Michigan and Ontario.

4.1.1 Criteria used to issue fish consumption advisories in Ontario and Michigan

Polychlorinated biphenyls, along with mercury, are responsible for most fish consumption advisories affecting the Detroit River. According to the Ontario Ministry of the Environment, 34 percent of all Ontario fish consumption advisories for Lake St. Clair and the St. Clair and Detroit rivers relate to PCB concentrations. In Lake Erie, PCBs are responsible for 70 percent of the fish consumption advisories issued by Ontario. In Ontario, consumption advisories for sport fish are issued when concentrations of PCBs in one or more captured fish exceed 0.5 µg/g wet weight. It is advised that no fish be consumed in Ontario when PCB concentrations in samples exceed 4 µg/g wet weight.
Ontario also issues different advisories for the more sensitive subpopulation of women of childbearing age and children under fifteen by advising the subpopulation to consume fewer meals each month.

In Michigan, different criteria are used to establish consumption advisories for the general public and the sensitive subpopulation of women of childbearing age and children under fifteen. Consumption advisories for the subpopulation are put into effect when PCB concentrations in the dorsal muscle of one or more sampled fish exceed 0.05 µg/g wet weight. It is advised that no fish be consumed when PCB concentrations in one or more fish exceed 2 µg/g wet weight. Michigan fish consumption advisories for the general public are put into effect when more than 10 percent of captured fish of a specific species and size range contain PCB concentrations exceeding 2 µg/g wet weight. It is recommended that no fish be consumed when more than 50 percent of captured fish of a specific species and size range contain PCB concentrations exceeding 2 µg/g wet weight.

Mercury is responsible for 66 percent of Ontario sport fish advisories for Lake St. Clair and the St. Clair and Detroit rivers and 30 percent of Ontario advisories for Lake Erie. The concentrations triggering fish consumption advisories for mercury are similar for Ontario and Michigan. In Ontario, consumption advisories for sport fish begin when dorsal muscle concentrations of mercury exceed 0.45 µg/g wet weight. It is recommended that fish not be eaten when mercury concentrations exceed 1.57 µg/g wet weight. Ontario recommends reducing the number of meals each month for women of childbearing age and children. In Michigan, advisories are issued when mercury concentrations in one or more fish samples exceed 0.5 µg/g wet weight. It is recommended that no fish be eaten when one or more fish samples contain mercury concentrations greater than 1.5 µg/g wet weight. As in Ontario, the sensitive human subpopulation, women of childbearing age and children are advised to consume fewer meals each month than the general population.

In addition to mercury and PCBs, a number of other chemicals are monitored in fish. The Ontario sport fish contaminant monitoring program routinely analyzes fish for mirex,
DDT, toxaphene, lindane, heptachlor, aldrin, chlordane, dioxins and furans, OCS and chlorinated benzenes in their tissues. Similar programs exist in Michigan. This report focuses on PCBs and mercury as specific advisories for other chemicals, with the exception of a dioxin advisory for carp in Michigan, are not currently in effect for the Detroit River.

4.1.2 Fish consumption advisories issued in the Detroit River

Table 5.6.1 summarizes consumption advisories for sport fish established for the Detroit River by the Ontario and Michigan governments in 2001. Ontario provides specific advisories for the upper and lower portions of the Detroit River, while Michigan issues advisories for the entire river. Consumption restrictions currently exist for 11 species of fish in the river. The large number of species for which advisories exist and the severity of some of the restrictions (no consumption is advised for eight species) indicate that the consumption of fish and wildlife as a beneficial use is severely degraded in the Detroit River Area of Concern.

A recent survey of shoreline fishing and fish consumption habits on the Canadian side of the Detroit River provides valuable information on the demographic composition of those who fish in the river, their attitudes towards fishing, and their fish consumption habits (Fish and Wildlife Nutrition Project 2000). The report recommends that 1) contaminant monitoring programs and fish consumption advisories address the ten most frequently consumed fish species in local jurisdictions and 2) fish consumption advisories include more of the popular fishing sites in the region. The study also ranked the most frequently-consumed fish species in the Detroit River: 1) yellow perch, 2) walleye, 3) white bass, 4) rock bass, 5) smallmouth bass, 6) white perch, 7) channel catfish, 8) bluegill sunfish, 9) largemouth bass and 10) black crappie. Other Detroit River species less often consumed include northern pike, brown bullhead, pumpkinseed, freshwater drum, muskellunge, common carp, rainbow trout, white sucker, sunfish, lake whitefish, sturgeon and coho salmon.
Information for fish consumers in Ontario was available for ten of the 20 species reportedly eaten by those fishing the Detroit River shoreline, while such information in Michigan was limited to five of the 20 species, as well as one species (redhorse sucker) not listed as frequently consumed by humans in the Fish and Wildlife Consumption project. Of the ten species most frequently consumed from the river, Ontario provides consumption recommendations for six, Michigan for only two. Advice on smallmouth bass (rank 5), bluegill sunfish (rank 8), largemouth bass (rank 9) and black crappie (rank 10) is not available for either jurisdiction. The analyses show a substantive overlap between the most attractive species for human consumption and those with the most elevated contaminant levels. It is currently recommended that the sensitive subpopulation not eat five of the ten most frequently consumed fish species: yellow perch, walleye, white bass, rock bass and channel catfish. Other species affected by a “no consumption advisory” include freshwater drum, muskellunge and common carp. These data indicate that provincial and state agencies still consider human exposure to PCBs and mercury from ingestion of contaminated fish to be a health concern in the Detroit River Area of Concern.

4.2 Surveys of Contaminant Residues in Detroit River Fish and Biota

Biological surveys were performed to develop a database of PCBs, organochlorine pesticides, mercury and trace metal residues in Detroit River biota. This database was aimed primarily at identifying factors governing contaminant transfer through the river’s food web, assessing appropriate organisms to be used as biomonitor of local environmental quality, and validating a bioaccumulation model of the river (Chapter 6.0).

A biological monitoring program was implemented in 2000 and 2001. Figure 4.1.1 identifies the location of five monitoring stations along the Detroit River. They included three Canadian sites (Peche Island, the Turkey Creek Outlet, Turkey Island), one U.S. site (Celeron Island) and a downstream site in western Lake Erie (Middle Sister Island). The upstream control site, Peche Island reflects contaminant exposures similar to those in Lake St. Clair. Celeron Island is an area of high contamination with elevated residues of
mercury, PCBs and organochlorine pesticides in water (Section 2.2) and sediments (Section 3.2). The Middle Sister Island station, which receives a constant plume of Detroit River outflow, has historically been used to monitor contaminant trends in a variety of aquatic animals, including benthic invertebrates, fish and sea birds (Koslowski et al. 1991; Morrison et al. 1996; Gewurtz et al. 2000; Hebert et al. 2000).

According to Russell et al. (1999), the Detroit River food web can be partitioned into five major feeding groups: plankton, benthic invertebrates, forage fish, benthic feeding fish and pelagic/piscivorous fish. Figure 4.1.2 summarizes the hypothetical structure of that food web. At each monitoring site, researchers sampled organisms occupying different trophic levels, i.e. species grouped by their feeding relationships in the aquatic food web. Benthic invertebrates were collected by grab samplers and sieved and sorted on site, yielding composite samples of 2 g each for organochlorines, trace element and mercury analyses. Forage fish were collected by seine and trawl nets. Forage fish of the same species were composited into samples consisting of five fish each for organochlorine and trace element analyses. Pelagic and piscivorous fish were collected by gill net, trawl net and electro-fishing techniques. Samples of these fish were prepared for analysis by removing 5 g of skinless dorsal muscle, consistent with protocols used by the Ontario Ministry of the Environment (MOE). All collections were processed and chemically analyzed: 202 samples for PCBs (40 PCB congeners), 168 samples for organochlorine pesticides (20 compounds), and 145 samples for mercury and 54 samples for trace element analyses (arsenic, cadmium, copper, nickel, lead and zinc). Table 4.1.1 summarizes the species collected and the number of samples analyzed at each monitoring site.

Chemical concentrations of organochlorine pesticides and PCBs are reported in two different units to distinguish between the different types of analyses conducted and to facilitate comparison with data sets in the scientific literature. Organochlorine pesticide and PCB concentrations are expressed in µg/g wet weight when biota residues are compared with tissue residue guidelines or when maximum contaminant residues in biota are reported. The units reflect the risk to humans consuming contaminated fish. When
organochlorine and PCB concentrations in biota are compared over time or among species the data are presented as µg/g lipid weight. This reduces variability attributed to the different fat contents of individual fish. Mercury and trace element concentrations are reported in µg/g dry weight when data are compared among species and in µg/g wet weight when biota residues are compared with tissue residue guidelines and objectives.

4.3 Polychlorinated Biphenyls in Detroit River Fish and Biota

PCBs were detected in all the biota samples analyzed in the current study. The highest PCB concentrations appeared in two carp (more than 66 cm long) collected from the Turkey Creek Outlet (4.66 µg/g and 3.33 µg/g wet weight). Elevated PCB concentrations also appeared in carp captured at Celeron Island (body length = 55 cm; PCB concentration = 1.13 µg/g wet weight) and Turkey Island (body length = 47 cm, PCB concentration = 0.85 µg/g wet weight) and in longnose gar samples from the Turkey Creek Outlet and Middle Sister Island (three fish with body lengths more than 56 cm, PCB concentration = 0.72 - 0.82 µg/g wet weight). PCB concentrations in these samples exceeded the minimum amount required to trigger fish consumption advisories in Ontario and Michigan. The IJC’s PCB Tissue Residue Objective for the Protection of Fish Consuming Birds and Animals (0.100 µg/g wet weight) was exceeded in 46 percent of all biota samples analyzed, including forage fish and benthic invertebrates. Thus, PCB concentrations in Detroit River biota are high enough to significantly threaten wildlife.

In the 1988 UGLCCS study, total PCB concentrations in carp ranged from 4.7 to 16 µg/g wet weight (UGLCCS 1988). Although the 1985 levels were higher than those in the current study, they are consistent with the maximum concentrations for the river. The UGLCCS study also reported total PCB concentrations in spottail shiners to range from 0.2 to 0.3 µg/g wet weight on the Canadian side of the river and from 0.9 to 2.6 µg/g wet weight on the U.S. side. These levels are consistent with those observed in the present assessment. PCB concentrations in spottail shiners collected at Peche Island, the Turkey
Creek Outlet/ Turkey Island and Celeron Island in 2000-2001 ranged from 0.02 to 0.09, 0.10 to 0.31, and 0.31 to 0.88 µg/g wet weight, respectively.

Two biological monitoring stations (Peche Island and Middle Sister Island) were the same as those employed in the food web surveys performed in 1991-1992 (Russell et al. 1999; Koslowski et al. 1994; Morrison et al. 1996). This correspondence permitted an evaluation of PCB concentrations in river biota over time. Figure 4.2.1 summarizes trends in PCB concentrations in different aquatic species at Peche Island and Middle Sister Island between 1991 and 2001. In each of these years, PCBs were observed to biomagnify through the food chain. The highest concentrations appeared in pelagic, piscivorous and benthic fish species; the lowest concentrations, in benthic invertebrates and forage fish. Both data sets indicate that PCB concentrations in Detroit River biota have not changed over the last ten years. The data are consistent with trends reported for other long-term biomonitoring programs in the area, including the Canadian Wildlife Service’s herring gull biomonitoring program (Hebert et al. 2000) and the Department of Fisheries and Ocean’s walleye monitoring program for Lake Erie (Mike Whittle, Personal Comm).

Figure 4.2.2 relates data for PCB concentrations in biota to animals’ sizes and feeding groups at each sampling location. PCBs biomagnify in the food webs at Peche Island and Turkey Creek/Island. Trends toward PCB biomagnification were less pronounced at Celeron Island and Middle Sister Island in western Lake Erie. Figure 4.2.3 examines the correlation between PCB concentrations in biota and sediments for organisms occupying different feeding groups. PCB concentrations in benthic invertebrates and forage fish closely resembled PCB concentrations in sediments sampled near each food web site. In contrast, the PCB concentrations in large fish species (those occupying pelagic, piscivorous and benthic feeding groups) did not resemble contaminant patterns in sediments. The data indicate that benthic invertebrates and forage fish can be used as local monitors of environmental quality, whereas, large fish are exposed to contaminants over broader areas. These findings are not surprising: some of the large
fish species travel over long distances and may be present in the Detroit River only for short times.

4.4 Organochlorine Pesticides in Detroit River Fish and Biota

Organochlorine pesticide analyses were undertaken for 168 biota samples. The chemical analyses including 13 chemicals or chemical classes: chlorinated benzenes (1,2,3,4-TCB; 1,2,4,5-TCB; QCB; HCB), lindane, chlordane, OCS, DDT, trans-nonachlor, cis-nonachlor, mirex, heptachlor and dieldrin. None of these compounds were found at concentrations that would require fish consumption advisories.

Four chemicals (1,2,3,4-TCB, 1,2,4,5-TCB, lindane and mirex) were detected infrequently (less than 50 percent of the time) in biota. These compounds were found at similar concentrations across the sample sites, with the exception of mirex. Although mirex was typically detected in 11 – 33 percent of the biota samples analyzed from a specific site, 92 percent of biota samples collected from the Turkey Creek Outlet exhibited detectable mirex residues. The highest mirex concentrations were observed in two common carp (0.007 and 0.013 µg/g wet weight) from this site. **Benthos and forage fish from this site also exhibited higher mirex concentrations than at other monitoring stations. The elevated mirex concentrations in biota at this site suggest a source of mirex in the vicinity of the Turkey Creek Outlet or possibly in Turkey Creek itself. Mirex concentrations in biota at this site registered below Ontario fish tissue guidelines used to establish fish consumption advisories.**

QCB, HCB, dieldrin and OCS were detected in 76 to 99 percent of the biota samples analyzed in the current study. The highest concentrations of QCB, HCB, dieldrin and OCS were 0.002, 0.010, 0.015 and 0.087 µg/g wet weight, respectively. For all these chemicals, the highest residue levels appeared in carp from the Turkey Creek Outlet. The ranges in chemical concentrations in biota for each of the previous organochlorine pesticides were similar at all sampling stations. These findings are consistent with the 1988 UGLCCS study, which found HCBs and OCS to be uniformly distributed in the
river. An exception to these findings, dieldrin exhibited elevated concentrations (two to three times higher residue levels) at Middle Sister Island, suggesting higher concentrations in Lake Erie. **HCB and OCS biomagnify in the food web at Peche Island and the Turkey Creek Outlet, whereas QCB and dieldrin do not biomagnify in the Detroit River food web.**

Chlordane was detected in 95 percent of the samples analyzed in the current study. The highest concentration for chlordane was 0.043 µg/g wet weight in a carp from the Turkey Creek Outlet. Chlordane residues were approximately two to three times higher in samples from the Celeron Island site than from other biomonitoring stations. DDT was detected in all the biota samples analyzed for organochlorine pesticides. The highest concentration for DDT was 1.15 µg/g wet weight in a carp from the Turkey Creek Outlet. As it was the case for chlordane, DDT concentrations were more elevated in benthic invertebrates and forage fish samples from Celeron Island than in those from other sites. Although DDT was not found at concentrations warranting sport fish consumption advisories, the levels in fish tissues exceeded environmental quality objectives for the protection of wildlife. Fifty-four percent of the biota samples had DDT concentrations exceeding the Canadian Tissue Residue Guideline for Protection of Wildlife (0.014 µg/g). **The high DDT concentrations occurred at all stations and involved organisms from all feeding groups. Both chlordane and DDT biomagnify in biota located at the Peche Island, Turkey Island and Turkey Creek sites.**

**4.5 Mercury in Detroit River Fish and Biota**

Mercury was detected in all 145 biota samples from the five monitoring stations. The highest mercury concentration in biota was 1.68 µg/g wet weight in a bowfin (fish length = 60 cm) from the Turkey Creek Outlet. Elevated residues of mercury (more than 1 µg/g wet weight) were also detected in a longnose gar sample (74 cm fish) from Peche Island and in four muskellunge samples (fish lengths from 91 to 116 cm) collected at Turkey Island. Mercury concentrations exceeding 0.5 µg/g wet weight were detected in bowfin, longnose gar, northern pike and carp samples from Peche Island, the Turkey Creek
Outlet, Turkey Island and Middle Sister Island. The mercury concentrations in all these samples were higher than the concentration used to establish fish consumption advisories for mercury in both Ontario and Michigan. The IJC Tissue Residue Objective for the Protection of Aquatic Wildlife and Fish Consuming Birds is $0.50 \mu g/g$ wet weight. This concentration was exceeded in 12 percent of the samples from the Detroit River.

**Elevated mercury concentrations were mainly associated with large top predators.**

Figure 4.4.1 summarizes trends in mercury concentrations in biota samples from each monitoring station. The range of mercury concentrations in any class of animals of a particular size was similar at all stations. Mercury, like PCBs and organochlorines, biomagnifies in the Detroit River food web. However, mercury concentrations in organisms at the upper trophic levels varied greatly, between ten and one hundred times among fish of similar sizes and feeding groups. Mercury concentrations in benthic invertebrates were also variable, particularly at the Middle Sister Island station. In contrast, forage fish exhibited much lower variability both within and among the sampling stations. **These data suggest that forage fish are the most appropriate biomonitors for assessing spatial and temporal trends of mercury.**

### 4.6 Trace Elements

Although less frequently analyzed, trace elements (arsenic, cadmium, copper, nickel and lead) were rarely detected in biota samples collected at the five monitoring stations. Detection frequencies follow: arsenic 1/54, cadmium 6/54, copper 1/54, nickel 5/54, lead 1/54. Zinc was detected in 44/54 samples; the maximum concentration was 66.7 $\mu g/g$ wet weight. The concentrations of zinc were similar at all monitoring sites and were below those affecting aquatic biota and wildlife.

### 4.7 Conclusions and Recommendations

**Contaminants in biota cause a number of beneficial use impairments such as restrictions on the consumption of fish and wildlife, degraded fish and wildlife, fish**
tumors or other deformities, and bird or animal deformities or reproductive problems. Fish consumption advisories economically constrain the sport fishing industry in the region. Further, current advisories include some of most frequently consumed fish species in the river and thus pose a threat to human health. All such advisories for the river can be attributed to either mercury or PCBs.

A recent study recommended that programs monitoring contaminants in sport fish provide consumption advice on at least the ten most frequently consumed species in each Area of Concern (Fish and Wildlife Nutrition Project, 2000). In the Detroit River, such information is currently available for only six of the ten most frequently consumed sport fish species. Some of the recommendations of the Fish and Wildlife Nutrition Project (2000) are supported by the current study.

Specifically, MOE should advise on the consumption of smallmouth bass, bluegill sunfish, largemouth bass and black crappie from the Detroit River. The Michigan fish consumption guide should be extended to include advice on white bass, rock bass, smallmouth bass, white perch, channel catfish, bluegill sunfish, largemouth bass and black crappie.

The Fish and Wildlife Nutrition Project also recommended that more information be available on popular fishing sites in the region. The present study of spatial trends in PCBs and mercury residues in biota indicates that large fish species, particularly those included in consumption advisories, integrate chemical exposures over large areas of the river. Hence, a fish captured at a popular fishing area may have become contaminated in other areas, possibly in highly contaminated Canadian or U.S. regions of the river or in lakes St. Clair or Erie.

It is therefore recommended that Canadian guidelines provide advice on large spatial areas, e.g. the entire Detroit River, as do the Michigan guidelines.

The current study indicates that PCB concentrations in all types of aquatic biota have not declined since the mid-1980s. At Peche Island and Middle Sister Island, PCB concentrations in biota remained unchanged between 1991 and 2000/2001. Maximum PCB concentrations in common carp and spottail shiners collected in 2000/2001 were
similar to such concentrations reported for these species in 1985 (Suns et al. 1985).

These findings confirm the conclusion in Chapter 2 that the river is not cleaning itself up over time.

The current study identifies PCBs and DDT as concerns relating to the degradation of fish and wildlife. The IJC objective for PCBs was exceeded in 46 percent of the biota samples. Similarly, total DDT concentrations in biota exceeded the Canadian Tissue Residue Guideline for the Protection of Wildlife in 54 percent of the biota samples.

It is recommended that further studies of reproductive success and other toxicological effects be conducted on fish-eating birds and wildlife of the region.
Table 4.1.1  Food web sample collections in the Detroit River 2000 - 2001

<table>
<thead>
<tr>
<th>Species</th>
<th>Peche Island</th>
<th>Turkey Creek Outlet</th>
<th>Turkey Island</th>
<th>Celeron Island</th>
<th>Middle Sister Island, Western Lake Erie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plankton Tow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BENTHOS</strong></td>
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<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
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<td></td>
</tr>
<tr>
<td>Leeches</td>
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<td></td>
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<td></td>
</tr>
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<td><strong>FORAGE FISH</strong></td>
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<td></td>
</tr>
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<td><strong>PELAGIC FISH</strong></td>
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<td></td>
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<td><strong>BENTIC FISH</strong></td>
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<td>Brown Bullhead</td>
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<td>Freshwater Drum</td>
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<td>Redhorse Sucker</td>
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</table>

First number recorded = Number of samples used for organochlorine analyses (202 total PCB analyses and 168 OC analyses)

[X] = Number of samples used for total mercury analyses (145 total analyses)

(X) = Number of samples used for trace element analyses (54 total analyses)
Table 4.6.1  2001 sport fish consumption advisories and restrictions in the Detroit River

<table>
<thead>
<tr>
<th>Species/Rank</th>
<th>Population</th>
<th>Jurisdiction</th>
<th>Size (cm)</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Perch (1)</td>
<td>Women &amp; children</td>
<td>MI</td>
<td>15+</td>
<td>One meal/wk</td>
</tr>
<tr>
<td></td>
<td>Women &amp; children</td>
<td>ON Upper</td>
<td>15+</td>
<td>No Consumption</td>
</tr>
<tr>
<td></td>
<td>Women &amp; children</td>
<td>ON Lower</td>
<td>15+</td>
<td>Four meals/mo</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Upper</td>
<td>15+</td>
<td>Four meals/mo</td>
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<tr>
<td>Walleye (2)</td>
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<td>MI</td>
<td>30+</td>
<td>One meal/wk</td>
</tr>
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<td></td>
<td>Women &amp; children</td>
<td>ON Upper</td>
<td>30-45</td>
<td>Four meals/mo</td>
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<td></td>
<td>Women &amp; children</td>
<td>ON Upper</td>
<td>45+</td>
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<tr>
<td></td>
<td>Women &amp; children</td>
<td>ON Lower</td>
<td>30-55</td>
<td>Four meals/mo</td>
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<tr>
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<td>ON Lower</td>
<td>30-55</td>
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<td>Women &amp; children</td>
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<td>20+</td>
<td>No Consumption</td>
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<tr>
<td></td>
<td>Women &amp; children</td>
<td>ON Lower</td>
<td>15+</td>
<td>Four meals/mo</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Upper</td>
<td>5-20</td>
<td>Eight meals/mo</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Upper</td>
<td>20+</td>
<td>Four meals/mo</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Lower</td>
<td>15+</td>
<td>Eight meals/mo</td>
</tr>
<tr>
<td>Smallmouth Bass (5)</td>
<td>A.I. NA</td>
<td>A.I. NA</td>
<td>A.I. NA</td>
<td>A.I. NA</td>
</tr>
<tr>
<td>White Perch (6)</td>
<td>Women &amp; children</td>
<td>ON Upper</td>
<td>15+</td>
<td>Four meals/mo</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Upper</td>
<td>15+</td>
<td>Eight meals/mo</td>
</tr>
<tr>
<td>Species/Rank</td>
<td>Population</td>
<td>Jurisdiction</td>
<td>Size (cm)</td>
<td>Details</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------</td>
<td>--------------</td>
<td>-----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Muskellunge (15)</td>
<td>Women &amp; children</td>
<td>ON</td>
<td></td>
<td>No Consumption</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON</td>
<td></td>
<td>No Consumption</td>
</tr>
<tr>
<td>Carp (16)</td>
<td>Women &amp; children</td>
<td>MI</td>
<td>15+</td>
<td>No Consumption</td>
</tr>
<tr>
<td></td>
<td>Women &amp; children</td>
<td>ON Upper</td>
<td>35+</td>
<td>No Consumption</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Lower</td>
<td>35+</td>
<td>No Consumption</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>MI</td>
<td>15+</td>
<td>No Consumption</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Upper</td>
<td>35-45</td>
<td>Four meals/mo</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Upper</td>
<td>45-55</td>
<td>Two meals/mo</td>
</tr>
<tr>
<td></td>
<td>General Public</td>
<td>ON Lower</td>
<td>35-45</td>
<td>One meal/mo</td>
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<td>A.I. NA</td>
<td>A.I. NA</td>
<td>A.I. NA</td>
</tr>
<tr>
<td>White Sucker (18)</td>
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<td>A.I. NA</td>
<td>A.I. NA</td>
<td>A.I. NA</td>
</tr>
<tr>
<td>Unidentified Sunfish (19)</td>
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<td>A.I. NA</td>
<td>A.I. NA</td>
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</tr>
<tr>
<td>Lake Whitefish (20)</td>
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<td>A.I. NA</td>
<td>A.I. NA</td>
</tr>
<tr>
<td>Redhorse Sucker (no rank)</td>
<td>Women &amp; children</td>
<td>MI</td>
<td>15-35</td>
<td>One meal/wk</td>
</tr>
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<td></td>
<td>Women &amp; children</td>
<td>MI</td>
<td>35+</td>
<td>Six meals/year</td>
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</tbody>
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Figure 4.1.1. Locations of food web sample monitoring sites in the Detroit River.
Figure 4.1.2. Hypothetical Detroit River food web. Feeding relationships are designated by the arrows (adapted from Russell et al. 1999 and Morrison et al. 1997. Benthic invertebrates are Oligochaetes, Chironomids, Amphipods, Mayfly, Zebra Mussels and Crayfish; Forage fish are Alewife, Rainbow Smelt, Round Goby, Spottail Shiner, Emerald Shiner, Brook Silverside, Young-of-the-Year Fish; Pelagic Fish are Black Crappie, Yellow Perch, White Bass, White Perch, Bluegill Sunfish and Gizzard Shad; Piscivorous Fish are Muskellunge, Northern Pike, Largemouth Bass, Smallmouth Bass and Walleye; Benthic Feeding Fish are Rock Bass, Common Carp, White Sucker, Freshwater Drum, Brown Bullhead and Channel Catfish.
Figure 4.2.2. Trophodynamic of PCB residues in aquatic biota in the Detroit River. Each graph presents food web data from different collection sites expressed according to organism size. Symbols are used to designate animals with different feeding behaviors.
Figure 4.2.3. Correlation between PCB concentrations in organisms and sediment for different animals grouped by feeding strategy. Benthic invertebrates and forage fish (top graph) had PCB concentrations that were significantly correlated with sediment PCBs. Pelagic fish, piscivores and benthic feeding fish PCB concentrations were not strongly correlated with sediments. The poor of correlation for these large fish species may be related to fish movement.
Figure 4.4.1. Trophodynamic of mercury residues in aquatic biota of the Detroit River. Different symbols indicate the locations for different animal species grouped by body size.
5.0 HYDRAULIC MODEL

The hydraulic and sediment transport models aim to provide a tool for predicting the movement of contaminants in the Detroit River. These models were developed to assess future monitoring needs and evaluate options for remedial actions. The hydraulic model describes the direction and magnitude of water flow in the river. The sediment transport model addresses the movement of particles in the water column, predicts the fate of a specific population of particles after they enter the water and forecasts the stability of contaminated sediment deposits under different flow conditions.

Both the hydraulic model and the sediment transport model are necessary to describe the fate of pollutants in the system. The hydraulic model is the backbone for the sediment transport model and must be calibrated using actual flow measurements to ensure that the sediment transport simulations are reliable.

In the current study, the sediment transport model was used to characterize the spatial patterns of sediment transport and deposition in the river during average flow conditions and to assess hazards arising from sediment transport during a rare storm event with a 20-year return period. This information was used to determine how changes in flow conditions could influence the fate of contaminated sediments in the river and affect sediment loadings entering Lake Erie. Future applications of the model will determine the fate and deposition of PCBs and mercury entering the Detroit River from Lake St. Clair and evaluate the fate and movement of contaminated particles along the Canadian shoreline originating from Canadian tributaries.

5.1 Model Formulation and Parameterization

The complex geometry and bathymetry (river bottom elevation) of the Detroit River affects the flow patterns in the river. A model that allows for flexible gridding of the river is necessary to address such complexities. A three-dimensional model was used to
address abrupt changes in water depth and secondary flows. The Curvilinear Hydrodynamics in 3-Dimensions (CH3D) model was selected as it satisfies these requirements and includes a sediment transport sub-model. The U.S. Corps of Army Engineers provided GLIER with the computer code required to construct the CH3D model for the Detroit River.

5.2 Requirements for Model Development

Field data sets describing the geometry and flow conditions of the Detroit River were required as input parameters for the hydraulic model and they were used to calibrate the model and validate its predictions. Before the model can accurately simulate flow in the system, it is necessary to design a grid for the river, establish boundary conditions and estimate critical parameters such as the hydraulic roughness of the riverbed and eddy viscosity. Some critical components in the development of the hydraulic model are described in the following sections of this chapter.

5.2.1 Bathymetry

In 2000, NOAA conducted a new bathymetric survey of the entire Detroit River and provided GLIER researchers with the raw soundings on river depth. GLIER processed these data incorporating water level corrections and filtering out anomalous data. Approximately 0.1 percent of the bathymetry measurements were removed because of apparent sampling errors. Approximately 5 percent of the river is too shallow to be accessed by the bathymetric survey vessel. In these areas, it was assumed that the bed elevation equalled the water level at the time of the NOAA measurements less an assumed minimum accessible depth of 0.75 m. The new bathymetry data set was incorporated into the model grid.

5.2.2 Grid generation

The CH3D model uses a curvilinear grid that conforms to flow boundaries and provides detailed description of the complex horizontal geometry of the river. This grid is shown
in Figure 5.2.1a. Figure 5.2.1b shows the bottom depth of the grid cells. The grid, generated using the Surface-Water Modeling System (SMS) interface provided by Environmental Modeling Systems, Inc., has 7,696 horizontal cells and five vertical layers. The dimensions of each cell in the grid are approximately 100 m by 100 m.

5.2.3 Water level data sets for lakes St. Clair and Erie

Water levels that vary with time along the river and at its head and tail waters were required to convert water depths measured by NOAA to riverbed elevations required by the model. Data from six gauging stations on the U.S. side of the river and two on the Canadian side were obtained from the National Ocean Service (NOS), and the Department of Fisheries and Oceans Canada, respectively.

Thirty-two years of hourly water level data from the water level gauge at the Fermi Power Plant on Lake Erie in Michigan were analyzed to determine the frequency and magnitude of wind-induced set-up on Lake Erie, suspected to significantly affect the flow conditions in the river. It was observed that sustained wind in Lake Erie was able to cause the lake set-down and affect the flow condition in the river. A frequency analysis of the data, summarized in Figure 5.2.2, was conducted to relate the storm return interval and the magnitude of drop in water levels. This analysis was used to determine the magnitude of water level decline in Lake Erie that is likely to occur once in 30 years. Water level drops of 1.25 and 1.8 m are expected with a reasonable probability every two and 20 years, respectively. Although infrequent, such events have much higher magnitude than normal water fluctuations in the system and were suspected to affect flow patterns in the system and the stability of contaminated sediment deposits. Following calibration, the sediment transport model was used to determine if these events would result in changes in the distribution of sediment deposition zones in the Detroit River.
5.2.4 Water velocity measurements at transects in the Detroit River

To adequately simulate the river flow patterns the hydraulic model was calibrated to conform to the flow conditions measured in the field. Flow velocity distribution was measured with an Acoustic Doppler Current Profiler (ADCP). This device simultaneously measures flow magnitude and direction along the surveyed cross sections of the river. The U.S. Army Corps of Engineers conducted ADCP surveys of the river in the spring, summer and fall between 1996 and 2000. GLIER processed the data from the 1998 and 1999 surveys. Seven cross-sections were surveyed in the upper half of the Detroit River and seventeen in the lower half. ADCP limitations have resulted in measurements only for water depths greater than 1 m. Although the manufacturer of the instrument claims a 2 percent measurement error, the data analyses suggest the error for velocity measurements in the Detroit River to be in the order of 10 percent.

5.3 Model Calibration

To ensure that the hydraulic model realistically described the river’s flow the computed and measured velocity vectors were compared and model parameters were adjusted until the measured and simulated data matched as closely as possible. When a reasonable match was achieved, the hydraulic model was considered to be calibrated and able to compute other processes that depend on flow such as sediment transport.

For hydraulic models, the main input parameter to be adjusted during calibration is bottom roughness at each cell in the grid. Sediments having similar characteristics (particle composition and size distribution) were considered to have the same bottom roughness.

The first step in model calibration is assembling water velocity measurements into a database that is compatible with the output from CH3D. This process is undertaken using in-house computer software that collocates the ADCP data with the CH3D grid and determines the model cells for which the field velocity measurements exist. The second
step in the calibration is to compare measured and calculated water velocities in each grid
to determine model discrepancy. The final step is to adjust the estimates of bottom
roughness to minimize this error. PEST (parameter estimation) software was used to
automate the calibration process by systematically changing bottom roughness values
over multiple computer runs and determining the optimized bottom roughness values to
minimize model errors.

Figure 5.3.1 shows the upper Detroit River in the vicinity of Belle Isle. Cell locations
where measurements of water velocities were conducted during the ADCP surveys are
indicated on the CH3D grid. Bottom roughness zones are also shown in Figure 6.3.1.
Following calibration, the model produced an average error of 10 percent between
measured and calculated water velocities. At some locations, the model error was
significantly higher than 10 percent, particularly at nearshore locations and near the Lake
Erie lower boundary. Transient water levels or lake currents generated by the wind were
likely responsible for the error. Despite these errors, the model results were considered
acceptable for the application described.

5.4 Hazard Assessment for Sediment Transport during a 20-Year Storm Event

A 20-year wind event was chosen to illustrate sediment resuspension in the river and to
study 1) changes in the sediment distribution in the river as a result of such an event, 2)
effects of such storms on the contaminated sediment loadings entering Lake Erie, and 3)
staibility of contaminated sediment deposits under infrequent but severe conditions.

Water level changes recorded during a December 1985 event are shown in Figure 5.4.1.
The rapid drop in the level of Lake St. Clair indicates rapid draining of the lake in
response to a change in the level of Lake Erie. Figure 5.4.2 summarizes the water
velocities predicted at the sediment/water interface during normal flow and during a 20-
year wind set-down event. Several areas clearly experience large increases in flow
velocities and associated sheer stresses during the event. The area south of Celeron
Island is one such area (Figure 5.4.2).
Model simulations compared steady flow conditions with those affected by the wind-generated water level changes in Lake Erie to determine sediment resuspension and transport potential. Each cell in the grid was assigned three sediment layers; the top (2 cm thick), middle (2 cm thick) and bottom (100 cm thick) layers have grain sizes equal to fine silt (30 μm), course silt (300 μm) and medium gravel (10 mm), respectively. The sediment model was run until sediment resuspension ceased and changes in bed elevation were negligible over time. Water level conditions at the boundaries of lakes Erie and St. Clair were allowed to change in accordance with measured water levels from a selected wind event. Comparing pre- and post-event sediment distributions identified unstable sediment zones.

Changes in flow velocity during a wind-induced water level change in Lake Erie caused pronounced changes in the stability of silt-sized sediment particles. The model simulation was run under the assumption, based on the preliminary results of the hydroacoustic bottom survey by NWRI, that the upper reaches of the river contain predominantly sand, gravel or consolidated material, resistant to erosion, with some coarse silt areas and occasional small pockets of fine silt. This area remains largely unaffected by flow increases. Large areas of fine silt and fine sand exist south and east of Fighting Island and some of these areas experience resuspension during high flow events. The Trenton Channel, west of Grosse Ile, consists predominantly of coarse silt, much of which could be resuspended during high flows. As the Trenton Channel widens at the south end of Grosse Ile, finer materials and coarse silts are deposited in the vicinity of Celeron Island. Figure 5.4.3 compares the river at the lower reach (having a stable bottom during average flow conditions) with the same bottom during a 20-year wind event. Fine silt is removed from much of the area around Celeron Island during the event, leaving only a small area in the lee of the island.

The simulation indicates that sediments around Celeron Island and downstream of this area are subject to periodic increases in flow velocity that could expose buried contaminated sediment. The 1999 surficial sediment survey indicates that these sediments are among the most contaminated in the river, particularly in terms of mercury, PCBs,
PAHs and organochlorine pesticides. Further, core samples taken from the U.S. downstream area indicated very high mercury concentrations (higher than MOE’s SEL guideline value) buried 10 cm below the sediment/water interface. Hence, these contaminated sediments are liable to release contaminants into Lake Erie during periodic storm events.

Future studies will address the depth of sediment scouring and will estimate the total mass of contaminants potentially released during these storm events.

5.5 Future Development and Applications

The hydraulic and sediment transport models are being refined to better simulate the dynamics of sediment deposits and compute sediment transport from point sources and tributaries. Calibration of the hydraulic model using Lake Erie set-downs during future high wind events is being planned to ensure that flow velocities are realistically simulated during such conditions. The sediment model will be complimented by sediment data collected from point source samples and cores, and acoustic bottom data from Environment Canada when they become available.

As pollutant source assessment and loadings inventories progress for the Detroit River, the hydraulic model can be extended to determine the fate of other types of contaminants entering the system. Although the current application of the model was restricted to contaminants closely associated with particles, it can also be applied to water soluble pollutants such as nutrients, and it can determine the fate of bacteria following release their from CSOs. Combined with the bioaccumulation model described in Chapter 6.0, the hydraulic model can be used to relate chemical loadings data to the river’s beneficial use impairments, assisting in the evaluation of prospective remedial activities required to delist the Detroit River as an Area of Concern.
Figure 5.2.1 Curvilinear grid for hydrodynamic and sediment transport simulations and grid bottom depths (m) below 180 m above the International Great Lakes Datum (IGLD85)
Figure 5.2.2 Return interval of the annual maximum water-level drop over 24 hours from previous 15-day average, plotted on log/normal probability scales.

Probability of exceedence (%) vs. Return Interval (yrs)
Figure 5.3.1 Grid cells with assigned bottom material types in the vicinity of Belle Isle. Symbol (○) indicates grid cells where ADCP measurements are available.
Figure 5.4.1  Water levels in lakes Erie and St. Clair used for resuspension simulation
Figure 5.4.2 Near-bottom flow velocity for lower section of Detroit River (a) during stable lake levels and (b) at peak of wind event. Lake Erie forms the lower boundary.
Figure 5.4.3 Simulated bottom type for lower Detroit River a) during average flow conditions and b) following a wind-induced Lake Erie level drop with 20-year return interval.
6.0 FOOD WEB BIOACCUMULATION MODEL

The bioaccumulation model, which predicts contaminant concentrations in different species of aquatic animals, was developed as part of the Detroit River Modelling and Management Framework to evaluate beneficial use impairments in the Detroit River AOC. Concentrations derived from the model are compared with those established to protect aquatic species (Canadian Tissue Residue Guidelines) or humans eating contaminated fish (Ontario or Michigan fish consumption guidelines). Hence, the bioaccumulation model is used to link environmental quality with hazards associated with beneficial use impairments in the Detroit River.

The term ‘hazard assessment’ is used rather than ‘risk assessment’ in reference to this model as it does not predict variations in chemical concentrations within a species occupying a specific area. Risk assessment requires information on where and when animals move in the river and the length of time they spend outside the modelled zone. Unfortunately, such information does not exist for most fish in the river, although progress is being made on selected species. The U.S. Geological Survey is currently performing radio-tracking studies of sturgeon in the Detroit River and Lake St. Clair to evaluate spawning habitat and fish activity. As such information becomes available for other fish species in the river the model can be enhanced to become a risk assessment tool.

The current bioaccumulation model is used to identify areas of the river where concentrations of contaminants in sediment and water are high enough to impair beneficial uses. For the purpose of this report, the bioaccumulation model assesses hazards associated with restrictions on fish consumption caused by PCBs. PCBs are responsible for most fish consumption advisories, and point source loadings of PCBs are known to occur in the river. The following questions are addressed in this chapter:

1) Are PCB concentrations in frequently consumed fish species in the Detroit River higher than those driving fish consumption advisories?
2) Are specific regions that have high PCB concentrations in sediments or water responsible for most fish consumption advisories in the river?

3) What concentrations of PCBs in water and sediments will drive fish consumption advisories for PCBs?

6.1 Bioaccumulation Model Description

GLIER developed a bioaccumulation model to predict concentrations of organic contaminants in biota in the western basin of Lake Erie (Morrison et al. 1997). The model has been widely published as a tool for research and management of the Great Lakes (Morrison et al. 1997; 1998; 2000). It has been used to estimate PCB bioaccumulation for the Lake Erie LaMP and the St. Clair River AOC.

The bioaccumulation model can predict maximum chemical residues for plankton, benthic invertebrates and a wide variety of fish species. Although the model was originally designed for PCBs, it can include other organic chemicals provided they meet certain assumptions about chemical behavior. The main data driving the model are chemical concentrations in water and sediments, and the organic carbon content of sediments. Such data can be obtained from direct measurements in a modelled area (Chapters 2 and 3) or through the hydraulic model (Chapter 5). The model also requires data on average annual water temperatures, dissolved oxygen concentrations, average body weights and lipid contents of different animal species, and feeding relationships in the aquatic food web. With this information, the model can be used to calculate an organism’s exposure to contaminants in water (through gill respiration) and from food (using the feeding rate of an animal and the chemical concentrations predicted for its food). The model also addresses chemical elimination that may occur in water during respiration, loss of contaminants through the animal’s feces, and reductions in chemical concentrations resulting from an animal’s growth.

The bioaccumulation model is a steady state model. As such, it assumes that chemical concentrations in animals reflect concentrations in water and sediments in a specific region and that these concentrations remain stable over time. Since the model assumes a steady state, it cannot be used to calculate the time required to reduce chemical concentrations in animals following a cleanup event. Instead,
it predicts a new steady state concentration in animals that reflects the contaminant levels in post-cleanup water and sediment. It may require several months or years for organisms (large fish species) to lose their pre-cleanup contaminant burdens and achieve the new steady state concentrations predicted by the model. To determine the time required for reducing chemicals in different biotic species, non-steady state population models are required. Such models are beyond the scope of the current project but could be developed in future studies in conjunction with more detailed risk assessment models. A more technical description of the bioaccumulation model appears in Morrison et al. (1997; 1998; 2000).

6.2 Bioaccumulation Model Validation

To increase confidence in the data derived from the bioaccumulation model it is necessary to compare model predictions with measured values at selected locations in the river (model validation). The database on PCB residues in river biota (Chapter 4) was used to validate model simulations. Data on PCB concentrations in water were obtained from mussel biomonitors collected near each food web station (Chapters 6.0). Data for PCB concentrations in sediment and organic carbon content in sediment were obtained from GLIER’s 1999 sediment survey (Chapter 3.0).

Figure 6.2.1 summarizes the model’s performance at each food web sampling station by comparing PCB concentrations (for specific species and sample locations) with values predicted by the model. Despite considerable variability in the data set, the model was able to adequately predict PCB concentrations in most species. It tended to predict slightly higher concentrations than were recorded at the different sampling stations. More than 50 percent of measured concentrations fell within a factor of 3.2, and more than 90 percent of concentrations fell within a factor of 10, of model predictions. Figure 6.2.2 compares model performance for animals of different sizes. For large fish species (more than 100g) the model tended to overestimate chemical concentrations; for small organisms the model both overestimated and underestimated such concentrations. Although it performed well for larger fish species from the relatively clean Peche Island site,
the model tended to overestimate PCB concentrations in large fish at other sites. This finding most likely results from fish migrations among the sampling sites.

Environmental fate and bioaccumulation models are typically capable of predicting contaminant concentrations only to within a factor of 10 of true values (DiToro et al. 1990). Thus, when the bioaccumulation model was used to predict PCB concentrations in the current study, its performance was typical of that of most ecotoxicological models.

6.3 Hazard Assessment for Sport Fish Consumption Advisories Caused by PCBs

The entire Detroit River was divided into 11 modelling zones. These zones were used to identify areas where PCB bioaccumulation in frequently consumed sport fish species will likely occur at concentrations requiring consumption advisories. The boundaries of the 11 zones, shown in Figure 6.3.1, were based on the following criteria: 1) the location of contaminant concentrations in sediments, 2) point sources, i.e. the Rouge River, Turkey Creek and River Canard and 3) habitat, bottom sediment characteristics and the potential for fish movement. The zones are generally consistent with the seven sub-areas established in the UGLCCS report to summarize patterns of sediment contamination in the Detroit River. The current study, however, attempts to further divide the river into Canadian and U.S. regions, when possible, while respecting the constraints of the zoning criteria. The upstream and downstream zones (1, 10 and 11) are also consistent with water sampling transects established by MOE.

PCB concentrations in water and sediments were identified for each model zone. As mussel biomonitoring stations did not exist in all designated zones, average water residues were extrapolated using data from the closest upstream or downstream biomonitoring sites. Table 6.3.1 summarizes PCB concentrations in water for each zone and identifies the biomonitoring sites used to calculate the zone-wide average for such concentrations. Table 6.3.1 also summarizes PCB concentrations in sediments in each modelling zone as measured in the 1999 sediment survey.

The hazard assessment focused on 16 species of fish. These included the ten most frequently consumed species in the area (Chapter 4) and other species from the
Two sets of numbers were used in the hazard assessment. The first was based on two values: the PCB concentration used by Michigan to set consumption advisories for sport fish (0.050 µg/g wet weight) and the concentration (2 µg/g wet weight) used to advise women of childbearing age and children under 15 against eating the fish. The second set of numbers was likewise based on two values: PCB concentrations used by Ontario to set consumption advisories for sport fish (0.50 µg/g wet weight) and the concentration (4 µg/g wet wt) used to advise the general public against eating any fish at all.

Figure 6.3.2 summarizes results from model simulations for PCB concentrations in frequently consumed sport fish species in each model zone. Figures 6.3.3 and 6.3.4 summarize hazard assessment results by location; they highlight regions of the river that contribute to excessive bioaccumulation of PCBs in sport fish. Notably, the model predicts that PCB concentrations in most sport fish species (11 of the 16 species modelled) from all 11 zones in the river will exceed the Michigan concentration of 0.050 µg/g used to establish consumption advisories for PCBs. Further, PCB concentrations at upstream locations (zones 1, 2 and 3) result mostly from trace quantities of PCBs in water. Replacing actual concentrations of PCBs in sediment with a value of zero in the model (and assuming sediments do not constitute a PCB exposure to biota) in zones 1, 2 and 3 yields predictions nearly identical to those summarized in Figure 6.3.2. Therefore, trace concentrations of PCBs in upstream water samples can cause PCB bioaccumulation in sport fish that warrant the Michigan restrictions on fish consumption by women and children under 15.

Model predictions exceeded the 2 µg/g concentration in sport fish in only two regions of the river: zones 9 (the Trenton Channel) and 11 (the U.S. shoreline downstream of the Trenton Channel). In these regions only two fish species (muskellunge and common carp) are predicted to have PCB concentrations above 2 µg/g. The model predicts that muskellunge and common carp living in regions 9 and 11 will attain PCB concentrations high enough to justify a ‘no consumption’ advisory in Michigan. The high PCB concentrations in fish in this region are attributed to high concentrations of PCBs in surficial sediments. Replacing the concentrations of PCBs in water in zones 9 and 11 of the model with the upstream concentrations yields similar results. Therefore, contaminated sediments cause
an excessive chemical bioaccumulation in fish in the lower regions of the river. Model predictions exceeded the Ontario PCB concentration of 0.50 µg/g in zones 5, 9 and 11 of the river. In zone 5, only muskellunge were predicted to have PCB concentrations higher than 0.5 µg/g, whereas, 11 of 16 sport fish species exceeded this concentration in zones 9 and 11. The same hazard conclusions were obtained when PCB concentrations in water estimated for zones 5, 9 and 11 were replaced with the actual upstream concentrations for PCBs in water in the model. These results reinforce the previous conclusion: high PCB concentrations in the sediment in these zones contribute to excessive PCB concentrations in sport fish. None of the 11 model zones are predicted to produce PCB concentrations in sport fish that exceed the 4 µµµµ µg/g limit required for ‘no consumption’ advisories in Ontario.

The bioaccumulation model can also be used to determine the magnitude of PCB concentrations in sediment that will cause excess PCB bioaccumulation in sport fish tissues. In this simulation, PCB concentrations in water were set at the upstream concentration values. Of the ten most frequently consumed sport fish species, black crappie, is predicted to achieve the highest PCB concentrations in their dorsal muscles. This tendency is caused by the combination of the lipid content in the dorsal muscle and the species’ feeding strategy. To ensure that PCB residues in black crappie remain below 0.5 µg/g, the concentrations of PCBs in sediment must be 2 µg/g OC weight or lower. To protect muskellunge, the concentrations of PCBs in sediment must be 0.6 µg/g OC weight or lower. The MOE sediment guidelines for PCBs are 0.06 µg/g wet weight (LEL) and 34 µg/g OC weight (SEL). Converting the LEL to an organic carbon unit (using the average Detroit River organic carbon content of 2.45 percent) yields an equivalent sediment concentration of 2.45 µg/g OC weight. These data indicate that sediments meeting the dredging criteria will not prevent PCBs from bioaccumulating in sport fish tissues at concentrations that will warrant fish consumption advisories in Ontario.
6.4 Mercury Bioaccumulation Model

Insufficient information about the bioavailability of mercury in Detroit River water and sediments prohibited the bioaccumulation model from being used as it was for PCBs. Unlike PCBs, mercury occurs in the environment as various metallic and inorganic forms and as organic complexes. Each compound exhibits differences in its environmental behavior, toxicity and bioavailability to aquatic animals. The method for analyzing mercury used in the DRMMF yields only a total mercury concentration (the method measures all forms of mercury). Although this method is consistent with those required for comparing mercury concentrations against environmental quality guidelines and objectives, it does not provide information about the amount of mercury in sediments that is available for uptake by aquatic biota.

Once mercury enters the aquatic food web, however, it biomagnifies in a manner similar to PCBs and other organochlorine chemicals. Thus, mercury exposures in upper trophic level animals, like PCB exposures, result primarily from an animal’s consumption of contaminated food. The bioaccumulation model was used to predict mercury concentrations in upper trophic level fish by employing mercury concentrations in forage fish as input parameters. This method differs from the PCB simulations that used chemical concentrations in water and sediments as input parameters. Using the model in this manner assumes that mercury is accumulated primarily as methylmercury in all fish species in the river, that mercury is assimilated from food and eliminated from tissues at rates similar to PCBs, and that forage fish are a good measure of local mercury bioavailability.

Figure 6.4.1 summarizes the model’s performance at each food web sampling station by comparing mercury concentrations (for a specific species and sample location) with values predicted by the model. Although the model was able to predict mercury concentration trends among different fish species, in most cases it
overestimated mercury concentrations in Detroit River fish. These errors were generally low, however, and within the tolerance range usually accepted for ecotoxicology models. More than 50 percent of measured mercury concentrations in Detroit River biota samples fell within a factor of three and more than 90 percent fell within a factor of seven, of model predictions. Unlike the PCB model, the bioaccumulation model rarely underestimated mercury concentrations in Detroit River fish (only seven samples had mercury concentration higher than predicted by the model). This result is caused by the more uniform distribution of mercury in the river and contrasts with that found for PCBs that exhibit large spatial gradients in sediment contamination. Thus, fish migration results in less error in model simulations for mercury than it does for PCBs in the river.

Mercury concentrations in forage fish were not available in other model zones of the Detroit River. Therefore, unlike the PCB model, the bioaccumulation model cannot currently be extended to assess hazards for fish consumption advisories caused by mercury. Future studies will address mercury concentrations in forage fish collected at all 11 model zones. These data will be used as input parameters in the bioaccumulation model to assess the hazard associated with fish consumption advisories caused by mercury.

6.5 Conclusions and Recommendations

Several conclusions can be derived from assessing the hazards of fish consumption advisories driven by PCB bioaccumulation in the Detroit River food web. First, the model simulations indicate that PCB concentrations in upstream water are high enough to cause concentrations in sport fish to exceed the Michigan advisory level for the sensitive subpopulation. Thus, there exists no remedial activity within the Detroit River watershed able to reduce PCB concentrations in sport fish to levels not requiring restrictions on eating fish from the river.

Using Ontario’s minimum concentration of 0.5 μg/g. In Ontario, only zones 5, 9, and 11 have sediment PCB concentrations that are high enough to drive consumption advisories in sport fish. Applying Michigan’s concentration level of
2 µg/g indicates that only zones 9 and 11 have high enough PCB levels in sediment to drive consumption advisories. **Model simulations clearly indicate that PCB bioaccumulation in fish living in zones 9 and 11 result from exposures to contaminated sediments.** Sport fish species typically have large foraging ranges. Therefore, **highly contaminated sediments, particularly in zones 9 and 11, will drive most of the fish consumption advisories observed in the Detroit River.**

| This finding suggests that regions 9 and 11 be identified as areas of high priority for future remediation activities. |

The hazard assessment also specifies target concentrations for PCBs in sediment that will protect fish consumers (using Ontario’s 0.5 µg/g level in fish tissues). **PCB concentrations of less than 0.6 µg/g OC weight in broad areas of the river’s sediment will protect consumers of all sport fish species.** If only ten of the most frequently consumed fish species are targeted, **PCB concentrations in sediment of less than 2 µg/g OC weight will protect fish consumers.** **Consumption advisories for muskellunge, however, may still be warranted.**

The target concentrations of PCBs in sediment are lower than the sediment guidelines used to restrict dredging activities.

### 6.6 Future Applications of the Bioaccumulation Model

Studies will be performed to quantify PCB concentrations in water in each model zone. These studies will permit a more accurate assessment of the hazard associated with fish consumption restrictions caused by PCB bioaccumulation in sport fish species. The studies will also determine mercury and PCB concentrations in forage fish sampled from each model zone of the river. These assessments will permit completion of a hazard assessment for fish consumption restrictions due to mercury bioaccumulation similar to that performed for PCBs. In addition, data on PCB concentration in forage fish from each model zone will be used to validate the PCB hazard assessment conclusions.
Hazard assessments will also be performed to evaluate degraded fish populations. These assessments will compare PCB or mercury bioaccumulation in fish at each model zone with PCB or mercury tissue concentrations known to cause toxic effects in biota. These assessments extend the bioaccumulation model to evaluate other ecologically relevant beneficial use impairments. The bioaccumulation model can also be extended to include other animal species such as fish-eating seabirds and fish-eating wildlife. The addition of these species to the model will allow evaluation of beneficial use impairments associated with wildlife species in the Detroit River Area of Concern.
### Table 6.3.1 PCB concentrations in water and sediments at each food web model zone

<table>
<thead>
<tr>
<th>Model Zone</th>
<th>Biomonitoring Sites Included in Zone Estimate</th>
<th>Sum PCB Concentration in Water (ng/L)</th>
<th>n</th>
<th>Sum PCB Concentration in Sediment (ug/g OC wt.)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LSC+RM</td>
<td>0.12±0.02</td>
<td>59</td>
<td>0.37±0.19</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>LSC+RM</td>
<td>0.12±0.02</td>
<td>59</td>
<td>0.19±0.07</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>LSC+RM</td>
<td>0.12±0.02</td>
<td>59</td>
<td>0.47±0.17</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>GLIER+WWTP</td>
<td>0.14±0.01</td>
<td>44</td>
<td>0.81±0.75</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>WWTP+DWWTP+TC</td>
<td>0.14±0.01</td>
<td>78</td>
<td>0.93±0.42</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>TC</td>
<td>0.21±0.02</td>
<td>30</td>
<td>0.79±0.18</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>GI+FI</td>
<td>0.08±0.04</td>
<td>6</td>
<td>0.84±0.46</td>
<td>18</td>
</tr>
<tr>
<td>8</td>
<td>TC+GI+FI</td>
<td>0.18±0.02</td>
<td>36</td>
<td>0.70±0.61</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>TT</td>
<td>0.72±0.25</td>
<td>2</td>
<td>5.29±3.76</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>MSI</td>
<td>0.20</td>
<td>3</td>
<td>0.76±0.18</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>TT</td>
<td>0.72±0.25</td>
<td>2</td>
<td>6.91±1.25</td>
<td>20</td>
</tr>
</tbody>
</table>

n = the number of samples used to compute the average PCB concentration in a specific model zone
Figure 6.2.1. Validation of the bioaccumulation model for PCBs. Observed PCB concentrations derived from the food web sample data base. Samples collected from different locations are indicated by different symbols. Solid lines indicate the area on the graph that corresponds to a perfect fit (ideal fit) and 10 fold over or under predictions by the model.
Figure 6.2.2. Validation of the bioaccumulation model for PCBs as a function of animal size. Model bias is calculated as the model predicted PCB concentration divided by the measured PCB concentration for a given sample. The data are presented as a function of animal size to evaluate if the model consistently over predicts or under predicts PCB concentrations in different types of aquatic species.
Figure 6.3.1. Food web model zone boundaries in the Detroit River. Dashed lines present the boundaries associated with the eleven food web model zones designated for the sport fish consumption hazard assessment. Grey dots on the figure indicate the location of sediment samples taken during the 1999 sediment survey.
Figure 6.3.2. Food web model predictions for PCBs in frequently consumed sport fish in model zones of the Detroit River. Symbols designated by (x) indicate measured PCB concentrations for a given species and location. Solid horizontal line indicate the OMOE guideline PCB concentration of 0.5 and 4 ug/g wet wt. Dashed line indicates the MI guideline PCB concentration of 0.05 and 2 ug/g wet wt.
Figure 6.3.3. Hazard assessment for sport fish consumption advisories due to PCBs. Graph A summarizes the hazard assessment using Michigan’s 0.05 ug/g PCB guideline used to establish fish consumption advisory information for women of childbearing age and children. Graph B summarizes the hazard assessment using Michigan’s 2 ug/g PCB concentration guideline used to establish a ‘no fish consumption’ advisory. Areas on the map that are shaded indicate areas of the Detroit River where PCB concentrations in sport fish exceed the guideline value.
Figure 6.3.4. Hazard assessment for sport fish consumption advisories due to PCBs. Graph A summarizes the hazard assessment using Ontario’s 0.50 ug/g PCB guideline used to establish fish consumption advisory information. Graph B summarizes the hazard assessment using Ontario’s 4 ug/g PCB concentration guideline used to establish a ‘no fish consumption’ advisory. Areas on the map that are shaded indicate areas of the Detroit River where PCB concentrations in sport fish exceed the guideline value.
Figure 6.4.1. Validation of the bioaccumulation model for mercury. Measured mercury concentrations were derived from the food web sample data base. Samples collected from different locations are indicated by different symbols. Solid lines indicate the area on the graph that corresponds to a perfect fit (ideal fit) and 3 and 10 fold over predictions by the model.
7.0 DATA RETRIEVAL, EXCHANGE, ARCHIVAL AND MANAGEMENT SYSTEM (DREAMS)

7.1 Introduction

An acronym for the Data Retrieval, Exchange, Archival and Management System, DREAMS is the database component of the Detroit River Management and Modelling Framework, developed by GLIER for the Detroit River Canadian Cleanup Committee. Environment Canada’s Great Lakes Sustainability Fund is the major supporter of this initiative. DREAMS provides centralized storage and timely, convenient access to research results aimed at determining the causes of the river’s beneficial use impairments to support management decisions affecting the Detroit River Area of Concern. Consequently, DREAMS allows researchers and resource managers to effectively address the volume and diversity of data produced by multiple assessments and modelling studies, which would otherwise be difficult to access and interpret.

The core of DREAMS is an electronic database that permits complex searches and is consistent with the requirements of a geographic information system. At present, DREAMS includes data sets generated by the DRMMF as well as those received from the US EPA. Other data from the Essex Region Conservation Authority, the Ontario Ministry of the Environment and the City of Windsor (CSO data from the Waterfront Study) are anticipated in 2002.

Further work is required to ensure that DREAMS is updated to include all relevant data for the river. A coordinated binational effort will be required and will involve researchers in universities, industry and government agencies.

7.2 System Description

The DREAMS system, consisting of an Internet-accessible database (www.uwindsor.ca/dreams) with basic online geographic analysis capability (GIS), was designed to:
• Build a systematic inventory of available and prospective field monitoring data sets, including technical details on sampling design, coverage, format, quality controls and availability (commonly known as ‘metadata’);

• Provide the platform and opportunity for Canadian and U.S. custodians of data required to manage the river to contribute their collections to DREAMS, and in turn benefit from streamlined access to the contributions of others; and

• Streamline the exchange of technical data among groups working on the Detroit River ecosystem.

The DREAMS database, which provides online access to 1999-2001 DRMMF data sets, is able to accept entries from technical groups associated with signatories to the Four-Party Agreement.

Figure 7.2.1 shows the DREAMS home page and several menu entries on the left. In addition to the typical entries such as mission statement, user manual, links and contacts, and a bulletin board, DREAMS has three basic components:

1. Online publications (to communicate designs and completed studies);
2. A database of metafiles (data descriptions) and actual results of recent and historical studies; and

7.2.1 Online publications

This component of the database (Figure 7.2.2) consists of several files (most in PDF or HTML formats) containing study designs, completed data sets and their analyses and interpretations. Most of the more than 30 files currently posted on the database are from studies conducted by GLIER between 1999 and 2001. The highlights of this application are 1) the ability to make study designs available for review before the studies begin (enabling review and improvement to address monitoring, modeling and management needs) and 2) the timely communication of results and their interpretations. Most results from GLIER’s 1999-2000 sediment quality assessments were available within a few
months of sampling events. As the database continues to grow, it is anticipated that it will attract more data and more users and contributors.

7.2.2 Metadata and data

The user interface with the Metadata and Data component consists of data entry forms customized by type of monitoring program, e.g. physical, chemical and biological data sets (Figure 7.2.3). Authorized users can view data immediately after entry through a searchable summary list, which links to the full data set. Each entry in the table is hot-linked to the full set of details for that data set. The system emphasizes universal access, self-service, instant availability of metadata (technical details of the monitoring program) and the rapid dissemination of results from completed studies. A key objective of this component of the database is to enable technical groups associated with the Four Party Agreement to efficiently exchange information.

7.2.3 DRCCC data sets by GLIER

This component of DREAMS consists of online searchable databases detailing the results of river monitoring programs conducted between 1999 and 2001. Four major sub-sets are available:

- The 1999 Detroit River sediment and water quality survey (150 sites were sampled and analyzed for about 200 physical, chemical and biological parameters, resulting in a matrix of some 30,000 measurements);
- The sediment quality results for a sub-set of the 1999 sites revisited in 2000;
- The results of 2001 subsurface sediment coring at selected locations; and
- The 2000/2001 Detroit River Biological Survey (five stations repeatedly sampled to determine trace metal and organochlorine contaminant concentrations in different species of aquatic animals).

Users can search this database using any standard Internet browser by selecting a location on the GIS maps or searching the database for specific parameters (Figure 7.2.4)
An extended version of the data sets along with their management system appears on a CD-ROM that is available from GLIER on request. This application, described in the user’s manual on DREAMS, includes auxiliary data sets such as field notes and quality assurance/control measures. The highlight of this component of DREAMS is the ability for technical groups associated with the Four Party Agreement to easily and rapidly share complete annotated data sets.

7.2.4 Other materials

During the past two years, GLIER has exchanged data with Canadian and U.S. agencies both within and outside of the DREAMS framework. Two data sets made available by the U.S. EPA are currently hosted on DREAMS: 1) the Detroit River sub-set of the data compiled from the UGLCCS study in 1985-1987 and 2) the Detroit River bibliography of 2002. This menu component of DREAMS also includes a discussion board and selected links to other sources of information on the Detroit River.

7.3 Conclusions

The highlights of the DREAMS database are:

- It is currently ready to use and relatively inexpensive to maintain;
- It provides fast and convenient access to data through an Internet interface;
- It is designed for binational use by the four agencies charged with primary responsibility for Detroit River management;
- It is coordinated with the needs of models; and
- It can support an extended Huron-Erie corridor construct, when required.
Figure 7.2.1  DREAMS home page, with components described in the menu to the left

Figure 7.2.2  Online Publications page of DREAMS
Figure 7.2.3  DREAMS metadata component – data entry and retrieval are password protected.

Figure 7.2.4  GIS sediment quality component of DREAMS
The Detroit River, one of the most significant watercourses in the Great Lakes, forms the lower 50 km of the Huron-Erie Corridor. This binational river provides important habitat for fish and birds, and it is a source of water to municipalities and major industrial complexes in the U.S. and Canada. The river has a complex history of contamination. In the 1960s and 1970s, high phosphorus loadings from municipal and agricultural sources contributed to the nutrient enrichment of Lake Erie, but effective remediation programs have since controlled these sources. Toxic chemicals such as mercury, PCBs, PAHs and organochlorine pesticides still appear at high concentrations in sediments and reflect complex mixtures of historic and current loadings (Detroit River Update Report 1999).

An effective remedial action plan must assess the relative importance of various chemical impacts to set priorities for addressing river-wide sources. Environmental managers are constantly challenged by the incompatibility between study designs required to track sources and loadings data, and data sets required to measure ecosystem health and beneficial use impairments. Addressing this incompatibility is becoming more critical as environmental management agencies must now demonstrate that past cleanup activities have been successful and that prospective programs will result in measurable environmental improvements (SOLEC 2000).

According to the International Joint Commission (IJC 1997), accountability in remedial action plans is established by “open sharing of information, clear definition of problems, identification of causes, agreement on actions needed and identification of who is responsible for taking action.” Recognizing the difficulty of achieving these goals, especially in a binational context, the IJC recommended that a comprehensive model be developed in partnership with relevant U.S. and Canadian agencies. The IJC also noted concerns about the scarcity and adequacy of environmental monitoring in the Detroit River. To address these concerns, monitoring programs should be based on an ecosystem
approach and such programs should be integrated with management and modelling initiatives.

The DRMMF was developed to address these issues using an ecosystem framework as promoted by the State of Lakes Ecosystem Conferences and the IJC. This conforms to the IJC’s recommendations by:

1) Developing an online database, DREAMS, as a public clearinghouse of information about environmental assessments, chemical sources and loading rates, and identifying the existence and ownership of all relevant data sets pertaining to the Detroit River Area of Concern;

2) Providing a current environmental quality assessment of water, sediment and biological quality and establishing a framework of coordinated monitoring programs in the Detroit River;

3) Developing numerical hydraulic and sediment transport models to establish the fate of contaminant loadings entering the Detroit River and assist in determining where these pollutants settle after their release into the river; and

4) Developing food web bioaccumulation models to link contaminant concentrations in water and sediments with contaminant residues in fish tissues and toxic effects in Detroit River biota.

Figure 1.1 is a schematic of the overall project design, which addressed three environmental media: water, sediments and biota. Contaminants in water and sediments and beneficial use impairments in biota were linked through the modelling and monitoring components of the project. For water, the hydraulic model establishes the flow patterns and associated contaminant transport pathways. Monitoring data sets establish the relative importance of chemical loadings (and the location of these loadings along the river) as well as the distribution of contaminants in suspended solids and water. For sediments, the hydraulic model established sediment transport rates and tracked the deposition and erosion of particles in the river. The monitoring data sets were used to determine the degree of sediment contamination. For biota, the project was primarily
concerned with quantifying beneficial use impairments. The sediment TRIAD approach was used to characterize the biological effects of sediment contamination. The food web bioaccumulation model was developed to assess chemical accumulation in fish tissues and address fish consumption advisories. All studies and modeling and monitoring surveys are summarized using the DREAMS database.

8.1 Environmental Quality of the Detroit River

The environmental monitoring program conducted between 1999 and 2001 updated the environmental status of the Detroit River. The project emphasizes contaminated sediment, often considered the major problem in the Detroit River Area of Concern (IJC 1997). The sediment data were to complement water quality studies by MOE, but these data have not yet been released.

The sediment survey involved 150 primary sampling stations that spanned the river system, with replicate samples collected at selected stations in 2000. The stations were chosen using a random sampling design that ensured statistical rigor and objective assessment of the entire river. Chapter 3 summarizes the environmental assessment of contaminated sediments, including the analysis of spatial and temporal trends for chemical contamination and beneficial use impairments associated with restrictions on dredging activities and degraded benthos. Chapters 2 and 6 summarize studies that assess water quality and contaminant residues in Detroit River biota. These studies were designed to complement the sediment surveys already described and to provide the necessary input parameters and validation data sets for the food web bioaccumulation model.

8.2 Hydraulic Model

The hydraulic model, developed in partnership with the U.S. Army Corps of Engineers, the U.S. EPA and NOAA, was used to calculate flow patterns and the resulting sediment transport in the Detroit River. In combination with field validation data sets (flow measurements, water levels, bathymetry, distribution of contaminants in sediments) the model will assist in predicting the transport and fate of sediments or sediment-associated
chemicals in the system. One of the important uses of this model is its ability to predict the effects of dramatic events such as rare but intense storm events, gale force winds or ice jams on the cycling of toxic contaminants in the system. The model development and an example of its application in simulating the sediment disturbance event are described in Chapter 5.

8.3 Contaminant Bioaccumulation Model

The contaminant bioaccumulation model, a tool for evaluating beneficial use impairments in the Detroit River AOC, was developed as part of the Detroit River Modelling and Management Framework. The model predicts contaminant concentrations in different species of aquatic animals. Data generated by the model are compared with tissue concentrations established for the protection of aquatic species (Canadian Tissue Residue Guidelines) or the protection of fish tissues for human consumers (MOE or Michigan guidelines used to establish fish consumption advisories). Chapter 4 describes the bioaccumulation model and how it can be applied to perform a hazard assessment of fish consumption restrictions due to PCBs.

8.4 DREAMS (Data Retrieval, Exchange, Archival and Management System)

DREAMS is a database with an online interface, which allows public access to relevant data sets, reports and information pertinent to the Detroit River. It was recognized early in the project that although a number of data collection programs were operating in the Detroit River, the resulting data sets resided in numerous agencies. It was often difficult to determine which data sets exist, which agencies were performing studies, and how to take advantage of existing data sets and prospective research plans.

The major goal of DREAMS is to provide a common data management system for the work of the Point Source, Non-point Source, Contaminated Sediment and Combined Sewer Overflows subcommittees. The core of DREAMS is an electronic database that accommodates complex search queries and is consistent with the data requirements of geographic information systems. These features permit the exchange of data sets and thus address one of the major IJC recommendations. Over time, it was recognized that
DREAMS could also be used to inform the public about local activities in the system. Chapter 7 of this report describes the current status of DREAMS and anticipated improvements to it.
9.0 CONCLUSIONS

- **Water Quality:**

  1) Mussel biomonitors were used to determine organic contaminant residues in water at selected Detroit River stations between 1996 and 2000. This technique is cost-effective and produces chemical concentration estimates comparable to direct measurement methods.

  2) Notable chemicals of concern included dieldrin, lindane and DDT. These chemicals were measured in water at concentrations that exceeded or approached water quality objectives.

  3) Trends in PCB water concentrations over space and time were determined. PCB concentrations in water remained relatively constant over time at monitored stations over five years. PCB concentrations in water did not exhibit upstream to downstream trends on the Canadian side of the river. Very low PCB water concentrations were measured in shipping channels off Fighting Island. In contrast, elevated concentrations were measured in Trenton Channel waters.

  4) Concentrations of trace metals, mercury and nutrients in water still need to be determined to evaluate the overall water quality of the Detroit River. Implementation of a comprehensive monitoring program to determine these parameters sources should be performed using a river-wide assessment.

- **Sediment Quality:**

  1) A comprehensive river-wide survey including 150 surficial sediment stations, suspended sediment traps and sediment cores was performed to evaluate contaminated sediments in the Detroit River.

  2) A number of contaminants were found to exceed OMOE sediment quality guidelines. These chemicals included mercury, PCBs, PAHs, HCB, DDT,
cadmium, nickel, copper, arsenic, chromium, zinc, manganese and lead. The high concentrations of these contaminants in surficial sediments contribute to restrictions on dredging activities. Of the above contaminants, mercury and PCBs contribute to restrictions on fish consumption. PAHs in surficial sediments result in tumors in fish.

3) Spatial patterns of contaminated sediments were examined in detail for mercury, PCBs and PAHs. Mercury exhibited an increasing trend from upstream to downstream locations in the river on both the Canadian and U.S. shorelines. The data indicate point sources of mercury in the Detroit River watershed on both sides of the river. PCBs and PAHs were found at elevated concentrations mainly on the U.S. side of the river. PCBs increased in concentrations from upstream to downstream locations in U.S. waters whereas PAHs were uniformly high along the entire U.S. shoreline.

4) A comparison between the chemistry of nearshore surficial sediments and suspended sediments in deep channels of the river indicates that upstream sources of suspended particulates entering the Detroit River are not accumulating in nearshore areas. Further, there is little or no cross channel mixing of contaminated sediments. Thus, U.S. contaminant sources do not contribute to elevated contaminant deposition at nearshore Canadian areas and vice versa. Contaminated particle deposition from nearshore sources does not appear to be transported over long distances under average flow conditions.

5) Sediment cores were taken at selected locations of the Detroit River to determine mercury concentration at various sediment depths. Core samples taken from three sites showed few or no trends in mercury concentrations with depths. This finding indicates little change in mercury loadings entering the river over time. Mercury concentrations in upper sediment layers at Connors Creek and at a U.S. downstream site were higher than at other Detroit River sites. These cores also showed high mercury residues buried 10 cm below the sediment surface. The similarity
of mercury profiles at depths at these two sites may indicate a common history of loadings entering these areas. The high mercury concentrations in buried sediments at the U.S. downstream site significantly threaten to increase contaminant loadings entering Lake Erie during sediment disturbance events.

6) Studies on water/sediment interactions of PCBs indicate that PCB releases from contaminated sediments to water are slow or negligible. Contaminated sediments are not expected to contribute to decreased water quality in overlying waters. These studies also indicate that PCBs enter the Detroit River in association with contaminated particles and/or move through the river by means of particle transport.

7) Studies on benthic invertebrate distribution in Detroit River sediments failed to show a clear relationship between sediment contamination and benthic community structure. Further studies are being performed to evaluate benthic community structure using Environment Canada’s BEAST methodology. These results will be combined with sediment toxicity assays performed by MOE to complete the TRIAD sediment assessment for Detroit River benthic communities and elucidate factors regulating chemical bioavailability.

8) The data on PCB and mercury concentrations in surficial sediments, mercury in buried sediments, and hazard assessments for sediment transport and fish consumption advisories point to the lower U.S. reach of the Detroit River as requiring remediation strategies. Clearly, contaminated sediments in this region of the river pose a substantial threat to a number of beneficial uses in the Detroit River AOC and to Lake Erie.

- **Biological Quality:**

  1) PCBs were observed to biomagnify in the Detroit River food web and attained concentrations in biota that exceeded guideline values used to establish fish consumption advisories in Michigan and Ontario.
2) PCB concentrations in benthic invertebrates and forage fish were strongly correlated with surficial sediment PCB residues. This finding indicates that these species are appropriate biomarkers of local environmental quality.

3) PCB concentrations in larger fish species were poorly correlated with PCB residues in surficial sediments. This finding is attributed to fish movements throughout the river. A major consequence of these movements is that local contaminated sediments may contribute to excessive PCB bioaccumulation in sport fish throughout the entire river.

4) DDT did not attain concentrations in fish tissues that exceeded guidelines for fish consumption advisories. However, DDT was found in concentrations in benthic invertebrates and forage fish that exceeded the Canadian tissue residue guidelines for the protection of wildlife.

5) Mercury was observed to biomagnify in the Detroit River food web and attained concentrations in biota that exceeded guideline values used to establish fish consumption advisories in Michigan and Ontario jurisdictions. Unlike PCBs, no spatial trends of mercury bioaccumulation could be established among the five food web sampling stations.

5) U.S. and Canadian government agencies have established fish consumption advisories for 11 species of Detroit River fish. Most fish consumption advisories are caused by PCBs and mercury. The large number of species for which advisories have been issued and the severity of some of the restrictions (no consumption advised for eight species) indicate that this beneficial use is severely degraded in the Detroit River Area of Concern.
• **Hydraulic and Sediment Transport Modelling:**

1) The hydraulic and sediment transport models developed for the DRCCC allow simulation of dramatic conditions (storm events) that may occur at low frequencies but have an important impact on contaminated sediments in the river. Analysis supporting the model’s development confirmed that rare events such as wind-induced water level changes in Lake Erie have occurred in the past and propagate throughout the river.

2) A hazard assessment was performed using the sediment transport model to evaluate the stability of Detroit River sediments during wind-induced water offsets in Lake Erie. The hazard assessment indicates that a large region of the U.S. downstream reach of the river is susceptible to periodic sediment scouring. This area has been identified as the most contaminated region of the river for mercury, PCBs and other toxic contaminants. Therefore, contaminated sediments in the lower U.S. reach of the river pose a significant threat of contaminating Lake Erie during wind-induced disturbance events.

• **Food Web Bioaccumulation Modelling:**

1) The bioaccumulation model is capable of linking contaminated sediments with beneficial use impairments such as restrictions on fish consumption or degraded fish populations.

2) The food web bioaccumulation model was used to perform a hazard assessment to determine if PCBs in water and sediments contribute to fish consumption advisories. The assessment indicated that trace PCB concentrations in upstream waters result in fish consumption advisories throughout the entire river. This conclusion was based on Michigan’s tissue residue criterion of 0.05 µg/g PCBs for the protection of women of childbearing age and children. These results indicate that there is no
remediation activity that could be performed in the Detroit River AOC to eliminate all consumption advisories.

3) The hazard assessment provided a different conclusion when Ontario’s criterion of 0.50 µg/g PCB for the protection of the general public was used. In this case, most fish consumption guidelines could be attributed to high PCB concentrations in sediments in the lower U.S. reach of the river. Similar conclusions were attained when Michigan’s criterion of 2.0 µg/g PCB for the protection of the general public was used. Based on pragmatic considerations, it is recommended that Ontario’s 0.50 µg/g PCB criterion for fish tissues be adopted as an interim criterion to monitor the progress of remediation activities affecting fish consumption advisories in the Detroit River Area of Concern.

4) The bioaccumulation model suggest that maintaining PCB concentrations in surficial sediments below 2 mg/kg OC will protect consumers of the ten most frequently consumed sport fish species according to the Ontario’s fish consumption guidelines. The fish habitats with higher sediments PCB content contribute to the fish tissue levels above the consumption guidelines, triggering consumption advisories thus impairing the beneficial uses of the river.

- Data Consolidation and Management

The DREAMS system allows environmental managers to effectively address the volume and diversity of data produced by an abundance of studies performed in the Detroit River Area of Concern. This database was designed to be consistent with model requirements and to support a GIS framework of data management and communication. DREAMS is currently ready to use, inexpensive to maintain and provides fast and convenient access to data through an Internet interface. Work needs to be performed to update and maintain DREAMS to include all relevant data sets for the Detroit River.
10. RECOMMENDATIONS

This report describes the current health of the Detroit River and provides a modelling and management framework to assist in establishing priorities for monitoring and remedial activities in this Area of Concern (AOC). Recommendations from GLIER’s 1999-2001 studies follow:

Beneficial Use Impairments

- Biological studies indicate that bioaccumulated residues of mercury, PCBs and DDT threaten sport fishing resources and fish-eating wildlife. PCB concentrations have not changed in Detroit River biota over the last 15 years. Efforts should be made to evaluate contaminant sources and loadings and, more importantly, to identify remedial strategies for contaminated sediments.

- Surveys of contaminant residues in sport fish species should be conducted every second year to identify temporal trends. Surveys of contaminant residues in forage fish should be used to determine local environmental quality, delineate areas of the river requiring remediation, and assess the effectiveness of cleanup activities.

- Several lines of evidence indicate that contaminated sediments in the lower U.S. reach of the Detroit River contribute to beneficial use impairments (restricted dredging activities, restrictions on fish consumption, fish tumors). These sediments also threaten Lake Erie during sediment disturbances. This area of the river should become a high priority for future remediation.

Water Quality

- Water quality studies indicate that dieldrin, lindane and DDT occur or are likely to occur at concentrations in water that exceed water quality objectives.
Monitoring programs for water quality must be established to include these chemicals as part of their routine analyses.

- Prospective water quality studies should provide a river-wide assessment consistent with modelling activities. The parameters to be addressed are dieldrin, lindane, DDT, PCBs, mercury, trace elements and nutrients. Water quality surveys should be conducted at least every second year. Selected monitoring sites should be sampled monthly to allow agencies to promptly respond to emerging chemical concerns and appropriately adjust their monitoring strategies.

**Sediment Quality**

- Sediment quality studies indicate that mercury, PCBs, PAHs, HCB, DDT, cadmium, nickel, copper, arsenic, chromium, zinc, manganese and lead occur at concentrations that require restrictions on dredging activity. Mercury, PCBs and PAHs also threaten sport fishing and produce tumors in fish. Prospective studies must evaluate point sources and loading information for these contaminants. High mercury concentrations in the lower Canadian river reach, for example, indicate active sources of this pollutant in the vicinity of or downstream from Turkey Creek.

- Sediment quality surveys should be re-evaluated every five years and should apply a stratified random sampling design that encompasses the entire river.

**Data Management and Communication**

- DREAMS, an online database used to compile the most current data on the Detroit River AOC, also serves as a repository for historical data relating to the system. A coordinated binational effort involving researchers in universities, industry and government agencies is required to ensure that DREAMS is updated to include all relevant data on the river.
APPENDICES

A. GLOSSARY

B. ABBREVIATIONS

C. LITERATURE CITED

D. DRCCC CHAIR PERSONS
APPENDIX A: GLOSSARY HEADINGS

Advecive processes
AOC  see Area of Concern
Area of Concern
Background (loadings)
Bathymetry
BEAST  see Benthic Assessment of Sediment
Beneficial use impairments
Benthic Assessment of Sediment
Benthic community structure
Benthic fish
Benthic invertebrates
Benthos
Bioaccumulation
Bioassay
Bioavailability
Bioconcentration
Biomagnification
Biomonitors
Biota
BUIs  see Beneficial Use Impairments
Calibration  see Data calibration
Cause/effect linkages
Chemical fingerprint
Chemical signature
Chemical speciation
Chironomids
Chlordane
CH3D  see Curvilinear Hydrodynamics in 3-Dimensions
Cluster analyses  see Multivariate statistical analyses
Combined sewer overflows
Congeners  see PCB congeners
Contaminant residues
CSOs  see Combined sewer overflows
Curvilinear Hydrodynamics in 3-Dimensions
Data set
Data calibration
DDT
Delisting criteria
Desorption
DFA  see Discriminant Function Analysis
Dieldrin
Discriminant Function Analysis
Downsratation
DREAMS
Ecosystem approach
Ecotoxicology
Eddy viscosity
Environmental fate
Food web
Forage fish
Freely-dissolved
  chemical concentrations
Geographic Information System
Geometry (river)  see River geometry
GIS  see Geographic Information System
Habitat
Hazard assessment
Hexachlorobenzene
Histogram
Horizons (sediment)  see Sediment horizons
Hydrophobic chemicals
Input parameters
Integrity (sample)  see Sample integrity
Invertebrates
LEL  see Lowest Effect Level
Lowest Effect Level
Median
Mercury
Metabolites
Metadata
Microhabitat
Model validation
µg/g
Multivariate statistical analyses
Organic contaminants
Organochlorine pesticides
PAHs  see Polynuclear aromatic hydrocarbons
PCB congeners
PCBs  see Polychlorinated biphenyls
Pelagic fish
Phytoplankton
Piscivorous fish
Plankton
Point sources
Polychlorinated biphenyls
Polynuclear aromatic hydrocarbons
Redox potential
RAP  see Remedial action plan
Reach (river)  
Remedial action plan  
Residues (contaminants)  
Risk assessment  
River geometry  
River reach  
Riverbed  
Sample integrity  
Sediment disturbance events  
Sediment horizons  
Sediment TRIAD approach  
Sediment/water fugacity ratio  
SEL  
Severe Effect Level  
Spatial trend  
Surficial sediment  
Temporal trend  
TOC  
Total Organic Carbon  
Toxicity  
Trace elements  
TRIAD  
Trophic levels  
Validation  
Water specific conductivity  
Watershed  
Zooplankton  

see River reach  
see Severe Effect Level  
see Total Organic Carbon  
see Sediment TRIAD approach  
see Model validation
### APPENDIX B: ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AOC</td>
<td>Area of Concern</td>
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<tr>
<td>BEAST</td>
<td>Benthic Assessment of Sediment</td>
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<tr>
<td>BUls</td>
<td>Beneficial use impairments</td>
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<td>CEA</td>
<td>Citizens Environment Alliance</td>
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<td>CSO</td>
<td>Combined sewer overflow</td>
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<tr>
<td>DDT</td>
<td>Dichlorodiphenyltrichloroethene</td>
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<tr>
<td>DFA</td>
<td>Discriminant Function Analysis</td>
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<td>DRLCC</td>
<td>Detroit River Canadian Cleanup Committee</td>
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<td>DREAMS</td>
<td>Data Retrieval, Exchange, Acquisition and Management System</td>
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<td>DRMMF</td>
<td>Detroit River Modelling and Management Framework</td>
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<tr>
<td>DWWTP</td>
<td>Detroit Wastewater Treatment Plant</td>
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<tr>
<td>EPA</td>
<td>U. S. Environmental Protection Agency</td>
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<td>ERCA</td>
<td>Essex Region Conservation Authority</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>HCB</td>
<td>Hexachlorobenzene</td>
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<td>IJC</td>
<td>International Joint Commission</td>
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<td>IPX</td>
<td>InPlace Pollutant Export Water Quality Modeling Framework (U.S. EPA)</td>
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<td>GLIER</td>
<td>Great Lakes Institute for Environmental Research, University of Windsor</td>
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<td>LaMP</td>
<td>Lakewide Management Plan</td>
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<tr>
<td>LEL</td>
<td>Lowest Effect Level</td>
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<tr>
<td>MOE</td>
<td>Ontario Ministry of the Environment</td>
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<tr>
<td>MSI</td>
<td>Middle Sister Island, Lake Erie</td>
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<tr>
<td>NOAA</td>
<td>U.S. National Oceanic and Atmospheric Administration</td>
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<tr>
<td>OC</td>
<td>Organochlorine</td>
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<tr>
<td>PAHs</td>
<td>Polynuclear aromatic hydrocarbons</td>
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<td>PCBs</td>
<td>Polychlorinated biphenyls</td>
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<td>RAP</td>
<td>Remedial Action Plan</td>
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<td>SEL</td>
<td>Severe Effect Level</td>
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<td>SOLEC</td>
<td>State of the Lake Ecosystem Conferences</td>
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<td>SPMDs</td>
<td>Solid phase membrane devices</td>
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<td>TOC</td>
<td>Total Organic Carbon</td>
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<tr>
<td>UGLCCS</td>
<td>Upper Great Lakes Connecting Channels Study</td>
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<tr>
<td>WWTP</td>
<td>Waste Water Treatment Plant</td>
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APPENDIX C: LITERATURE CITED


APPENDIX D: DETROIT RIVER CANADIAN CLEANUP COMMITTEE

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