CHAPTER VIII

LAKE ST. CLAIR

A. STATUS OF THE ECOSYSTEM

1. Ecological Profile

Watershed Characteristics

The St. Clair system including the St. Clair River and Lake St. Clair is a significant waterway economically, biologically and physically. Together with the Detroit River, the system forms the connecting channel between Lake Huron and Lake Erie.

Located on the international boundary between the United States and Canada, Lake St. Clair borders Lambton, Kent and Essex counties in Ontario, and Macomb and Wayne counties in Michigan. It has a shoreline length of approximately 272 km plus the delta shoreline area. It possesses a maximum natural depth of 6.5 m, a maximum length of 43 km, a width of 40 km and an area of about 1,115 km^2. In Ontario, wetlands and agriculture dominate the shoreline, while in Michigan the entire shoreline is highly urbanized. Because of its modest depth, the lake has no commercial harbors. To accommodate heavy commercial marine traffic, however, a navigation channel has been dredged to a depth of 8.3 m running in a northeast-southwest direction between the St. Clair cutoff in the St. Clair River Delta and the head of the Detroit River (Figure II-4).

The eastern shoreline of the lake is low lying and characterized by agricultural and recreational land uses. Low barrier islands less than 170 m in width and probably not more than 1 m above lake level parallel the shoreline and are colonized by marsh vegetation. The wetland zone, which is approximately 1 km wide, extended farther inland (east) in the past. Approximately 40% of the low plain has been ditched and drained since 1916. The coastal barriers provide a line of defense from wave attack to the lagoon and wetland zone. The annual net erosion rates on the south shore of Lake St. Clair are in excess of 2 m/yr (1). However, other coastal reaches on the south shore are actually accreting at rates of up to 0.4 m/yr.

On the western shore, permanent residential homes occupy about 30 km of lake shoreline, with industrial and commercial uses occupying only 2 km of shoreline. Most of the shoreline is in private ownership, but 12 km is publicly owned and dedicated to recreation and wildlife preserves.

Despite the various intensive and conflicting land and water uses to which the St. Clair system is subjected, the system continues to provide recreation to many Americans and Canadians. Typically more walleye, bass, muskellunge and centrarchid panfish are taken from Lake St. Clair each year than from any of the Great Lakes or other Great Lakes connecting channels. These anglers and boaters are served by more than 140 commercial, municipal and private marinas in Michigan and Ontario.

Hydrology

The physics of Lake St. Clair is important in determining the distribution and fate of contaminants and other substances in the sediment and water column. The St. Clair River contributes 98% of the water to the Lake St. Clair basin, with the remaining 2% being contributed by other lake tributaries, including the Clinton, Thames and Sydenham Rivers. The average discharge of the St. Clair River from 1900 through 1981 was 5,200 m^3/s with a range from 3,000 m^3/s to 6,700 m^3/s. Outflow from the lake, which is through the Detroit River to Lake Erie, is only about 3% greater than the inflow from the St. Clair River. Average flushing times for the St. Clair River, Lake St. Clair and the Detroit River are 21 hours, 5 - 7 days and 19 hours respectively (2).

Flows in the system are controlled principally by the inflows from Lake Huron and the outflows to Lake Erie, which in turn depend largely on the difference in water levels between these two lakes. Fluctuations of water levels and flows do occur at the head and mouth of both the St. Clair and Detroit Rivers in response to seasonally fluctuating water levels in the upstream and downstream lakes as well as wind set-ups on each of the lakes during periods of high winds and storms. Ice jams are a common occurrence on the St. Clair River and often reduce the river flow, thereby both raising the level of Lake Huron and lowering the level of Lake St. Clair. For example, in 1984 an ice jam reduced the monthly average flow to about 2,520 m^3/s, which caused a drop of 0.4 m in lake level.

Lake St. Clair has an established elevation of 174.65 m above sea level, but the average lake level from 1900 through 1983 was

174.87 m. The lake had a maximum elevation of 175.64 m, and a minimum elevation of 173.71 m.

The St. Clair River empties into Lake St. Clair through a large delta consisting of three main channels in the upper delta (North Channel, South Channel and Chenal Ecarte) and a number of secondary channels in the lower delta. The delta area, commonly referred to as the St. Clair Flats, extends 18 km from the open waters of Lake St. Clair towards the St. Clair River. Channel depths are extremely variable, but the three active distributaries average 500 m wide and 11 m deep. At the mouths of the channels, depths decrease abruptly due to river mouth bars 2 to 4 m below mean lake level. The North Channel, the South Channel and the Chenal Ecarte contribute 53%, 42% and 5% of the river flow to Lake St. Clair respectively (3).

Wind forces largely determine the water mass distribution and circulation patterns in the lake. In general, the main surface movement to the lake's outflow in the Detroit River appears to be along the south shore for southwest to north winds, and along the west shore of the lake for northeast to south winds. Two distinct water masses have been identified: a northwestern mass consisting primarily of Lake Huron water flowing from the main channels of the St. Clair River, and a southwestern mass of more stable water enriched by nutrient loadings from Ontario tributaries and shoreline development. The margins of the masses may shift according to wind direction and speed, but the overall discreteness of the distributions is maintained.

Habitats and Biological Communities

The St. Clair system contains one of the largest coastal wetlands in the Great Lakes. Topographic maps and navigation charts indicate there are 13,230 ha in Lake St. Clair and the St. Clair Delta. The wetlands include the following major types:

1. Open water wetlands have variable water depths and thus support submersed plants in deeper waters and emergent aquatic macrophytes in more shallow water. They commonly occur in interdistributary bays and shallower waters along the perimeter of Lake St. Clair.

2. River channel wetlands are composed largely of submersed species but occasionally emergent macrophytes occur on point bars.

3. Beach and shoreline wetlands are represented by a mix of species.

4. Cattail marsh wetlands colonize broad zones located at the lower St. Clair Delta and at the mouth of the Clinton

River. Stands of hybrid cattails (Typha x glauca) are associated with clayey and organic sediments. Shallow openings are colonized by floating and submersed species.

5. Sedge marsh wetlands are mainly composed of tussocks of sedges.

6. Abandoned river channel wetlands support emergent and submersed aquatics.

7. Wet meadow wetlands contain low, woody plants interspersed with grasses.

8. Shrub wetlands are dominated by mixed shrubs, water tolerant trees, and understory plants typical of wet meadows.

In general, all wetland types occur in the St. Clair Delta area. A sedge marsh wetland dominates the shallow regions. Where water depths exceed 0.3 m the sedges are replaced by cattail marsh, which is extensive, especially in Ontario. In deeper water, the cattail marsh gives way to open water wetlands dominated by the hardstem bulrush. This zone of emergents is less dense lakeward, where submersed macrophytes occur in bays at low density. The size, location and structure of the wetland plant communities shift in response to the periodic changes in water levels of Lake St. Clair.

Benthic macroinvertebrates also exhibit spatial zones within Lake St. Clair. In one recent study of benthic invertebrates and sediment chemistry, six community assemblages were identified. Two communities were associated with the periphery of the lake and in Anchor Bay, three communities were found in the deeper waters, 2 to 7.5 m deep, and one grouping was found in the lower reaches of the St. Clair River and Thames River.

Local Ecological Relationships

i) Nutrient Cycling

Lake St Clair is a highly productive north-temperate lake. The distribution of nutrients and chlorophyll within the lake are influenced primarily by lake currents and the flow of Lake Huron water through the delta system. Concentrations of chemical variables and chlorophyll tend to increase across the lake from northwest to southeast. Because of nutrient inputs from agricultural drainage, sewage discharge and greater stability in water mass, the southeastern area is more eutrophic than the remainder of the Ontario section of the lake. The northwestern water mass consists primary of Lake Huron water flowing from the main channels of the St. Clair River. The southeastern water mass consists of more stable water enriched by nutrient loadings from

Ontario tributaries, and can be considered to be mesotrophic, bordering on eutrophic.

Thermal and chemical stratification do not occur and oxygen concentrations remain near 100% saturation throughout the lake. Moderate alkalinity, low specific conductance and low pH variability indicate Lake St. Clair is a well-buffered, hard water lake. The input of high quality water from Lake Huron, through the St. Clair River, maintains the water quality and the biota in the open waters of Lake St. Clair similar to conditions in southern Lake Huron.

ii) Food Webs

The primary producers in the St. Clair system are phytoplankton and macrophytes. At least 71 species of phytoplankton and 21 taxa of submersed macrophyte have been identified from the St. Clair system. According to Edwards *et al*., (2) about 215,330 tonnes of plant biomass are produced in the St. Clair system each year, of which about 25% and 75% originates in the St. Clair River and in Lake St. Clair respectively. The estimated phytoplankton biomass, 96,900 tonnes, represents about half the total plant biomass produced in the system. Because of the short flushing time of the system, however, most of the phytoplankton probably passes into Lake Erie before it is utilized by other trophic levels. Most of the periphyton and macrophytic biomass dies back in the fall, over-winters on the bottom, and moves downstream in spring just after ice break-up. Additional allocthonous organic matter which is added to Lake St. Clair from municipal sewage treatment plant equals approximately 25% of the total annual primary production of all vegetation in Lake St. Clair.

Lake St. Clair has relatively low densities of limnetic zooplankton. In general, cladocera (28 species) are present in higher densities than cyclopoid copepods (5 species), and cyclopoids are more abundant that calanoid (7 species) or harpacticoid (4 species) copepods. The overall low abundance of limnetic zooplankton in Lake St. Clair has been attributed to well-developed macrophyte beds and the rapid flushing time of Lake St. Clair.

In excess of 300 taxa of macrozoobenthos have been reported from Lake St. Clair. Oligocheata, Chironomidae, Gastropoda, Ephemeroptera, Trichoptera and Amphipoda comprise the most significant biomass of macrozoobenthos. Nymphs of the mayfly *Hexagenia* may reach densities up to 3,000 nymphs/m^2. Species richness is greatest among the Chironomidae, Trichoptera and Oligochaeta.

iii) Trophic Relationships

Details of the relationships between the flora and fauna in the St. Clair system, beyond the generalized limnological interactions commonly thought to occur, have yet to be determined. The St. Clair River and Lake St. Clair are major sources for submersed and emergent plants that provide substrate for periphyton and for invertebrates that are fed upon by fish and waterfowl. They also provide cover for young fish. As detritus, the plants serve as food for macrozoobenthos. Poe et al., (4) showed that a percid-cyprinid-cyprinodontid fish community was dominant in Lake St. Clair in vegetatively complex areas occupied by many plant species, and that a less diverse, centrarchid community dominated in the areas with fewer plant species.

High productivity of benthic macroinvertebrates in Anchor Bay and around the delta of the St. Clair River in Lake St. Clair is probably related to the large accumulations of macrophytes in those areas. The macroinvertebrates are probably not food limited for at least half the year.

iv) Links to the Great Lakes

The St. Clair system provides important spawning and nursery habitat for fishes that are permanent residents and for others from Lake Huron and Lake Erie which enter the system to spawn. Of the approximately 70 species of fish recorded as residents or migrants in Lake St. Clair, at least 45 have spawned in the St. Clair system. Large numbers of lake herring and lake whitefish from Lake Erie historically migrated into Lake St. Clair to spawn over the large Chara beds along the western side of the lake.

Lake sturgeon were also historically abundant and supported a commercial fishery, but overfishing reduced the population and now only a limited recreational fishery is permitted. The shallow marshes of the St. Clair Flats are the only known nursery areas for the species in Lake St. Clair.

Walleyes and yellow perch spawn in Anchor Bay of Lake St. Clair, along the south shore of the lake, in the Clinton, Sydenham and Thames Rivers, and in the St. Clair delta. Stocks that were depressed from historical levels have rebounded in the past decade and major spawning runs now occur in the St. Clair system. Yellow perch populations of southern Lake Huron and the St. Clair system are closely linked. Many of these fish apparently overwinter and spawn in Lake St. Clair and the St. Clair delta, and then spend the rest of the year in the St. Clair River and Lake Huron.

Smallmouth bass and muskellunge support important recreational fisheries in Lake St. Clair and have extensive spawning grounds in the lake. Smallmouth bass spawn along the shoreline of the lake from the Thames River and the southeast edge of the lake, north into the St. Clair delta, and along the north and west shorelines of the lake to the head of the Detroit River. Virtually all of the delta and the shoreline of Anchor Bay are also nursery areas for smallmouth bass. Muskellunge spawning areas extend more or less continuously along the shoreline of the lake across the St. Clair delta, into Anchor Bay, and intermittently along the west shoreline to the head of the Detroit River. Marshes of the St. Clair delta are the only recorded muskellunge nursery areas.

Exotic fish species which now inhabit Lake St. Clair, as well as the Great Lakes, include the common carp (<u>Cyprinus carpio</u>), the alewife (<u>Alosa pseudoharengus</u>), the rainbow smelt (<u>Osmerus mordax</u>) and the white perch (<u>Morone americana</u>). The carp have recently made up much of the commercial fish catch, and the smelt plus alewife together are the most abundant fish larvae in the St. Clair system. The white perch, first captured in Lake St. Clair in 1977, now provide an important recreational fishery.

The extensive wetlands of Lake St. Clair are also an important concentration and nesting area for waterfowl. Major concentration areas extend from the lower St. Clair River to the middle of Lake St. Clair. The coastal wetlands and shallow waters of Lake St. Clair make it a critical resting and feeding habitat. Species whose primary migration corridor traverse Michigan with a resting stopover in the vicinity of lake St. Clair include the American goldeneye, bufflehead, canvasback, hooded merganser, ruddy duck and Canada goose. Important species of ducks that nest in the St. Clair area include mallards, blue-winged teal, black ducks, redheads and wood ducks.

<u>Climate</u>

The climate of the region is characterized by mild summers and cold winters. Average annual air temperatures range from a high of 23.6°C in July to a low of -4.4°C in January. Monthly precipitation ranges from a high of 8.10 cm to a low of 3.6 cm. In winter, temperatures are commonly below 0°C and ice occurs on most of the lake. Water temperatures during the summer months are near 21°C. Precipitation is mainly rain and is evenly distributed throughout the year.

2. Environmental Conditions

Water Quality

i) Tributaries

Because the St. Clair River provides 98% of the water to Lake St. Clair, the mass loading of contaminants to the Lake is mainly from this single input. Additional loadings from other tributaries do occur, however, and local impacts have been observed due to degraded tributary water quality. In the following discussions, references to Lake St. Clair tributaries exclude the St. Clair River.

Tributary water quality data from six tributaries (Thames, Sydenham, Puce, Belle and Ruscom Rivers in Ontario, and the Clinton River in Michigan) in 1984 and 1985 indicated the presence of eight pollutants (PCBs, HCB, OCS, P, Cd, Cl, N and Pb) that were designated as parameters of concern for the UGLCC Study. In these streams, P, Cd, Pb and Cl concentrations ranged from 0.014-0.94, 0.002-0.0022, 0.003-0.58 and 11-349 mg/L respectively (Table VIII-1). Estimated daily loadings from each river are presented in Table VIII-2. Expression of loadings on a daily basis is somewhat artificial, since true loadings from tributaries have been shown to be strongly flow-dependent and seasonal. However, expression in this manner should facilitate comparison with other sources of loadings presented in this report.

The organic contaminants, PCBs, HCB and OCS were usually not found in quantifiable concentrations in unfiltered water samples (5). PCBs associated with suspended sediments from the Belle, Sydenham and Thames Rivers were found in concentrations up to 1,560 ng/g, 60 ng/g and 61,190 ng/g respectively. Suspended sediments were not sampled from the other rivers.

The phosphorus concentration in water from all six tributaries exceeded the Ontario Provincial Water Quality Objective (PWQO) of 30 ug/L for rivers in all samples, except for some samples from the Sydenham River. Estimates of loadings from the tributaries ranged from 23.5 kg/d from the Puce River to 2,021 kg/d from the Thames River. All sampled Canadian tributaries together provided a loading of 3,052 kg/d, while the Clinton River contributed an additional 340 kg/d (Table VIII-2).

The largest nitrate + nitrite loadings to Lake St. Clair came from the Thames River (31,435 kg/d), Sydenham River (4,542 kg/d) and Clinton River (2,186 kg/d).

Concentrations of chlorides in unfiltered water ranged from 11 mg/L in the Sydenham River to 349 mg/L in the Clinton River. The Clinton River concentrations exceeded the 250 mg/L concentration set as the U.S.EPA Secondary Maximum Contaminant Level for aes-

TABLE VIII-1

Comparison of Canadian and U.S. tributary pollutant concentrations and loads for the study area (1984-1985).

	Canadian Tributaries[a]	U.S. Tributary[b]
Combined Drainage Areas (ha)	567,310[c]	190,004
Percent of Study area	47	16

Parameter (units)	Canadian Tributaries Monitored	Concentrations Water	Suspended Sediment (ng/g)	Average Loads (annual)[c]	Concentrations[d] Water	Suspended Sediment (ng/g)	Average Loads (annual)
PCBs ng/L	T,S,B,K	<QLD	<QLD-61,190	NS	X	X	X
HCB "	T,S,B	<QLD-4	<QLD-53	NS	X	X	X
OCS "	T,S,B	<QLD	<QLD-24	NS	X	X	X
P mg/L	T,S,B,R,P,K	0.014-0.94[f]	X	22.6 kg/ha[e]	0.06-0.69[f]	X	0.653kg/ha
N "	T,S,B,R,P	0.01-12.7	X	40 "	0.76-2.6	X	4.1 "
Cl "	T,S,B,R,P,K	11-220	X	287 "	41-349	X	360.5 kg/ha
Pb "	T,S,B,K	0.003-0.58[f]	X	0.07 " [e]	X	X	0.03 "
Cd "	T,S,B,K	.0002-.0008[f]	X	0.002 " [e]	.001-.0022	X	0.0016 "
atrazine ng/L	T	<QLD-30,000	X	16.0 g/ha	0.43 ug/L[h]	X	0.28 g/ha
alachlor "	T	<QLD- 6,900 [g]	X	0.7 "	0.63 " [h]	X	0.08 "
metolachlor "	T	<QLD- 8,000	X	6.7	0.32 " [h]	X	0.01 "
cyanazine "	T	<QLD- 5,000	X	NS	0.47 " [h]	X	0.048 "

NOTE:

a	Six Canadian tributaries include the Thames (T), Sydenham(S), Belle (B), Ruscon(R), Puce (P) and Pike (K) Rivers
b	U.S. tributary is Clinton River
c	Excluding Pike Creek
d	U.S. pesticide data for the period April 15 to August 15, 1985 only
e	Average Sydenham and Thames Rivers only
f	Concentrations exceeded water quality standards
g	Concentrations exceeded one or more proposed water quality standards for drinking water
h	Time weight mean concentrations
X	No data available
<QLD	Less than quantitative limits of detection
NS	Insufficient data for load calculations

TABLE VIII-2

U.S. and Canadian tributary loading of UGLCCS parameters into Lake St. Clair (kg/d).

Tributary	NO3-N	Cadmium	Chlorides	Lead	Phosphorus
Belle River (Canada)	516	-	6007	-	71
Puce River (Canada)	282	-	4535	-	23
Ruscon River (Canada)	647	-	4984	-	43
Sydenham River (Canada)	4542	0.696	50,483	11.2	893
Thames River (Canada)	31,453	1.82	190,318	123.1	2021
Clinton River (U.S.)	2186	0.83	187,661	15.6	340

Note:

Values are presented here in rounded form and may differ from that in the text. Loadings for other U.S. tributaries mentioned in the text were not calculated thetic effects, the Health and Welfare Canada Maximum Acceptable Concentration, and the Ontario Maximum and Maximum Desirable Concentration for aesthetics. The greatest loadings were provided by the Thames River (190,318 kg/d), Clinton River (182,661 kg/d) and Sydenham River (50,483 kg/d).

The range of cadmium concentrations in unfiltered water were 0.2-0.4 ug/L in the Belle River, 0.2-0.7 ug/L in the Sydenham and Thames Rivers, and 0.1-2.2 ug/L in the Clinton River. These concentrations were generally greater than the Great Lakes Water Quality Agreement (GLWQA) specific objective and PWQO of 0.2 ug/L, and some were greater than the chronic AWQC of 1.1 ug/L (assuming water hardness of 100 mg/L). Estimated loadings from the Clinton, Thames and Sydenham Rivers were .83 kg/d, 1.82 kg/d and 0.696 kg/d respectively.

The Belle, Sydenham and Thames Rivers all contained concentrations of lead in some samples that exceeded the chronic AWQC of 3.2 ug/L (assuming a hardness of 100 mg/L). The Thames River contained concentrations which also exceeded the acute AWQC of 82 ug/L, as well as the GLWQA specific objective and PWQO of 25 ug/L. Major loadings of lead were provided by the Thames River (123.1 kg/d), Clinton River (15.6 kg/d) and Sydenham River (11.2 kg/d).

The pesticides atrazine, cyanazine, metolachlor and alachlor were detected in Thames River water samples between 1981 and 1985 with a frequency of occurrence of 99%, 16%, 7% and 4% respectively at concentrations from less than detection limits to 3.0, 5.0, 8.0, and 3.0 ug/L respectively (Table VIII-1). In the Clinton River in 1985, the pesticides as ordered above were observed with frequencies of 95%, 73%, 2.7% and 21.6% respectively at concentrations from less than detection limits to 1.9, 0.2, 0.2 and 0.9 ug/L respectively.

Some U.S. agencies have proposed drinking water standards for the four pesticides discussed above. None of the measured concentrations of the pesticides in either of the rivers exceeded the proposed standards, except for the State of Wisconsin standard for alachlor (0.5 ug/L).

ii) Open Lake St. Clair Water

Water temperature in Lake St. Clair is determined in part by the shallow depth and short hydraulic retention time of the water. Highest temperatures are reached in August, and average about 22.5°C. Temperatures may be 2 to 4°C lower in Anchor Bay because of the greater inflow from the St. Clair River, and they may be 5 to 6°C higher in the coastal wetlands. The lake is too shallow to stratify thermally, and dissolved oxygen concentrations are usually at saturation.

In general, surface water temperatures at the outflow of Lake St. Clair exceed the upper limit (19°C) of the range selected for residence by adult rainbow trout from about late June through mid-September, and they exceeded the upper limit of the range (17°C) selected for residence by juvenile lake whitefish in Lake Huron from about mid-June through late September. Thus, Lake St. Clair may provide optimum thermal habitat for indigenous Great Lakes cold water fishes only during the cooler months of the year. Anchor Bay may contain suitable thermal habitat for cold-water fishes for a slightly greater portion of the year than the rest of the lake.

Because of the large contribution of water from the St. Clair River into Lake St. Clair and the relatively short residence time of water in the lake (5 to 7 days), the water quality of Lake St. Clair largely reflects that of the St. Clair River.

Concentrations of contaminants within the water may be inferred by comparing those in the incoming water with those in water at the head of the Detroit River. Studies of water from the St. Clair and the Detroit Rivers were conducted in 1985, with samples analyzed for a number of chemical parameters, including organochlorine pesticides (OCs), PCBs, and a variety of other chemicals of industrial origin including chlorobenzenes (CBs), hexachlorobutadiene (HCBD), hexachloroethane (HCE) and octachlorostyrene (OCS). Details of the analytical procedures were provided by Chan _et_ _al_., (6).

Organochlorine Pesticides and PCBs:

Concentrations of total PCBs in unfiltered water at the head of the Detroit River averaged 0.0014 ug/L from two surveys. This concentration was slightly above the Ontario Provincial Water Quality Objective (PWQO) of 0.001 ug/L. The difference in concentration of PCBs between the mouth of the St. Clair River and the head of the Detroit River was not significant, i.e., less than detectable and 0.0014 ug/L in two surveys of the St. Clair River, 0.00139 ug/L and 0.00144 ug/L in two surveys of the Detroit River. Because the concentrations of other organic compounds (HCBD, HCB, OCS and HCE) were lower at the Detroit River than at the mouth of the St. Clair River (7), however, a source of PCBs may exist within the Lake St. Clair basin. At the head of the Detroit River, the concentration of PCBs was greater on the U.S. side than on the Canadian side, suggesting that a source of PCBs may exist on the western shore of Lake St. Clair.

Concentrations for the organochlorine pesticides in the dissolved phase were in the low ng/L range or less along the St. Clair River. While there were some seasonal variations noted, no marked spatial variation was observed, either downstream or cross-river. Because concentrations were also similar at the head of the Detroit River, an argument similar to that for PCBs above can be made for the possible existence of a source for these pesticides in the Lake St. Clair basin.

Chlorobenzenes, Octachlorostyrene:

In contrast to the behaviour of the pesticides and PCBs noted above, increases in the concentration of HCBD, HCB, and OCS indicate significant sources of inputs of these industrial compounds to the St. Clair River, but the plume of contaminants remains close to the Canadian shore and does not disperse uniformly across the river. In the upper delta, concentrations were highest in the Channel Ecarte, which receives Canadian nearshore water. Because this stream contributes only 5% of the total river flow to Lake St. Clair, however, the major loading of these substances to the lake would come from the South Channel. Diminished, but measurable concentrations of these chemicals in the dissolved phase were observed at the head of the Detroit River in 1985, showing that some contaminant carryover from the St. Clair River occurred, but also that some significant loss processes occurred within the lake. Similar findings were reported for a survey conducted in 1984 (8). For example, loss processes in Lake St. Clair may account for up to 95% reductions in HCB and OCS between the St. Clair and Detroit Rivers (8).

Phosphorus, Chlorides and Metals:

Concentrations of total phosphorus, chlorides and metals in whole water and suspended solids from the mouth of the St. Clair River and the head of the Detroit River in 1984 are presented in Table VIII-3. All measured concentrations in water were below the relevant surface water standards or guidelines except for some observations of excessive iron in the Detroit River. Similarly, the mean concentrations of the following parameters that were measured at the head of the Detroit River in 1985 were below all relevant criteria, objectives or guidelines: total phosphorus, 8.6 ug/L; cadmium, 0.023 ug/L; zinc, 1.217 ug/L; mercury, 0.008 ug/L; copper, 1.29 ug/L; and nickel 0.966 ug/L. A significant increase (71%) in phosphorus concentration in both whole water and suspended sediments was observed between the mouth of the St. Clair River and the head of the Detroit River, thereby indicating that Lake St. Clair and/or its basin are a net source for phosphorus.

The metals and chloride exhibited variable responses across Lake St Clair in 1984. The concentration of total iron in both whole water and in suspended solids was greater at the head of the Detroit River than at the mouth of the St. Clair River, while that of zinc was greater only associated with suspended solids. Lead and mercury concentrations tended to be greater in the Detroit River than in the St. Clair River, but cross channel differences were detected. Chloride concentrations were not observed to be different in the two river reaches.

TABLE VIII-3

Concentrations of total phosphorus, chlorides and metals in whole water and suspended solids from the mouth of the St. Clair River and the head of the Detroit River, 1984, range and (mean)a.

Whole Water

Location	Fe mg/L	Pb ug/L	Hg ug/L	Zn ug/L	TP ug/L	Chloride mg/L
St. Clair River						
North Channel	0.054-0.220 (0.130)	<3	<0.01	0.5-3.0 (1.5)	6-12 (8.8)	5.77- 6.82 (6.30)
South Channel	0.063-0.170 (0.085)*	<3	<0.01	0.5-5.0 (2.4)	7-10 (8.5)	7.82-10.94 (9.06)
Detroit River						
West side	0.088-0.380	<3	<0.01	0.3-3.0	9-21 (14.0)	7.09-12.45 (9.0)
East side	0.130-0.920	<3	<0.01	0.5-1.0	12-20 (15.5)*	7.34-11.93 (9.1)

Suspended Solids

	Fe mg/g	Pb ug/g	Hg ug/g	Zn ug/g	TP mg/g	Sus.Solids mg/L
St. Clair River						
North Channel	16-22 (19.0)	10-26 (20.5)	0.03-0.14 (0.09)	74-86 (81.0)	0.5-1.0 (0.8)	5.6-12.7 (8.3)*
South Channel	14-18 (16)	25-49 (40)	0.16-0.35 (0.27)	70-110 (81.5)	0.6-1.0 (0.8)	5.6-11.1 (7.1)
Detroit River						
West side	21-31 (25.3)	39-62 (52.5)	0.06-0.17 (0.18)	110-130 (120)	1.2-1.6 (1.4)	4.6-22.2 (5.5)*
East side	21-34 (26.0)	36-40 (38.3)	0.17-0.47 (0.32)	93-130 (111)	1.2-2.2 (1.5)	5.3-16.3 (6.9)*

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a from Johnson and Kauss (8).
* denotes median value instead of mean.

Biota

i) Plankton

In 1984, relatively high biomass concentrations of phytoplankton were recorded during early June (1.17 g/m^3) compared to that in late July (0.27 g/m^3)(9). In spring, the species composition was dominated by Diatomeae (67-90%), with significant contributions from Chrysophyceae and Cryptophyceae phytoflagellates. During summer, the community structure was equally composed of Chrysophyceae (34%) and Diatomeae (34%). From May through September, Chlorophyta (greens) contributed only once substantially, during late July (24%). The contribution from Cyanophyta (blue-greens) was relatively low.

Zooplankton abundance in Lake St. Clair in June and July, 1984, ranged from 35 to 93 organisms/L, and from 500 to 1,500 ug/L in total biomass (10). These densities are among the highest reported for the Great Lakes. Cladocerans were proportionately dominant in both numbers and biomass. This pattern of cladoceran predominance is in contrast to the other Great lakes in which copepods routinely dominate to a much greater extent. Lake St. Clair is a more typical cladoceran habitat than the other lakes, because it is shallow, more productive, and may not contain dense populations of planktivorous fish to which cladocerans are particularly vulnerable. In addition, the high flushing rate of Lake St. Clair may favor species with shorter generation times. Large zooplankters such as _Holopedium_ and _Leptodora_ were not abundant. Copepods comprised approximately 1/3 numerically and 40-50% by biomass of the zooplankton community.

ii) Macrophytes

At least 12 submersed plant taxa occur in Lake St. Clair (11,12). Common native taxa are _Chara_ sp. (macroalga), _Vallisneria americana_, _Potamogeton richardsonii_, _Elodea canadensis_, _Potamogeton_ sp. (narrow-leaved forms), and _Najas flexilis_. _Chara_ sp. includes _Nitella_ sp. and muskgrass, both of which overwinter as green plants. _Nitella_ is often found in deeper water to a depth of 27 m where few other plants are present. Submersed plant stands in the lake are usually composed of 2-3 species, and most occur at depths less than 3.7 m. The 0.0 to 3.7 m depth interval in Lake St. Clair covers approximately 628 km^2, and plant coverage of the bottom within this depth interval is 35%. Estimated annual production of submersed aquatic plants in Lake St. Clair is 13,780 tonnes ash-free dry weight (13).

No detailed studies on species composition, distribution and relative abundance of emergent macrophytes in Lake St. Clair have been completed. The estimated total areal extent of emergents in the lake in the late 1970s was 9,170 ha (14). Estimated production of emergent aquatic plants in Lake St. Clair is 60,990 tonnes ash-free dry weight/yr (13).

The drift of live (chlorophyllous) submersed plant matter out of Lake St. Clair in the surface waters was measured in 1986 (15). Of the 6 submersed plant and macroalgae taxa present in drift samples collected from April through October 1986 immediately below Belle Isle near the head of the Detroit River, Vallisneria americana, Potamogeton richardsonii, and Myriophyllum spicatum occurred most frequently. Substantial drift occurred in all months. Drift biomass was lowest in April and highest in September at 14 and 1,183 g wet weight/1000 m^3 filtered). The submersed plant biomass leaving Lake St. Clair as surface drift during April to October, 1986, was calculated to be 32,052 tonnes wet weight or about 1,602 tonnes ash-free dry weight. This calculation may underestimate the biomass of macrophyte drift because the Detroit River discharge in 1986 was probably greater than the 1900-1980 average that was used for river flow. Concern exists that the drift of plant material containing contaminants may facilitate the dispersal of contaminants within the UGLCC Study area, including western Lake Erie.

iii) Benthos

Lake St. Clair supports a healthy and diverse community of benthic fauna. Nematoda, Amphipoda, Diptera (Chironomidae), Ephemeroptera, Trichoptera, Gastropoda, and Pelecypoda are abundant in the St. Clair River system. The taxonomic diversity of macrozoobenthos in Lake St. Clair (65 taxa) was lower than that in the St. Clair River (98 taxa) and the Detroit River (80 taxa), however (12).

In 1985, a total mean density of mayfly (Hexagenia) nymphs of 194 nymphs/m^2 was found throughout the UGLCC Study area, including 279 nymphs/m^2 in Lake St. Clair. The maximum density was also found in Lake St Clair at 3,099 nymphs/m^2. Nymphal production ranged from 165 to 2,321 mg dry wt./m^2/yr in the study area, with a maximum rate of 4,011 mg dry wt./m^2/yr at the single location studied in Lake St. Clair. The river production values were similar to the range of values reported in the literature, but production in Lake St. Clair was about twice the highest published value.

Macroinvertebrate taxa were identified at 47 sampling stations in Lake St. Clair in 1983 (16). Six benthic invertebrate communities were identified with different species assemblages (Table VIII-4). Two communities occurred generally in the shallow periphery of the lake, three communities were found in the deeper waters, and one was present in the St. Clair River and mouth of the Thames River (Figure VIII-1). Discriminant analysis suggested that the six communities were associated with different environmental conditions. The "shallow periphery" communities occurred at sites with coarser, sandy sediments and lower con-

TABLE VIII-4

Species composition (mean number per 516 cm2) of benthic communities in Lake St. Clair, May 1983. P denotes a mean density of less than one individual per sample. Communities are grouped by habitat type (16).

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	LAKE--SHALLOW		LAKE--DEEP			RIVER
AQUATIC CATERPILLARS:						
Pyralidae		P			P	P
BEETLES:						
Dubiraphia		P			P	P
TRUE BUGS:						
Corixidae	1.3	P				
CADDISFLIES:						
Cheumatopsyche		P				P
Hydropsyche		P				P
Ceraclea		P				P
Mystacides		P		P		P
Oecetis		P	P	P		P
Setodes		P				
Molanna	P					P
Neureclipsis						P
Phylocentropus			P		P	P
MAYFLIES:						
Baetisca		P				
Caenis	P	P				1.7
Eurylophella	P	P				
Serratella						P
Ephemera				P		
Hexagenia	P	P	16.9	17.0	44.2	3.3
Stenonema						P

TABLE VIII-4. (cont'd 2)

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	LAKE--SHALLOW		LAKE--DEEP			RIVER
TRUE FLIES:						
Ceratopogonidae	16.3	P	P		1.0	3.2
Chaoborus					1.3	
Chironomus	P	P	5.4	2.1	7.2	P
Cladopelma	P	P				
Cladotanytarsus		P				
Cryptochironomus	1.9	2.4	1.3	1.5	27.2	2.8
Demicryptochironomus	P	P	P	P	16.8	
Dicrotendipes			P		1.7	P
Harnischia				P		
Microtendipes			P			
Nilothauma		P				
Paratanytarsus						P
Phaenopsectra						P
Polypedilum	13.0	2.2	2.2		13.5	29.3
P. illinoensi	13.2	P				2.0
Pseudochironomus	P	7.5	3.3	P		24.9
Rheotanytarsus		P				
Stictochironomus	P	4.0	7.2	P	6.2	44.7
Tanytarsus				P		
Tibelos			5.7	P	8.8	98.5
Pothastia	P	P	P	P	P	
Epicocladius			P	P	P	
Heterotrissocladius		P	P			
Hydrobaenus	P		1.1		1.0	P
Cricotopus/Orthocladius	P	P				7.3
Parkiefferiella?	P	1.5	P	P	P	
Monodiamesa		P			P	P
Ablabesmyia		P	P	2.0	3.7	P
Clinotanypus		P		P	P	P
Coelotanypus	P	1.1	2.2	6.0	1.5	

TABLE VIII-4. (cont'd 3)

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	LAKE--SHALLOW		LAKE--DEEP			RIVER
Djalmabatista			P		P	
Procladius	P	P	6.6	5.2	16.7	7.5
Thienemannimyia-gp		P				P
Empididae	P					
CRUSTACEANS:						
Gammarus		5.4	14.5	P	2.0	22.7
Hyalella azteca		P	2.1			2.6
Asellus			4.4			1.2
Lirceus			P			5.3
CLAMS:						
Pisidium		2.8	P	1.1	6.5	4.8
Sphaerium		1.2	1.3	P	P	
Unionidae		P	P	P		
SNAILS:						
Bithynia	P		P	P		
Amnicola		P	1.9			
Probythinella		P	P	P	P	P
Somatogyrus		P	P	P		
Fossaria		P				
Lymnaea						P
Physa		P	P			10.3
Goniobasis		2.4	1.0	P		P
Pleurocera		P		P		
Valvata		P	P			P
LEECHES:						
Erpobdellidae			P			P
Glossiphonidae			P	P		P

TABLE VIII-4. (cont'd 4)

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	LAKE--SHALLOW		LAKE--DEEP			RIVER
POLYCHAETES:						
Manaynunkia speciosa		P	2.2	P	P	
WORMS:						
Lumbricidae			P		P	2.6
Stylodrilus herringianus		P	P		P	1.8
Naididae	P	P	P	P	1.3	P
Aulodrilus americanus				P		1.3
A. pleuriseta				P		
Branchiura sowberbyi			P	2.4		P
Isochaetides curvisetosus		P				
Ilyodrilus templetoni		P		P		P
Isochaetes freyi		P				P
Limnodrilus angustipenis			P			
L. cervix	P			P		3.9
L. claparedianus	P	P	3.6	P	P	1.0
L. Hoffmeisteri	P	1.9	5.7	4.2	14.5	10.1
L. maumeensis		P			5.7	P
L. udekemianus		P			3.0	1.0
Potamothrix moldaviensis	3.1	P		P	1.2	5.5
P. vejdovskyi	P	P	P			
Quistadrilus multisetosus					9.8	10.2
Spirosperma ferox	P	5.4	21.7	P	2.8	12.4
NEMATODES	P	3.3	11.2	11.5	12.2	P
FLATWORMS		P	P	1.1	2.8	13.9
MEAN NUMBER OF TAXA	6.8	10.4	15.4	10.2	18.8	20.9
MEAN DENSITY OF ORGANISMS	60.3	60.9	141.9	80.4	253.3	369.5

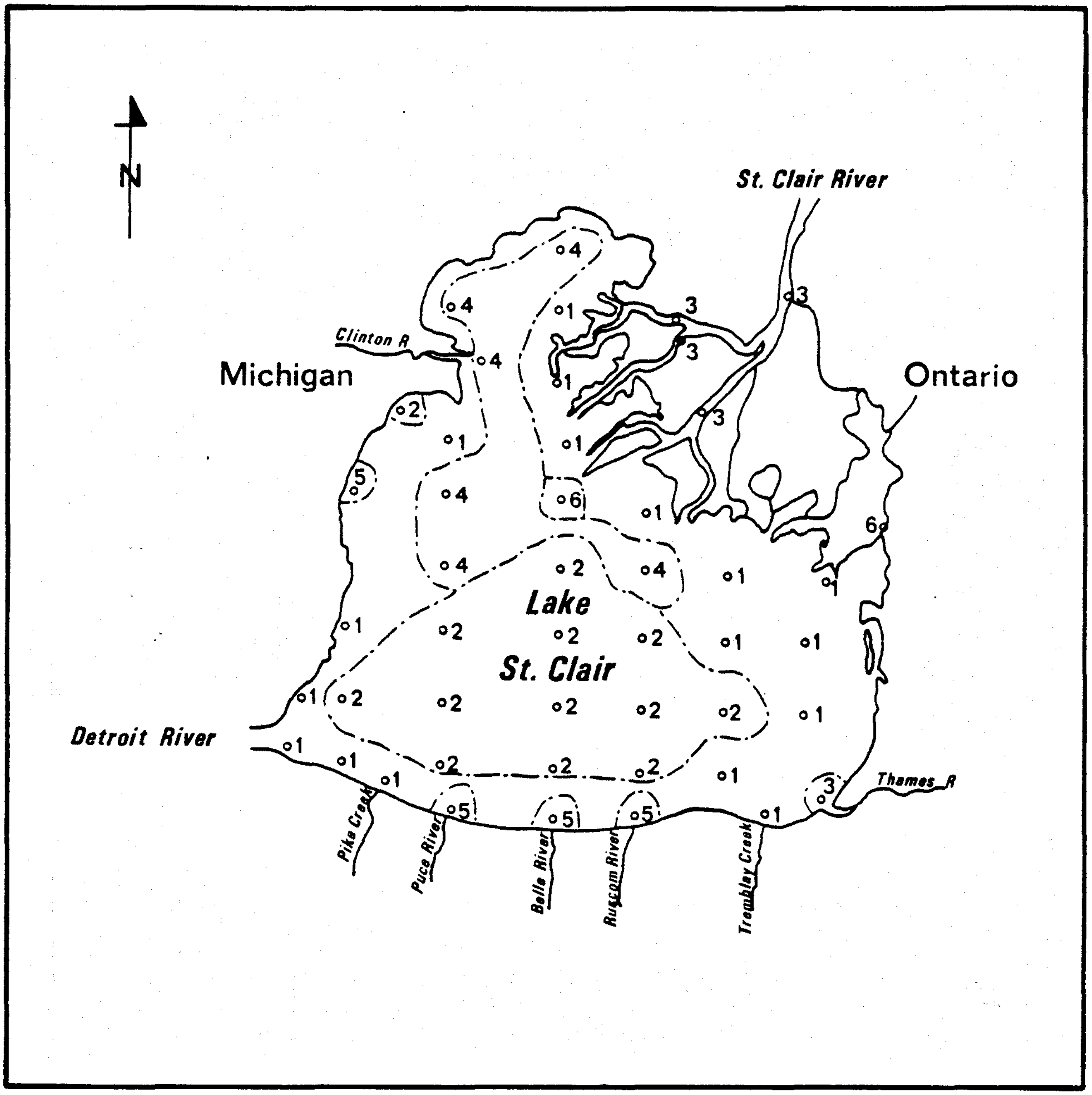

FIGURE VIII-1. Distribution of benthic invertebrate communities in Lake St. Clair, Anchor Bay and the St. Clair River, May 1983 (16).

centrations of metals, organic carbon and nutrients relative to the "deeper water" communities (Table VIII-5). Poor correlations were found between the measured physicochemical variables and the community separations, however, implying that one or more additional variables were influencing the community structure.

Based on the distribution of the benthic communities, mesotrophic conditions prevailed in the central basin of the lake and Anchor Bay and in the lower part of the St. Clair River, while oligo-mesotrophic conditions were present in the shallower nearshore areas of the lake and Anchor Bay. Neither the St. Clair or Thames rivers had any perceivable effect on the environmental quality of the lake. Impairment of environmental quality was observed at the mouths of the Puce, Belle, and Ruscom rivers and near a sewer outfall from St. Clair Shores, Michigan. The locally impaired environmental quality may be related to the discharge of oils and grease into the lake. In addition, reduced environmental quality related to organic matter enrichment was observed in deeper parts of the study area near the St. Clair River delta.

Concentrations of lead (up to 40 ppm), cadmium (up to 19 ppm) and octachlorostyrene (OCS, up to 0.15 ppm) in Lake St. Clair clams were generally highest in that portion of the lake which receives the majority of the St. Clair River discharge, i.e., adjacent to the South Channel outlet. There are no Michigan or Ontario guidelines or objectives for OCS or Cd in fish.

In contrast, the concentration of PCBs in clams, up to 0.7 ppm exhibited a different distribution with highest concentrations along the southwest shore of the lake rather than in the St. Clair River (17). By comparison, the GLWQA includes a specific objective of 0.1 ppm PCBs in whole fish. A positive correlation between clam tissue and sediment concentrations was observed only for PCBs and OCS, however, suggesting that sediment distribution patterns of lead and cadmium may not provide much information on contaminant exposure of clams.

iv) Fish

The fish community of Lake St. Clair is diverse and abundant, consisting mainly of warm-water and mesothermic species. Cold-water species are found in the lake, but not as year-round residents. Of the more than 70 species recorded as native or migrants, 34 use the lake for spawning (18). Most of the 28 native species spawn in shallow water along the delta (St. Clair Flats) or other shoreline areas or in tributaries to the lake. Of the exotic species, rainbow smelt and sea lamprey spawn in tributaries, and alewives, carp, goldfish and gizzard shad spawn in bays, marshes and other shallow areas.

Because of the proximity of Lake St. Clair to large urban populations, recreational fisheries are active year-round. In Michigan

TABLE VIII-5

Mean values (geometric mean) of physicochemical sediment variables associated with the benthic communities in Lake St. Clair, May 1983. All units are expressed as mg/kg unless otherwise stated. Communities are grouped by habitat type (16).

	BENTHIC COMMUNITY					
	5	1	4	2	6	3
	Lake-Shallow		Lake-Deep			River
Fe (g/kg)	6.14	6.79	8.96	14.16**	12.96**	9.43
Al (g/kg)	2.31	2.73	5.43	8.87	8.65	4.83
Cd	0.10	0.12	0.28	0.40	0.50	0.38
Cr	8.75	9.67	15.26	23.89	24.42	12.93
Cu	2.89	3.81	10.24	17.86	22.56	15.06
Hg	0.01	0.07	0.17	0.49**	0.32**	0.23
Ni	4.26	4.61	9.26	15.69	15.97	9.68
Pb	2.35	3.62	13.69	23.11	24.46	15.07
Zn	13.69	20.33	41.17	62.03	65.68	50.92
Oil and Grease (g/kg)	0.59	0.31	0.53	0.79	1.09*	0.26
Loss-On-Ignition(%)	0.65	0.59	1.62	2.45	3.77	3.30
Total Organic Carbon	1.42	2.36	11.50	15.62	24.82	19.87
Total-P (g/kg)	0.20	0.21	0.25	0.48*	0.44*	0.38
Total Kjeldahi-N (g/kg)	0.22	0.22	0.51	0.79	1.18*	1.05*
Grain Size (phi units)	1.58	1.86	3.90	4.65	4.30	3.76

Based on the U.S. EPA Guidelines for Pollution Classification of Great Lakes Harbour Sediments (22):

* Means that the sediment is considered moderately polluted

** Means that the sediment concentration exceeds the Ontario Ministry of the Environment's Guidelines for Open Water Disposal (22).

waters, yellow perch (59%) and walleye (18%) were the main species harvested by boat anglers in 1983-1984. In Ontario waters in 1986, the main species were walleye (59%), yellow perch (24%) and smallmouth bass (4.6%). Yellow perch dominated the ice fishery.

PCB concentrations in edible portions of walleye and yellow perch were approaching 0.25 ppm and 0.05 ppm, respectively, in 1985 (7). These concentrations are below the U.S.Food and Drug Administration (U.S.FDA) action level of 2 ppm, but the concentration in walleye exceeded the GLWQA specific objective of 0.1 ppm for whole fish.

The concentration of mercury in the edible portions of walleye, northern pike, white bass and yellow perch were approaching 0.3 to 1.0 ppm in 1985. These concentrations of mercury do not exceed the U.S.FDA action level of 1 ppm, but they do in some cases exceed the Ontario objective.

Habitat Alterations

Of an estimated 22,366 ha of wetlands that existed in Lake St. Clair in 1873, more than 9,000 ha were lost to shoreline development by 1968. Losses are most evident in the Clinton River, the St. Clair delta and the eastern shore of the lake. In all three areas, the margins of the wetlands have been modified. On the eastern shoreline the wetlands at one time were approximately 2.5 km wide, but now they are about 0.8 km in width.

In Ontario, wetlands are currently being lost to agriculture. The wetlands from the Thames River north to Chenal Ecarte dwindled from 3,574 ha in 1965 to 2,510 ha in 1984 (19) Draining for agriculture accounted for 89% of the wetland loss, whereas marina and cottage development consumed the remaining 11%. During the record high lake level in the early 1970s, about 1,000 ha of emergent shoreline marsh from Mitchell Bay southward to the Thames River were also temporarily lost (20). This loss was tempered in part by the flooding of transition vegetation which occurred on the upland (east) margin of the wetlands.

The St. Clair delta and the Anchor Bay area in Michigan are also subject to flooding, but the recent wetland losses there are due mainly to diking and filling for urban development. In the Clinton River area, wetland losses occurred from both landward and lakeward boundaries and the remaining wetlands are now isolated from Lake St. Clair.

Navigation-related dredging has also altered aquatic habitat within Lake St. Clair. In the 1950s, the minimum channel depth in the St. Clair River, South Channel and Lake St. Clair was dredged to 8.2 m as part of the Great Lakes-St. Lawrence Seaway.

Navigation dredging projects have altered the flow regimes of Lake St. Clair and replaced productive shoal water habitat with less productive channel habitat. Bulkheading, dredging and backfilling by landowners has also resulted in the loss of significant amounts of littoral habitat in the system. The loss of shoal and littoral waters, along with the removal of gravel and the lack of delta growth represent loss of habitat that is utilized by many Great Lakes fishes to satisfy spawning and other early life history requirements.

Bottom Sediments

i) Physical Characteristics

The thickness and grain size distribution of bottom sediments is an important aid to understanding the transport, accumulation and resuspension of polluted sediments in Lake St. Clair. Based on a coring survey completed in 1986, the modern sediment thickness corresponds roughly with lake depth (21). The maximum thickness of over 30 cm is generally confined to the St. Clair River delta and a narrow band extending from the delta southwest toward the head of the Detroit River (Figure VIII-2).

Analysis of grain size distribution, based on 1984 data (21), indicated the most common size interval in sediment samples to be 0.063 to 0.125 mm (3-4 PHI units). This size particle occurred as a band trending NW-SE across mid-basin and in the north and eastern portions of Anchor Bay. Coarser unimodal sediment (0.125 to 0.500 mm, 1 - 3 PHI units) was present opposite the Chenal Ecarte and Clinton River mouths on the northeast and west coasts, and in the central portion of Anchor Bay. Coarser bimodal sediments with gravel and sand modes occurred along the south and southwest shores. Size modes finer than sand (0.063 mm, 4 PHI units) were found only in a small area in the western part of the central basin.

The distribution of sediment composition based on percentage gravel, sand and silt-clay (mud) was similar to that observed for the modal size distribution. Gravel content was generally less than 1% with the exception of the south and southwest margin of the lake where it ranged from 5 to 45%. Sand was the major component of the surface sediments and ranged from 30 to 100%. The highest percentages of sand occurred at the mouths of the delta distributary channels and in the south and southwest area of the lake. Percent silt and clay (muds) ranged from 1 to 68% with highest percentages in the west-central part of the basin (Figure VIII-3).

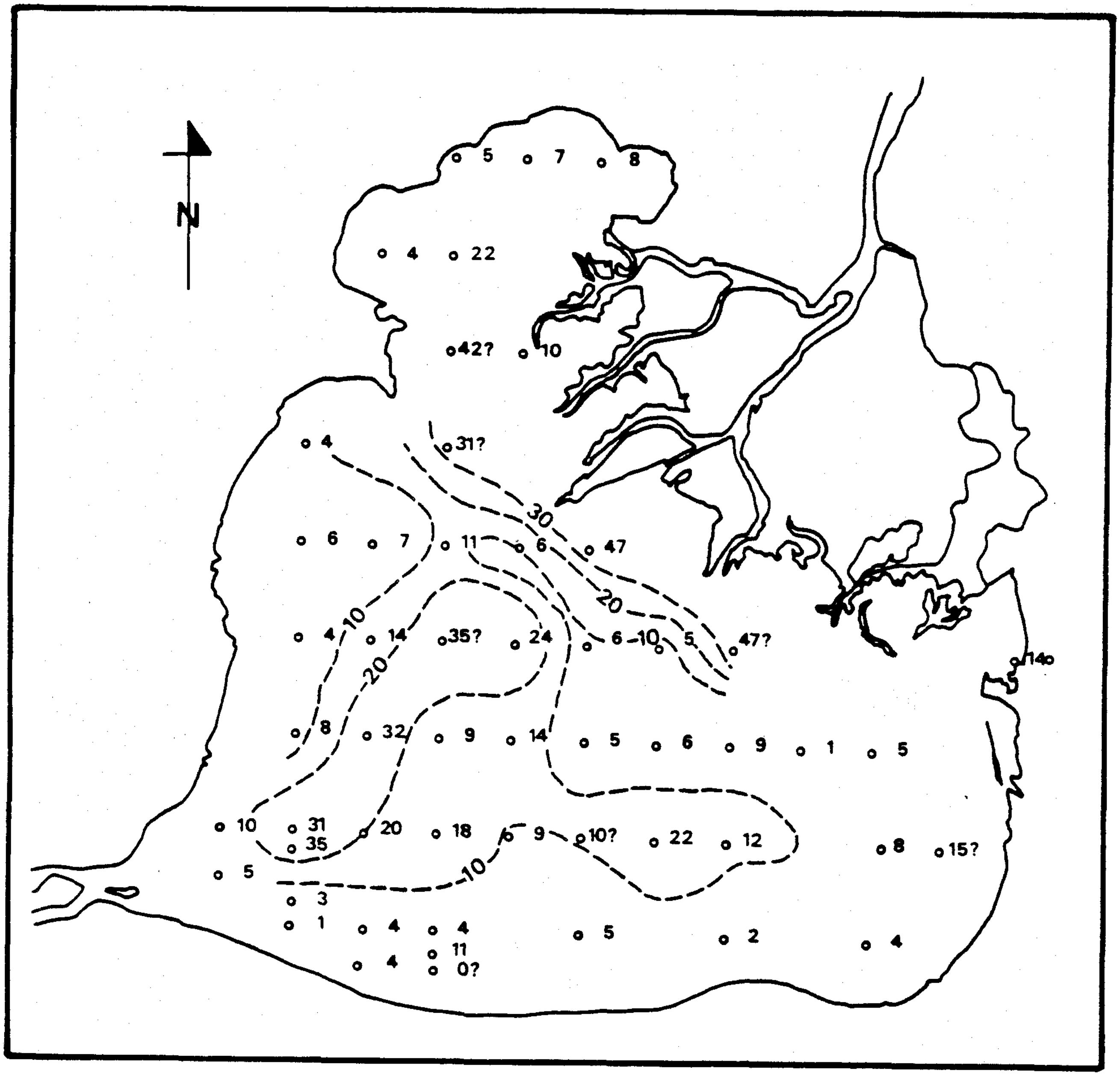

FIGURE VIII-2. Thickness of modern sediment (cm).

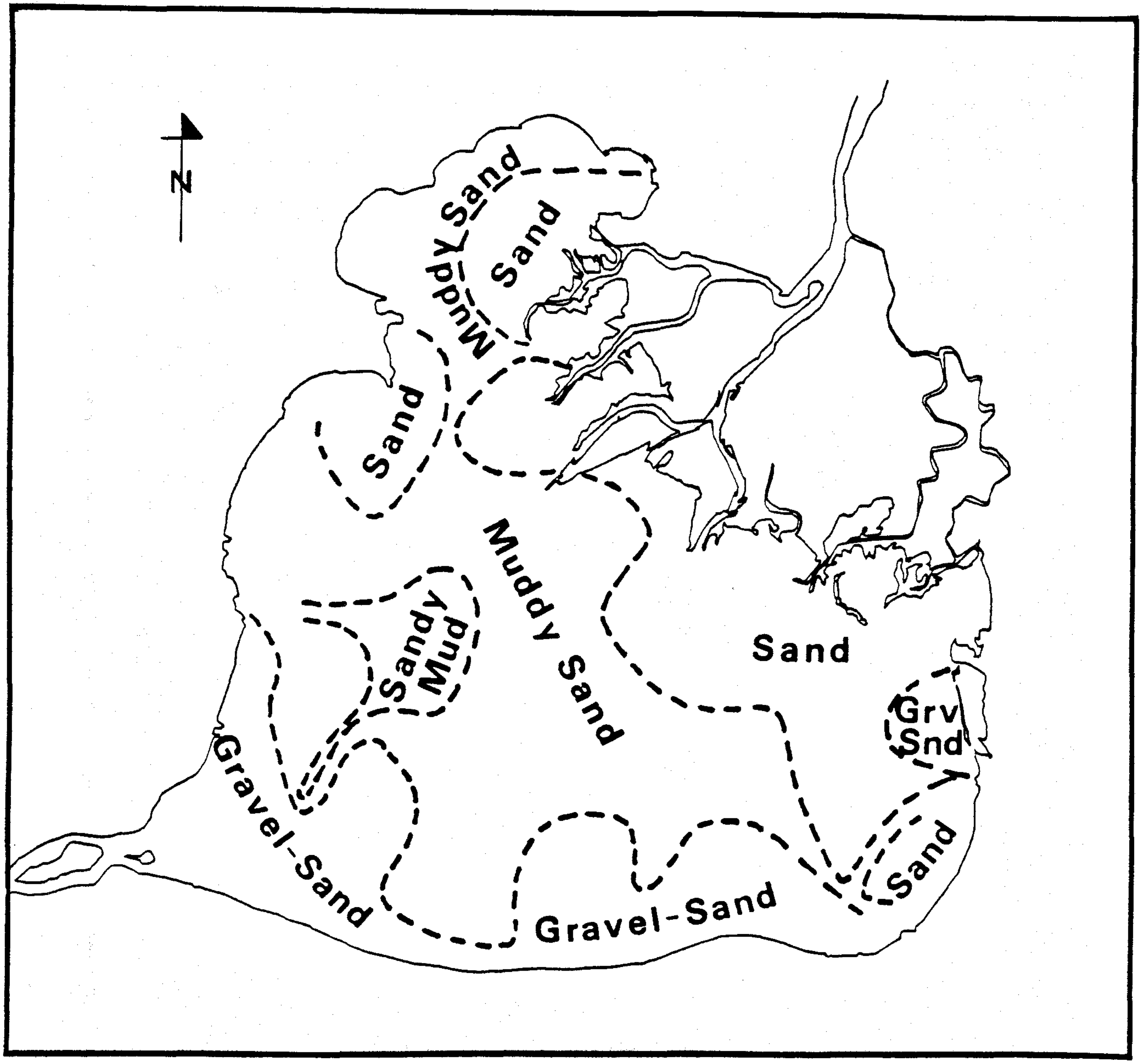

FIGURE VIII-3. Distribution of sediment types.

ii) Evidence of Historical Inputs of Contaminants

Organic Contaminants:

Distributions of hexachlorobenzene (HCB), octachlorostyrene (OCS), polychlorinated biphenyls (PCBs), hexachlorobutadiene (HCBD), pentachlorobenzene (QCB) and total DDT plus degradation products in Lake St. Clair surficial sediments (0-1 cm) in 1985 are shown in Figure VIII-4. The data were derived from the sampling pattern identified in Figure VIII-5. The highest contaminant concentrations were found near the centre of the lake in the region of greatest water depth, thickest layer of recent sediments over glacial clay, and greatest accumulation of fine-grained sediment. Some minor accumulation of contaminants also was found in Anchor Bay at the northern end of the lake. For the most part, the sediments in the rest of the lake were sandy, and contained low concentrations of organic contaminants. Although the mean contaminant concentrations were not particularly high compared to other areas in the Great Lakes Basin, with the possible exception of HCB, the maximum concentrations reached significant levels for many of the Sarnia-source contaminants (Table VIII-6).

In most, but not all, instances, higher concentrations of PCBs were found at greater depths in the sediments in 1985, corresponding qualitatively with the loading history of PCBs. The highest concentrations, 0.06 ppm, exceeded the Ontario Ministry of Environment (OMOE) Guidelines for Dredged Spoils for Open-Water Disposal and the IJC Guidelines for In-water Disposal of Dredged Materials of 0.05 ppm. However, these concentrations did not cause the lake to be classified as "polluted" by U.S.EPA Pollutional Classification Guidelines for Great Lakes Harbour Sediments where sediments containing greater than 10 ppm PCBs are classified as "polluted". PCBs were also found in the Cottrell Drain and at the mouth of the cutoff channel of the Clinton River at concentrations of 2.0 and 0.6 ppm, respectively. Up to 0.03 ppm PCBs were found in the Sydenham River, based on two samples.

Two localized areas of high HCB sediment concentrations were found in Lake St. Clair in 1985. One was in the central portion of the lake, and another was in the eastern section, northwest of the mouth of the Thames River. The maximum concentration found was 0.17 ppm. HCB was also detected in sediments of the Milk River (0.003 ppm), Marsac Creek (0.002 ppm), Swan Creek (0.002 ppm), Sydenham River (0.007 ppm) and the Thames River (0.001 ppm). No specific guidelines exist for HCB in sediments.

The highest concentration of OCS, 0.021 ppm, was found in the central portion of the lake. OCS was detected in sediments of the Sydenham River (0.001 ppm), but information on OCS in sediments of U.S. tributaries is not available. No specific guidelines exist for OCS in sediments.

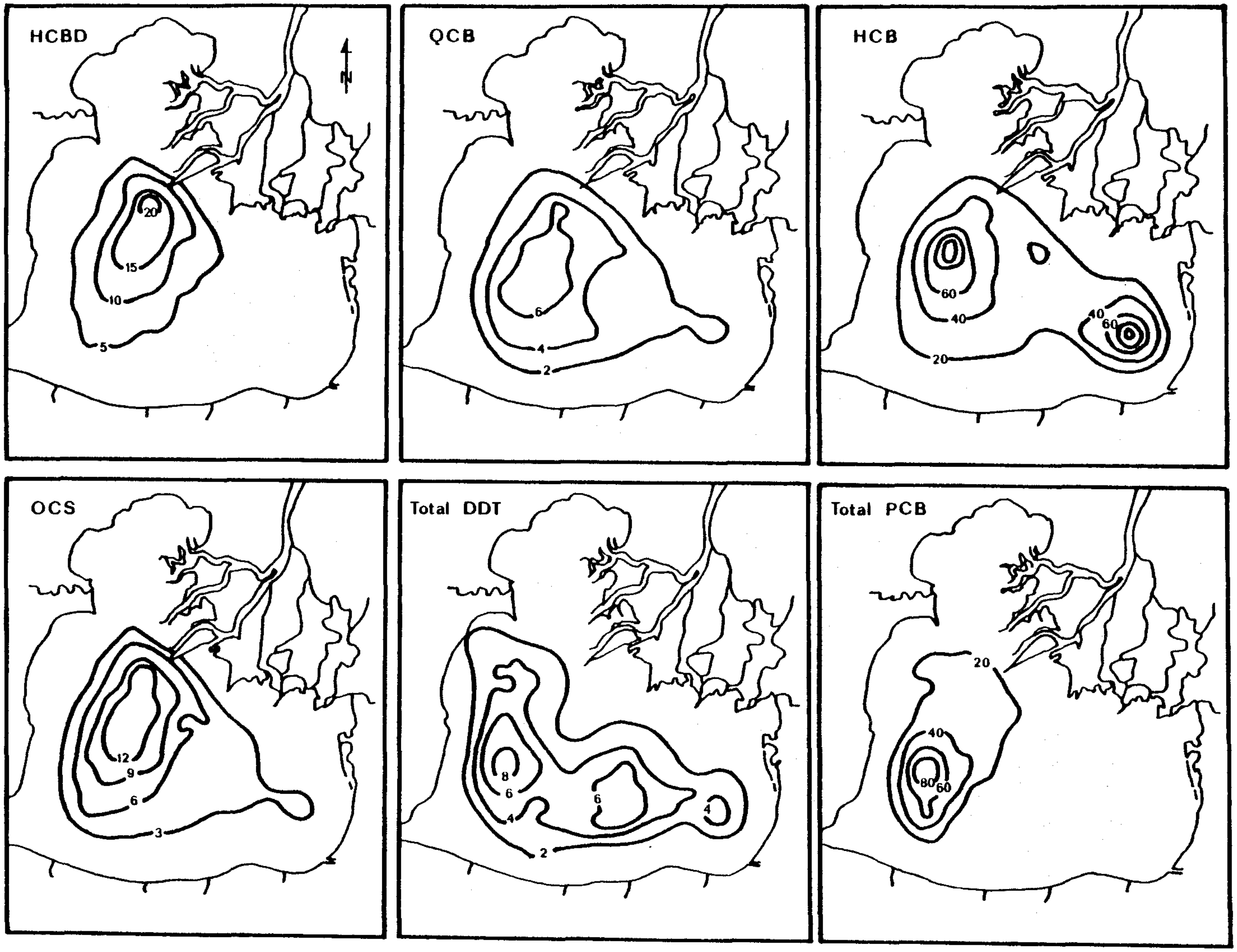

FIGURE VIII-4. Distribution of contaminants in Lake St. Clair surficial sediments (mg/kg).

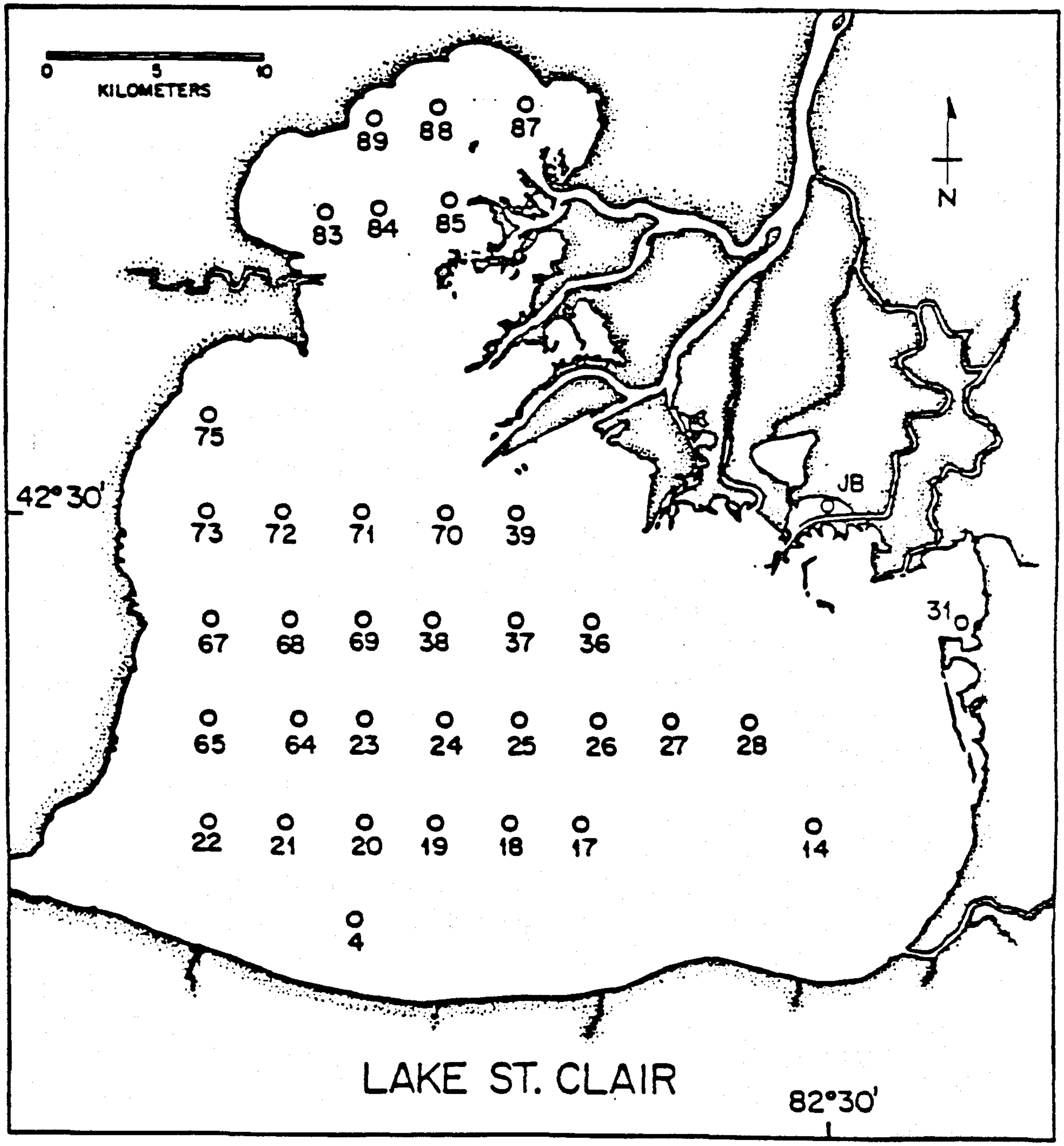

FIGURE VIII-5. 1985 Lake St. Clair sediment core stations.

TABLE VIII-6

Chlorinated organic compounds in surficial (0-1 cm) sediments of Lake St. Clair (ug/kg).

Compound	Range	Mean
Hexachlorobenzene (HCB)	0.4-170	32
Octachlorostyrene (OCS)	ND-21	4.8
PCBs	ND-21	19
Hexachlorobutadiene (HCBD)	ND-32	5.4
Pentachlorobenzene (QCB)	ND-8.7	3.2
Total Trichlorobenzene (TCB)	ND-28	4.3
Total Tetrachlorobenzene (TeCB)	ND-20	3.7
Total DDT and metabolites (SDDT)	ND-12	3.8

Information on PAHs in Lake St. Clair sediments or in Canadian tributaries was not available. In U.S. tributaries, PAHs were found in surficial sediments at concentrations ranging from 0.4 to 14.3 ppm. The highest concentrations were found in the Milk River (14.3 ppm), Cotrell Drain (13.8 ppm), Clinton River (12.1 ppm) and Frog Creek (10.7 ppm). No specific guidelines exist for PAHs in sediments.

Cyanide of a concentration up to 0.7 ppm was found in the Clinton River sediments. In Lake St. Clair sediments, three samples near the southeast shore and one sample south of the Clinton River were reported to contain 0.5 to 0.8 ppm cyanide, although these values were reported to be below the analytical criterion of detection. These concentrations exceed the OMOE and IJC Guidelines of 0.1 ppm, and cause a classification of "heavily polluted" by U.S.EPA classification guidelines. Information on cyanide in Canadian tributaries was not available.

High concentrations of oil and grease (up to 3,700 ppm) were also found in the Clinton River. This concentration exceeds the OMOE and IJC Guideline of 1,500 ppm, and causes a classification of "heavily polluted" by U.S.EPA Classification Guidelines. Of 45 stations sampled in Lake St. Clair in 1985, the sediments in only 3 contained between 597 and 637 ppm oil and grease. The rest contained less than 343 ppm, causing a classification of "unpolluted" by U.S.EPA Classification Guidelines. Oil and grease results from 1984 indicated levels between 635 and 707 ppm for Canadian tributaries. Somewhat elevated levels were determined from 1985 samples, with a peak of 3,131 ppm obtained from Sydenham River sediments. Concentrations from the Belle and Thames Rivers and Pike Creek were 433, 792 and 1,018 ppm, respectively.

Metal Contaminants:

Concentrations of metals measured in surficial (0-1 cm) layers of the sediment samples collected in 1985 (Figure VIII-5) indicated that some enrichment of cadmium and zinc has occurred over the average concentrations of metals in surficial sediments in Lake Huron (22). For Cd and Zn, 22 and 21 samples respectively, of 36 samples collected, had concentrations elevated above the Lake Huron averages of 1.4 and 62 ug/g respectively (Table VIII-7). The concentrations generally remained below OMOE, IJC and U.S.EPA guidelines, however, except for the region near to the mouth of the Clinton River. Sediments from the Clinton River were found to contain up to 6.3 ppm Cd and 430 ppm Zn, both of which exceed U.S. Classification Guidelines for heavily polluted sediments of 6 ppm and 200 ppm respectively. The Milk River sediments also exceeded the guidelines with 380 ppm Zn.

Concentrations of chromium, copper, nickel and lead were mostly below the Lake Huron averages, and below OMOE, IJC and U.S.EPA

TABLE VIII-7

Concentrations of metals (mg/kg) and total carbon (weight percent) in surficial sediment samples from Lake St. Clair.

Station	Interval	Bismuth	Total Carbon	Cadmium	Chromium	Copper	Nickel	Lead	Antimony	Zinc
LSTCL-85-04	0-1	.182	3.94	2.70	43.1	23.0	32.6	34.3	.180	84.9
LSTCL-85-14	0-1	.273	4.84	2.22	61.3	34.2	34.0	31.6	.254	130.
LSTCL-85-17	0-1	.208	4.42	3.71	54.2	26.4	40.8	31.0	.281	103.
LSTCL-85-18	0-1	.185	4.73	2.87	39.4	26.1	33.3	37.8	.182	90.7
LSTCL-85-19	0-1	.160	4.02	2.10	36.8	20.7	32.4	30.6	.126	81.8
LSTCL-85-20	0-1	.236	3.89	1.35*	34.3	23.5	29.3	35.2	.170	84.4
LSTCL-85-21	0-1	.241	4.36	2.34	30.1	24.6	25.7	40.0	.160	80.4
LSTCL-85-22	0-1	.147	3.75	1.93	39.7	19.1	33.2	13.6	.234	60.0
LSTCL-85-23	0-1	.258	4.74	2.11	39.2	32.2	33.5	41.1	.173	92.8
LSTCL-85-24	0-1	.242	4.86	2.23	41.5	29.5	32.0	46.0	.287	91.8
LSTCL-85-25	0-1	.179	3.27	2.60	38.2	20.4	30.3	28.8	.156	83.6
LSTCL-85-26	0-1	.176	4.61	3.25	41.4	23.3	32.0	29.3	.176	89.1
LSTCL-85-27	0-1	.162	3.78	1.86	38.0	20.1	32.0	29.8	.151	82.1
LSTCL-85-28	0-1	.0587	1.06	1.48*	17.7	5.10	14.7	12.2	.0707	41.4
LSTCL-85-31	0-1	.0616	2.96	1.48*	22.9	9.46	20.4	11.8	.0796	39.7
LSTCL-85-36	0-1	.130	-0	2.23	28.8	16.4	25.8	26.7	.132	71.7
LSTCL-85-37	0-1	.109	3.11	2.23	25.6	14.6	22.4	19.5	.0935	62.9
LSTCL-85-38	0-1	.146	4.76	2.06	24.9	24.5	23.1	32.0	.155	73.8
LSTCL-85-39	0-1	.0578	2.38	1.67*	16.3	9.08	15.2	8.42	.0921	41.5
LSTCL-85-64	0-1	.180	5.18	2.74	34.9	33.0	31.2	33.4	.211	89.1
LSTCL-85-65	0-1	.0921	3.30	1.16*	23.8	14.5	20.8	21.0	.173	62.0
LSTCL-85-67	0-1	.137	2.96	1.66*	22.6	12.9	22.9	25.2	.129	57.7
LSTCL-85-68	0-1	.168	3.62	1.66*	20.9	23.3	26.1	29.5	.230	78.2
LSTCL-85-69	0-1	.226	5.27	2.44	36.3	33.0	29.8	33.2	.236	90.7
LSTCL-85-70	0-1	.0687	2.75	2.25	17.4	10.1	15.2	20.9	.0689	47.6
LSTCL-85-71	0-1	.152	5.13	1.02*	23.4	20.6	21.9	24.5	.197	82.0
LSTCL-85-72	0-1	.0921	2.48	1.22*	18.7	11.2	18.8	11.4	.122	47.4
LSTCL-85-73	0-1	.0644	.970	1.39*	18.2	6.86	14.7	12.7	.0645	38.0
LSTCL-85-75	0-1	.0734	.965	1.23*	18.4	8.69	15.9	17.5	.0652	50.4
LSTCL-85-83	0-1	.119	1.76	1.48*	21.0	10.3	17.4	13.0	.0858	41.8
LSTCL-85-84	0-1	.126	3.45	2.38	21.1	13.8	18.8	17.4	.148	55.7
LSTCL-85-85	0-1	.0382	1.27	1.66*	16.3	5.11	9.74	-.525*	.0481	31.8
LSTCL-85-87	0-1	.114	2.87	3.04	18.9	14.0	19.2	13.6	.138	84.7
LSTCL-85-88	0-1	.122	2.96	2.20	24.1	13.8	19.5	16.5	.162	57.0
LSTCL-85-89	0-1	.131	2.32	2.29	24.9	12.1	18.9	14.4	.144	49.1
LSTCL-85-JB	0-1	.125	4.89	1.36*	22.9	15.1	19.6	32.6	.110	69.7

* Below limit of detection
-0 = No data

Guidelines, except for an area near to the mouth of the Clinton River. The distribution of the metals in Lake St. Clair sediments did, however, indicate greater concentrations in the central, south and southeast areas than in the north and west areas. Concentrations of lead and copper in the Clinton and Milk Rivers, and of Ni in the Clinton River exceeded the OMOE and IJC Guidelines, and cause a classification of "heavily polluted" according to U.S.EPA Classification Guidelines.

Mercury (Hg) enrichment in the surface sediments was confined to central Lake St. Clair, where up to 1.2 ug/g dry weight was found. By comparison, surficial sediments in Lake Huron contain an average of 0.22 ug/g (22). Except for the central area, most of Lake St. Clair surficial sediments contained less than 0.3 ug Hg/g, the value for OMOE and IJC Guidelines. The concentration profiles of Hg in at least three cores in 1985 indicated lower concentrations of Hg at the surface of the cores than at a depth of 5-6 cm, thereby implying the deposition of less contaminated recent material. The background concentrations deep in the core, however, were less than 0.1 ug Hg/g. Concentrations of Hg in Clinton River sediments were found up to 0.7 ppm, exceeding the OMOE and IJC Guidelines, but not U.S.EPA Classification Guidelines for "polluted" sediments.

The depth-integrated concentrations of metals in cores from the same samples as above were generally similar to those in the surficial sections, except for significantly greater concentrations of Cd in the composited samples (Table VIII-8). Using the guidelines for OMOE evaluations of dredging projects for sediment contaminated by metals, which are roughly equivalent to U.S.EPA guidelines for moderately polluted sediments (22), the guidelines were exceeded in 100%, 75%, 36% and 8% of the cores for Cd, Cr, Ni and Cu respectively.

In a separate study of surficial sediments conducted in 1985 in which sampling sites were selected specifically to collect fine-grained sediments capable of supporting mayfly (Hexagenia) nymphs, sediment at only 2 of the 45 stations were heavily polluted with mercury. Sediments at 2-9 (4-20%) of the stations were moderately polluted with nickel, copper, chromium and zinc. Five to 10 (11-22%) of the stations sampled contained mercury, PCBs or copper in excess of OMOE guidelines for contaminated sediments. Concentrations of contaminants were generally highest in sediments at stations near L'anse Creuse Bay offshore of the Clinton River Cutoff Canal. A 1984-85 study of Canadian tributary mouths indicated that Provincial dredging guidelines were exceeded at a number of tributaries for chromium, copper, iron and nickel. An assessment of heavy metal concentrations measured on suspended solids (RSP) indicated a higher frequency of guideline exceedence.

TABLE VIII-8

Concentrations of metals (mg/L) in composited sediment samples from Lake St. Clair.

Station	Bismuth	Calcium	Cadmium	Chromium	Copper	Iron	Magnesium	Manganese	Nickel	Lead	Antimony	Zinc
LSTCL-85-04	.231	48500.	3.11	47.0	22.7	32100.	20100.	428.	32.8	24.3	.149	80.8
LSTCL-85-14	.194	47000.	2.83	42.8	24.3	29300.	15200.	392.	31.2	24.2	.174	84.9
LSTCL-85-17	.166	49500.	4.35	34.1	19.1	23500.	25700.	366.	25.0	17.7	.151	67.1
LSTCL-85-18	.180	54800.	4.19	31.7	17.4	22400.	24800.	367.	24.5	19.4	.168	62.9
LSTCL-85-19	.150	67300.	2.56	29.5	16.5	23800.	25500.	400.	24.2	17.4	.161	60.6
LSTCL-85-20	.193	47200.	4.10	33.1	16.5	23900.	25100.	348.	23.8	18.6	.172	63.0
LSTCL-85-21	.173	42000.	3.45	30.2	19.1	22900.	28100.	366.	25.0	19.3	.155	60.4
LSTCL-85-22	.179	63400.	3.46	33.0	19.1	25000.	20700.	300.	25.6	14.9	.193	62.8
LSTCL-85-23	.175	64600.	3.72	29.5	22.6	23500.	29300.	339.	28.1	23.4	.165	67.1
LSTCL-85-24	.226	57200.	4.63	30.7	20.9	23800.	27200.	347.	29.6	23.0	.140	69.5
LSTCL-85-25	.186	54700.	3.91	33.0	21.7	23800.	25500.	353.	27.7	22.6	.146	71.7
LSTCL-85-26	.132	62200.	4.35	28.1	15.6	22300.	23800.	359.	25.6	10.5	.164	56.1
LSTCL-85-27	.148	64700.	6.15	31.6	18.2	22600.	24000.	373.	25.0	18.6	.108	62.8
LSTCL-85-28	.158	71000.	2.74	40.5	21.7	33000.	15900.	446.	30.2	18.6	.121	71.6
LSTCL-85-31	.0906	37000.	3.01	14.8	6.88	12600.	13100.	260.	13.3	6.24*	.0789	31.7
LSTCL-85-36	.133	24500.	4.00	23.4	13.9	15600.	21900.	234.	18.8	20.2	.104	49.5
LSTCL-85-37	.172	50700.	4.43	35.0	18.2	24400.	22500.	332.	27.8	18.9	.135	62.5
LSTCL-85-38	.173	59800.	4.00	26.0	28.8	19000.	30100.	274.	20.9	30.3	.187	76.2
LSTCL-85-39	.087	27000.	3.38	15.5	7.77	10500.	14300.	147.	13.3	9.69	.0625	36.2
LSTCL-85-64	.243	53400.	4.00	35.1	25.2	25400.	30000.	353.	27.7	27.1	.219	80.6
LSTCL-85-65	.193	49800.	3.28	37.5	19.1	26900.	20700.	347.	29.8	12.5	.220	69.5
LSTCL-85-67	.159	27000.	2.12	32.8	18.2	26300.	17900.	307.	24.0	14.5	.193	69.5
LSTCL-85-68	.148	42200.	3.92	28.2	15.6	23000.	20500.	294.	23.6	9.29	.152	60.7
LSTCL-85-69	.250	53700.	4.90	42.5	40.1	27800.	27700.	360.	29.8	34.6	.231	98.5
LSTCL-85-70	.106	49500.	3.72	21.7	22.5	16200.	20400.	213.	17.7	21.3	.130	62.6
LSTCL-85-71	.120	52000.	3.27	24.5	16.4	19200.	25700.	286.	19.6	14.5	.182	64.8
LSTCL-85-72	.116	21900.	3.45	25.7	13.8	20100.	17700.	239.	20.8	15.3	.161	55.9
LSTCL-85-73	.144	33300.	4.00	28.8	13.9	23500.	13200.	293.	24.2	12.5	.133	51.6
LSTCL-85-75	.135	34500.	2.92	23.6	13.6	20200.	13800.	306.	20.9	12.1	.0750	51.6
LSTCL-85-83	.179	20700.	2.56	39.3	18.2	27700.	14500.	399.	29.7	12.1	.0952	56.0
LSTCL-85-84	.116	37200.	3.47	18.1	13.9	14800.	23000.	194.	18.3	12.1	.119	60.8
LSTCL-85-85	.0822	14400.	2.11	11.0	5.12	8590.	9710.	120.	10.1	4.0*	.0407	29.4
LSTCL-85-87	.167	35800.	4.36	28.8	16.5	21100.	20000.	240.	22.4	13.7	.206	62.8
LSTCL-85-88	.116	36500.	4.65	25.2	14.5	18100.	16200.	237.	21.6	13.5	.087	61.9
LSTCL-85-89	.221	29600.	3.20	31.3	15.7	21200.	11900.	281.	23.0	32.8	.173	58.5
LSTCL-85-JB	.102	20800.	3.56	17.6	10.4	11400.	10500.	134.	15.8	19.0	.0887	47.4

* Below limit of detection

Phosphorus Enrichment:

Total phosphorus concentrations in surficial sediments were higher in three discrete areas during the 1983 survey: the mouth of the cutoff channel of the Clinton river, the mouth of the Thames River and the south-central portion of the lake. Concentrations were below OMOE and IJC Guidelines (1,000 ppm), but are classified as either "moderately polluted" (420-650 ppm) or "heavily polluted" (>650 ppm) by U.S.EPA Classification Guidelines. In tributaries, the highest concentrations were found in the Clinton River (3,100 ppm), which exceeded all relevant guidelines.

iii) Evidence of Current Inputs of Contaminants

In sediment cores taken in 1985 from Lake St. Clair, PCBs, DDT and OCS exhibit higher concentrations deeper in the sediment than at the surface. Reduced surface concentrations apparently reflect the decrease in loading of the chemicals which has likely occurred in recent years. Both HCB and HCBD concentrations, however, increased near the top of the cores. This suggests that loadings of these chemicals to Lake st. Clair were evidently not dropping, and may even had been increasing in 1985. These results are consistent with those of a 1985 study within the St. Clair River that showed HCB and HCBD (hexochlorobutadiene) concentrations in water to be elevated on the Canadian side of the mouth of the river (7).

Studies of sediments from the St. Clair River have shown that the ratios of HCB to OCS are useful for tracking the source of contaminants in that river (23). The HCB/OCS and HCB/QCB ratios were 1.3 and 4.0, respectively, for sediments near the Scott Road Landfill, a site which contains waste byproducts from Dow's early production of chlorine and chlorinated solvents. The HCB/OCS and HCB/QCB ratios in sediments just below Dow's outfall and where nonaqueous wastes have leaked into the river were 16 and 23 respectively. In sediment cores from the central area of Lake St. Clair in 1985, the ratio of HCB/OCS changed from 2 lower in the core to 9 at the surface. Similarly the HCB/QCB ratio increased from 4 near the bottom to 20 near the surface. These trends were thus consistent with decreasing waste losses from the Scott Road Landfill and an increase in the relative importance of Dow's current effluent discharge and waste losses from the plant site.

Localized Hot Spots of In-Place Pollutants:

A survey of metal contaminants in surficial sediments of Lake St. Clair conducted in 1983 included sampling sites closer to the nearshore areas than were the sites in the 1985 survey (24). In 1983, near the Cutoff Canal of the Clinton River, relatively elevated concentrations of Cu, Zn, Ni, Cd, Cr, and Pb were observed. Similar concentrations were also observed in the

Chenal Ecarte near Mitchell Bay. Distributions and concentrations of Cu, Zn, Pb and Cr across Lake St. Clair were similar to the findings of the 1985 survey, the nickel and cadmium concentrations were about half of those reported for 1985 sediments. The reason for this discrepancy has not been defined.

iv) Sediment Transport

Due to the strong hydraulic circulations, sediments from either tributary sources or from resuspension during severe storms are generally transported considerable distances, on the order of several km from their origin, before they either deposit to the lake bed or enter the outflow. Besides direct sediment transport by the lake circulation, it is possible that sediments are transported from nearshore zones to the open lake depositional basins by gravity currents associated with heavier turbid water. A thin layer of more turbid water was observed near the bottom at one open lake observation site. Evidence supporting this method of sediment transport is seen in the sediment concentration contours of zinc, copper and organic carbon, which indicate a source of these parameters at the mouth of the Thames River.

v) Sediment Burial

Since only 30 cm, at most, of sediment has accumulated in Lake St. Clair in post-glacial times, the lake must be considered as nearly nondepositional. However, the isotopic studies of bottom sediments (25) suggest that the burrowing activities of such organisms as Oligochaete worms can mix newly deposited sediment to an average depth of around 5 cm. At that depth the sediment could be buried for long periods of time. Mass budget studies of various tracers indicate residence time of sediments ranging from 3 to 6 years with a mean of 4 +/- 1 year. In the contaminant modeling studies, the burial process was quantified at a rate of 0.1 cm/yr throughout the lake. However, it should be noted that this burial rate inferred from the modeling studies leads to a sediment accumulation which is about two orders of magnitude too large. On the other hand, it is possible that precultural rates of burial were much less than the present rates of burial.

vi) Sediment Residence Time

Two sediment residence times are of concern: 1) the residence time of newly suspended or tributary input sediment in the water column, and 2) the sediment residence times of deposited sediments in the lake. Estimates of the time during which contaminants bound to sediments could exchange with the water column are based on measured and inferred settling rates of suspended particles in Lake St. Clair. The settling velocities of the fine-sized components of suspended sediment which presumably originate from nearby deposits range from 2 to 5 m/d, but are mainly about 4 m/d. Thus once suspended, particles remain in suspension for somewhat less than a day before being deposited. This is probably a maximum residence time in the water column since the particles were separated before analysis. Flocculation of particles could decrease the residence time of particles to several hours. This notion is supported by the application of the simple sediment model to five time series of suspended sediments, neglecting horizontal transport. The mean settling velocity inferred from the model was 21 m/d.

An approximate residence time for deposited sediments may be estimated from the strength of the hydraulic flow and the settling time. If, for example, fine sediment particles are resuspended for 8 hours on the average, then they would be transported by the main hydraulic flow about 2 km towards the outflow before being deposited as the storm event subsides. For particles deposited in the depositional basin, at least 12 storm events would be required to move them a distance of 20 km to the outflow area. Because the physical measurements of suspended sediments were unable to distinguish between local resuspension in deep water and the transport by the lake circulation from shallower areas, it is impossible to estimate the number of storms per year capable of resuspending fine sediments in the deeper zones of the lake. It is probably safe to say that there would be at least two storms per year of sufficient strength to initiate sediment resuspension in the deeper area. Therefore, one might conclude that strongly adsorbed contaminants would take about 6 years to move to the outflow area.

There are several processes which could lengthen this residence time. As the sediments travel towards the outflow, there would be a progressively shorter wind fetch. Consequently, the wave energy available for resuspension would decrease towards the outflow region in the prevailing wind direction. This finding was supported by the wave, wind and sediment data of Hamblin *et al*., (26) who showed that suspended sediment levels are high in the Detroit River inflow area only during major storms from the northeast. Those storms which are from the prevailing wind direction do not result in appreciable export of suspended sediment from the lake.

The one-dimensional bottom sediment model of Robbins and Oliver, (27) shows erosion of sediment becomes progressively more difficult as erosion proceeds because of compaction. Therefore, while there may be several storms per year capable of initiating sediment resuspension, it is possible that major storms occurring only once in 20 years or even 100 years can erode appreciable amounts of bottom sediments.

Due to the many uncertainties at this time in the understanding of the physical processes involved in estimating the residence time for strongly attached contaminants on fine sediment particles, estimates of the residence times can be better achieved through budget methods.

Residence times for bottom sediments in Lake St. Clair based on long term budgets of radioactive tracers, mercury and various organic contaminants are given in Table VIII-9. Residence times range from 3 to 6.2 years with a mean of 4 +/- 1 years. Some of these estimates were based on the assumption that there is no exchange with the overlying water during resuspension events.

TABLE VIII-9

Sediment reservoir residence times inferred from radionuclide storage as of 1985 and changes in mean contaminant levels from 1970 to 1974 (25).

Constituent	Residence Time(yr)
Cesium-137	6.0
Excess lead-210	3.0
Mercury	4.0
DDE	3.6
TDE	4.6
DDT	2.9
Total PCBs	6.2
Mean	4+/-1

B. SPECIFIC CONCERNS

A summary of specific concerns for Lake St. Clair, based on the following discussion may be found in Table VIII-10. Included are the specific concerns, the use impairments prompting the concerns, the media affected, and the geographic scope of the use impairment.

1. Conventional Pollutants

Due to the agricultural base of the Lake St. Clair geographic area's counties, the nonpoint source pollutants of greatest concern are suspended sediments, nutrients and pesticides. These concerns were documented in 1985 through the small watershed assessment process (28). These pollutants can impair the use of Lake St. Clair area resources for drinking water supplies, fisheries and wildlife, recreation, industrial shipping and agriculture.

Nutrients and Eutrophication

Nonpoint source water quality problems are aggravated or pronounced by variations in stream-flow. During high flow periods, most surface waters display their poorest quality, with significant increases in biological oxygen demand, nutrients, pesticides and sediments from nonpoint sources. When low flows occur, the nonpoint source material deposited during high flow events have an impact because they are no longer diluted. Scouring and the deposition of sediments is also a significant nonpoint source impact. Both water quality and water quantity are therefore important to consider in devising control and management plans. The input of relatively clean, low nutrient water from Lake Huron via the St. Clair River, and the short flushing time of Lake St. Clair has prevented nutrient concentrations from increasing and has kept eutrophication to a minimum.

Although phosphorus concentrations in Lake St. Clair per se do not appear to be a problem, the lake basin does contribute phosphorus to the water which enters Lake Erie via the Detroit River. The Water Quality Agreement specifically calls for "improved measurement of tributary loadings to the Lower Lakes for the purpose of providing improved nonpoint source loading estimates". Because tributary loadings of nutrients have been shown to exceed those from atmospheric or point sources, accurate tributary loading data are important to identify total loadings from the lake basin. Michigan and Ontario have target nonpoint source loadings of phosphorus to Lake Erie to meet as part of their phosphorus loading reduction program, and the contribution from the Lake St. Clair basin may be significant.

TABLE VIII-10

Specific concerns in Lake St. Clair, uses impaired, media affected, and geographic scope of the perceived problem.

CONCERN	POTENTIAL USE IMPAIRMENT	MEDIA	GEOGRAPHIC SCOPE
Phosphorus	use associated with eutrophication of Lake Erie	water	tributaries
Pesticides	potential reduction of plant productivity	water	wetlands
	toxicity to benthic community	sediments	tributaries
Oil and grease	toxicity to benthic community	sediments	whole lake
Heavy metals	toxicity to biota	sediments water	tributaries
Mercury	toxicity to biota	sediments	whole lake
	human health hazard (when consumed)	fish	whole lake
PCBs	human health hazard (when consumed)	fish ducks	whole lake Walpole Island
	toxicity to benthic community	sediments	tributaries
PAHs	human health hazard	sediments	tributaries
Phthalate esters	human health hazard	sediments	tributaries
Habitat alterations	lowered wildlife production	biota sediments water	wetlands

Beach Closings

In 1986, there were eight U.S. bathing beaches on Lake St. Clair in Macomb and Wayne counties (29). All were monitored for water quality, and none were temporarily closed due to water quality problems. This issue does not appear to be a problem.

Aesthetics

In the nearshore regions, the water is brownish-green. Over the navigation channel the water colour tends to cloudy-green, but the water is clear green near the centre of the lake away from the navigation channel. Noxious odors and floating mats of algae are generally not present. Mid-summer water transparency ranges from 0.6 m near the shore to about 2.6 m near the open lake. Aesthetics is therefore not a major issue concerning Lake St. Clair.

2. Toxic Organics and Heavy Metals

Ambient Waters

For compounds that persist and bioaccumulate, loadings into the Great Lakes are of concern regardless of the concentrations at which the compounds are delivered. Even when loadings occur at concentrations below detection limits, such compounds can bioaccumulate and exert significant ecosystem effects. Such compounds have received extensive study within the Great Lakes. Most of the current generation of pesticides have short environmental half-lives and have little tendency to bioaccumulate. They are present, however, at much higher concentrations than most of the persistent organics (30). Their ecological effects have received very little study in comparison with studies of persistent organics.

The most commonly applied agricultural pesticides were the herbicides atrazine, alachlor, metolachlor and cyanazine. Data and tables have been provided (5,31). Maximum measured concentrations of these pesticides in the Thames and Clinton Rivers in 1985 and unit area loads from the watershed to these rivers are summarized in Table VIII-1. The 1985 Thames River estimated loading rates for atrazine, metolachlor and alachlor were 6,892 kg (16 g/ha), 2,875 kg (7 g/ha), and 299 kg (0.7 g/ha) respectively (Table VIII-1). Atrazine was detected in 93% of all samples. Alachlor, which was banned in 1985, was detected in approximately 15% of the samples collected in 1984 to 1985. During April through August, 1985, the Clinton River estimated loading rates for atrazine, metolachlor, alachlor, and cyanazine were 52.2 kg (0.28 g/ha), 1.3 kg (0.1 g/ha), 14.2 kg (0.08 g/ha), and 9.1 kg (0.05 g/ha) respectively. The unit area loadings of atrazine and metolachlor from the Thames River watershed were therefore approximately 1 to 2 orders of magnitude greater than those from the Clinton River watershed.

In general, the 1985 concentrations of pesticides observed in the Michigan tributaries would have little effect on fish or aquatic invertebrates, but could affect photosynthetic rates of some algae and rooted aquatic plants. However, the 1985 pesticide loads for the Clinton River is very likely to be significantly less than the average load for this river, due to the near absence of runoff events following pesticide applications in this watershed.

Biota

In edible portions of Lake St. Clair fish, PCBs have declined generally and with the exception of carp, channel catfish and muskellunge, all species have not exceeded the Health and Welfare Canada guideline of 2.0 ppm. Mean PCB concentrations in muskellunge have increased since 1980 (32).

Measurements of DDT in Lake St. Clair fish have not exceeded the Health and Welfare Canada guideline of 5 ppm in any of the 13 species tested. As with the PCB data, highest concentrations were detected in channel catfish and carp, and they were lowest in yellow perch.

Concentrations of HCB and OCS in channel catfish from Lake St. Clair are greater than those from southern Lake Huron. In carp, OCS concentrations are greater in fish from Lake St. Clair than in those from southern Lake Huron. Chlorinated dioxins and dibenzofurans have been detected in Lake St. Clair channel catfish and carp, but not in walleye.

A survey of contaminants in spottail shiners from 1977 through 1986 indicated that the highest contaminant burdens were associated with the south channel of the St. Clair River. Shiners from Mitchell Bay were less impacted, and those from the southeastern part of the lake near the mouth of the Thames River and from the southern part of the lake near the mouth of the Detroit River were not measurably impacted by contaminant loadings from the St. Clair River. Concentrations of PCBs, HCB, OCS, DDT and Chlordane in spottails from Lake St. Clair were generally similar to those in southern Lake Huron, except for elevated levels of PCBs and HCB in fish from the South Channel.

Current mean concentrations of mercury in walleye, northern pike and carp fillets are less than 25% and yellow perch and white bass less than 20% of 1970 levels (33). Mercury concentrations in muskellunge, however, did not decline between 1975 and 1985 (32).

Despite declining concentrations of contaminants in the fish, a Public Health Fish Consumption Advisory exists for both U.S. and Canadian waters. As of 1987, the Advisory included "No Consumption" for largemouth bass over 14", muskellunge and sturgeon. "Restricted consumption" of no more than one meal per week for the general population was advised for larger specimens of walleye, white bass, smallmouth bass, yellow perch, carp, rock bass, black crappie, largemouth bass, bluegill, pumpkinseed, freshwater drum, carp-sucker, brown bullhead, catfish and northern pike. Nursing mothers, pregnant women, women who expect to bear children and children age 15 and under were advised to not eat the fish listed because of the potential for effects of contaminants on the infant or child.

For 1988, Michigan will retain the advisory as issued for 1987. Ontario, however, will reduce the advisory such that no "No Consumption" category will be issued. The advise toward pregnant mothers and their children will still remain in effect.

A comparison of the abundance of mayfly (Hexagenia) nymphs in the UGLCC Study area where visible oil did and did not occur in the sediments indicated substantially lower densities ($61/m^2$) in the presence of visible oil than in the absence of visible oil ($224/m^2$).

The annual production of Hexagenia nymphs was measured in the UGLCC Study area along with sediment concentrations of oil, cyanide, Hg, Cd, Cr, Cu, Ni, Pb and Zn. Production averaged 2,086 mg dry wt./m^2/yr at 3 locations where sediment levels of contaminants were not in excess of guidelines established by the U.S. and Canada for distinguishing polluted sediments. Elsewhere in the study area, the guidelines for polluted sediments were exceeded by as many as 7 contaminants at a single location, and production averaged only 364 mg dry wt./m^2/yr. In Lake St. Clair, where production was highest, only Hg exceeded the guideline.

Wildfowl:

Recent analyses (34) have indicated elevated levels of pentachlorobenzene (QCB), PCBs, HCB and OCS in duck populations resident in the St. Clair River marshes near Walpole Island. Mean OCS concentrations of 115 ppb and PCB concentrations ranging from 1.5 to 4 ppb were found in nonmigratory mallards in samples of breast and liver tissue. At present no wildfowl consumptions advisories exist for HCB, OCS and QCB. While a comparison of the PCB concentrations with the Wisconsin guidelines (35) of 3 ppm do not indicate a major health concern and consequent loss of use of the wetland habitat, there is considerable evidence that organic compounds moving down the St. Clair River are being trapped within the wetland region. Wildfowl consumption advisories are being considered by the appropriate governmental agencies in the

Lake St. Clair region (Ontario Ministry of Natural Resources, Michigan Department of Natural Resources and Canadian Wildlife Service).

Sediments

Results of sediment surveys in Lake St. Clair that were conducted within the last few years indicate that some accumulation of contaminants has occurred in the deeper, thicker bottom sediments, but no particular areas or hot spots of highly contaminated sediments were located. The data showed that sediments in several tributaries to the lake contained much greater concentrations of pollutants than were found in the open lake deposits. Therefore, the areas requiring further attention for possible remedial actions were within the regions of tributary discharge.

In 1985, bottom sediments from 12 U.S. tributaries to Lake St. Clair were analyzed for UGLCCS parameters of concern and other contaminants. The data are presented in Table VIII-11 and summarized below.

i) Pesticides

DDT and its metabolites were found in 9 of the 12 tributary sediment samples. The maximum concentration was found in the Milk River (383 ug/kg). The p'p forms of DDT predominated, and DDT and DDE generally were more prevalent than DDD. The p'p forms were detected in 10% of sediment samples from the mouths of Ontario tributaries.

Other chloro-organic pesticides were also found in 9 of 12 tributary sediment samples. Gamma-chlordane was the pesticide most commonly found, ranging from 2 ug/kg in the Clinton Cutoff Canal to 196 ug/kg in Cottrell Drain. The sample from the Milk River contained the greatest number of pesticide compounds identified, including the only occurrence of Aldrin outside of the Detroit River tributaries. With exception of a single sample containing 2, 4-D from Pike Creek no other pesticides or herbicides were measured in bottom sediments from Ontario tributaries.

Hexachlorobenzene (HCB) was found in only 6 samples at levels of 1 to 7 ug/kg.

ii) Organic Contaminants

PCBs were found in 9 of 12 tributary samples with concentrations up to 1,974 ug/kg in the Cottrel Drain. Most of the PCB was found as aroclor 1254, although in the Cottrel Drain aroclor 1248 was dominant. Aroclor 1260 was found only from the Milk River sediments.

TABLE VIII-11
Contaminants in Lake St. Clair tributary sediments (mg/kg), 1975.

	Location*											
Parameter	CCT-11	CCT-12	CCT-13A	CCT-14A	CCT-15	CCT-15A	CCT-16A	CCT-17	CCT-18A	CCT-19	CCT-20	CCT-21
Calcium	27000	30000	22000	24000	38000	36000	17000	17000	20000	31000	10000	5000
Magnesium	4400	4300	4200	4400	4500	4700	4100	4300	4200	4600	4500	3200
Sodium	170	120	100	150	170	170	190	220	230	130	100	100
Potassium	1400	700	200	1700	2000	1600	1400	4500	1900	2100	1400	200
Arsenic	9	7.5	1.6	7.5	6.5	9.5	3.4	4.9	5.3	6.7	5.3	1.3
Barium	150	46	11	69	93	150	64	120	94	130	66	10
Berylium	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1
Bismuth	9.5	11	11	12	11	10	8.8	25	25	0.7	0	0
Cadmium	2.2	1.1	0.3	1.9	1.3	6.3	0.2	0.2	0.5	0.2	0.4	0.2
Chromium	63	21	15	68	45	140	21	40	32	32	21	4.7
Cobalt	11	6	3.1	13	11	15	7.8	12	7.4	15	11	3
Copper	110	39	10	58	78	130	22	71	48	28	42	4.8
Lead	410	130	14	130	110	240	56	81	140	36	40	10
Manganese	400	260	110	610	460	670	350	350	270	550	310	47
Molybdenum	1.6	1.2	1	1.2	1.2	2.1	1.2	1.4	1.7	2.5	1.6	1
Nickel	51	20	10	83	40	100	31	37	19	43	29	6
Silver	2.6	0.3	0.3	1.2	1	3.5	0.3	0.6	1	0.4	0.3	0.3
Strontium	45	39	21	33	52	53	32	46	42	65	22	6.3
Vanadium	25	15	7.2	27	25	26	20	51	27	36	25	5.5
Zinc	380	150	34	220	190	430	140	140	170	110	100	19
Tin	15	6.6	4	6	4.5	11	4	4.9	5.5	4	4	4
Aluminum	12000	5000	2000	13000	14000	13000	9000	24000	11000	19000	12000	1800
Lithium	23	11	5	26	29	27	16	40	19	42	25	3.5
Selenium	1.1	0.4	0	0.7	0.6	0.6	0	0.3	0.4	0.3	0.6	0
Iron	24000	12000	4000	28000	24000	32000	16000	30000	18000	36000	20000	3000
Yttrium	9.7	5.8	2.2	11	11	11	7	13	8	13	11	2.2
Mercury		0.2	0.1	0.3	0.3	0.7	0.1	0.2	0.4	0.1	0.1	
COD	54000	14000	18000	35000	81000	38000	30000	51000	30000	33000	39000	11000
Oil and Grease	3290	2010	650	1230	2400	3700	650	650	2250	650	650	650
Ammonia		90	75	300	310	230	150	240	190	240	70	17
TKN		1300	800	6900	4300	2900	1700	3600	1700	1900	3100	770
Phosphorus		600	430	3000	1300	3100	2000	1600	1500	1100	820	220
Cyanide	0.1	0.1	0.1	0.2	0.4	0.7	0.1	0.3	0.3	0.1	0.3	0.1
Total Solids	45.85	55.45	77.13	34.01	29.12	41.1	53.2	40.1	44.4	45.1	37.4	65.5
Total Volatiles	8.07	6.41	0.74	7.67	8.37	7.8	4.7	7.3	8	4.6	6.9	1.8
Total PCBs (ug/kg)	198	1974	199	596	226	185		85	635	31		
Total PAHs "	14300		13800	800	1400	12100	3600	800	400	10700		
Total DDT "	383		271		87	30	146	72	8	33	25	
HCB "	3									2	2	
G. Chlordane	57	196	2	-	-	17	6		13	3	5	
DN-Butylphthalate	400	2000	200	4000	1600	-	200	2600	1900			
BIS(2-Ethylbenzyl) phthalate (ug/kg)	5600	4200	3000	3400	4400	16200	900	1200	10400			

*11-Milk River, bridge, 12-Cottrell drain, North Channel, 13a-Clinton River cutoff upstream, 14a-Ventre Beuf Drain/Black Creek, 15-Clinton River, 15a-Clinton River upstream, 16-Vase Creek upstream, 17-Salt River, at mouth, 18a-Frog Creek, upstream, 19-Marsac Creek 20-Swan Creek, mouth, 21-Unnamed trib., East of Swan Creek.

PAHs were found in 9 of the samples, with the maximum total PAHs being reported in sediments from the Milk River (14,300 ug/kg). Elevated concentrations were found also in the Cottrel Drain (13,800 ug/kg), Clinton River (12,100 ug/kg), and in Frog Creek (10,700 ug/kg). Most samples were dominated by 3-, 4- and 5-ring PAHs. Naphthalene was found only from the Clinton River. Cottrel Drain, Milk River and Frog creek had the highest number of individual PAH compounds with 11, 9 and 8 respectively.

Phthalate esters were found in 9 of 12 samples. Occurrences of all the four phthalate esters that were found throughout the UGLCC Study area were found in the Lake St. Clair tributary sediments, including the 4 highest concentrations of di-n-butyl phthalate (in sediments from the Ventre Beuf Drain/Black Creek, Salt River, Cottrel Drain and Frog Creek) and the only occurrences of diethyl phthalate in the UGLCC Study area. Bis(2-ethylhexyl)phthalate was found in 9 of 12 samples with concentrations up to 16,200 ug/kg in the Clinton River.

iii) Metals and Conventional Pollutants

Several tributary sediment samples contained concentrations of metals and conventional pollutants in excess of U.S.EPA Guidelines (22) for nonpolluted sediments. These guidelines, number of tributaries with exceedences of the guidelines, and the rivers with maximum concentration of each parameter are presented in Table VIII-12. Most of the maximum concentrations occurred in either the Clinton River or the Milk River. The Ventre Beuf Drain/Black Creek sediments contained elevated concentrations of the agricultural contaminants, ammonia, TKN and phosphorus.

3. Habitat Alterations

The delta marshes, estuaries, lagoons and channel wetlands that fringe the shores of Lake St. Clair in both Michigan and Ontario are among the most biologically productive areas in the Great Lakes system. Because they occur in the proximity of a densely populated, highly industrialized and intensively farmed region, the wetlands have suffered losses in both quality and quantity (36). The remaining wetlands perform many important hydrological and ecological functions, including providing habitat for fish, furbearers and waterfowl.

Although portions of the wetlands have been permanently lost or severely degraded, the prospects for future preservation of remaining wetlands and for at least partial rehabilitation of selected areas are reasonable good. Wetland legislation and other policies designed to protect the environment are in place or under consideration. A comprehensive discussion of the Lake St. Clair wetlands, including their ecological features, human

TABLE VIII-12

Exceedences of U.S. guidelines for heavily polluted sediments for metals and conventional pollutants in U.S. Lake St. Clair tributaries.

Parameter	Guideline	# of tribs with exceedences[a]	maximum measured concentration	River with maximum
Cd	6 mg/kg	1	6.3 mg/kg	Clinton
Cr	75 mg/kg	1	140 mg/kg	Clinton
Cu	50 mg/kg	4	130 mg/kg	Clinton
Pb	60 mg/kg	7	410 mg/kg	Milk
Mn	500 mg/kg	3	670 mg/kg	Clinton
Ni	50 mg/kg	3	100 mg/kg	Clinton
Ag	-	-	3.5 mg/kg	Clinton
Zn	200 mg/kg	3	430 mg/kg	Clinton
Se	0.8 mg/kg[b]	1	1.1 mg/kg	Milk
Fe	25,000 mg/kg	4	36,000 mg/kg	Marsac Creek
As	8 mg/kg	2	9.5 mg/kg	Clinton
Ba	60 mg/kg	9	150 mg/kg	Clinton
Bo	-	-	25 mg/kg	Frog Creek Salt River
COD	80,000 mg/kg	1	81,000 mg/kg	Clinton
O&G	2,000 mg/kg	5	3,700 mg/kg	Clinton
NH_4	200 mg/kg	6	330 mg/kg	Milk
TKN	2,000 mg/kg	6	6,900 mg/kg	Ventre Beuf Drain/Black Creek
P	650 mg/kg	9	3,100 mg/kg	Clinton
CN	0.25 mg/kg	5	0.7 mg/kg	Clinton
TVS	8 %	3	8.4 %	Clinton

[a] U.S.EPA Guidelines for the Pollutional Classification of Great Lakes Harbour Sediments (22).

[b] Lake Erie background concentration (22).

impacts, and management issues has been presented by Herdendorf, et al. (36), to which the reader is referred for details beyond the scope of the UGLCC Study.

C. SOURCES

1. Municipal Point Sources

Identification

In 1986 there were 18 major (flow > 3.7×10^3 m^3/d or 1.0 U.S. MGD) municipal wastewater treatment facilities and 29 minor municipal facilities discharging to the basin (37). Only four of these, however, discharged directly to Lake St. Clair. Several of the U.S plants discharged to the Clinton River, Michigan, and most of the Canadian plants discharged to the Sydenham and Thames Rivers, Ontario. Total flow from municipal sources was 559×10^3 m^3/d.

The major facilities were predominantly activated sludge systems with phosphorus removal, while the minor facilities were predominantly lagoon systems or trickling filter plants. All U.S. plants were served by separated sewer systems. Three of the larger Canadian municipalities have some combined sewer systems which represent varying percentages of the total serviced area in each municipality (Chatham, Wallaceburg, and London).

The largest urban centre, London (population 277,000), has 25% combined sewers. Chatham, population 36,000, and Wallaceburg, population 12,000, each have 37% of their sewer systems combined.

In the U.S., five major municipal waste water treatment plants (WWTP) were identified and selected for sampling: New Baltimore WWTP discharges directly to Lake St. Clair, while the WWTPs at Mt. Clemens, Pontiac, Rochester and Warren discharge to the Clinton River. Three waste water treatment plants in Canada were selected for study: The Belle River-Maidstone WWTP discharges directly to Lake St. Clair, the Chatham WWTP discharges to the Thames River, and the Wallaceburg WWTP discharges to the Sydenham River. The sources were sampled for the 18 UGLCC Study parameters plus additional conventional pollutants, metals and organic contaminants. One to six day surveys were conducted at each facility between October 1985 and November 1986.

Based on the study of municipal dischargers, of greatest concern were the Wallaceburg WWTP, the Mt. Clemens WWTP and the Warren WWTP. Trace organics, heavy metals, phenols, ammonia and phosphorus were the notable pollutants contributed by these plants. All three received industrial wastewaters as a significant portion of their influent.

Classification

In terms of effluent loading for the sources surveyed, the following facilities were considered to be major contributors of the parameters studied:

1. Wallaceburg WWTP: Total copper, total nickel, total iron, and ammonia-nitrogen.

2. Chatham WWTP: Chloride, ammonia-nitrogen, lead, total suspended solids, and oil and grease.

3. Warren WWTP: PCBs, HCB, cyanide, total cadmium, total chromium, total zinc, total nickel, total cobalt, chloride, phosphorus, total organic carbon, and BOD.

4. Mt. Clemens WWTP: PCBs, phenols, oil and grease, total lead, total mercury, total iron, phosphorus, ammonia-nitrogen, total suspended solids and BOD.

All sources were in compliance with applicable guidelines or site-specific limitations for the study parameters, except for the Mt. Clemens WWTP which exceeded the Great Lakes Water Quality Agreement effluent limitation for total phosphorus of 1.0 mg/L. However, the following sources were discharging elevated concentrations of contaminants which were not subject to site-specific effluent limitations, requirements or guidelines:

1. Wallaceburg WWTP: Total cadmium, total chromium, total copper, total nickel, and ammonia-nitrogen.

2. Mt. Clemens WWTP: PCBs, total phenols, total mercury.

3. Warren WWTP: PCBs.

The Warren WWTP and the Chatham WWTP, although classified as major sources of the UGLCC Study parameters, were operating efficiently and were discharging low concentrations of all parameters, except PCBs at the Warren WWTP. Their ranking as major contributors was due to their flows being considerably larger than most of the other sources. The municipal waste water treatment facilities at Belle River, New Baltimore, Rochester and Pontiac were considered to be minor contributors of the parameters studied.

Extent of Contributions to the Problems

A summary of the major municipal point source loadings of the UGLCCS parameters to Lake St. Clair is presented in Table VIII-13. Included is information on analytical detection limits, flows, average concentrations, loads, and percentage of total point source contribution for each facility for each parameter. Municipal point source contributions of immediate concern were identified:

TABLE VIII-13

UGLCCS study point source loadings of UGLCCS parameters[1] to Lake St. Clair by major contributors.

PARAMETER	MDL(s) (ug/L)	FACILITY	MICH/ ONT	OUTFALL NAME(S)	FLOW $10^3 m^3/d$	AVERAGE CONCENTRATION[2] (ug/L)	kg/d	% TOTAL POINT SOURCE CONTRIBUTION
Total PCBs	0.001	Mt. Clemens WWTP	M	Final effluent	13.3	0.54	0.002	78.5
	0.001	Warren WWTP	M	Final effluent	109	0.019	0.0073	21.5
						TOTAL	0.0093	100
Hexachloro-benzene	0.001	Warren WWTP	M	Final effluent	109	0.0059	0.00059	70.2
	0.020	Chatham WPCP	O	Final effluent	39.4	0.0051	0.00020	23.8
	0.00001	Mt. Clemens WWTP	M	Final effluent	13.3	0.0048	0.00005	6.0
						TOTAL	0.00084	100
Octachloro-styrene	0.000001	Mt. Clemens WWTP	M	Final effluent	13.3	0.000044	0.00000045	100
						TOTAL	0.00000045	100
Total Phenols	10	Mt. Clemens WWTP	M	Final effluent	13.3	77.0	1.03	59.5
	10	Pontiac WWTP	M	Final effluent	46.9	9.6	0.451	26.1
	10	New Baltimore WWTP	M	Final effluent	5.11	27.0	0.138	8.0
	1	Wallaceburg WPCP	O	Final effluent	7.88	0.37	0.030	6.4
						TOTAL	1.73	100
PAHs		Wallaceburg WPCP	O	Final effluent	7.88	0.46	0.0036	100
						TOTAL	0.0036	100
Total Cyanide[3]	5	Warren WWTP	M	Final effluent	109	7.0	0.761	80.0
	5	Mt. Clemens WWTP	M	Final effluent	13.3	8.0	0.11	11.6
	5	Rochester WWTP	M	Final effluent	8.7	5.0	0.0435	4.6
	5	New Baltimore WWTP	M	Final effluent	5.11	7.0	0.0358	3.8
						TOTAL	0.950	100

TABLE VIII-13. (cont'd 2)

PARAMETER	MDL(s) (ug/L)	FACILITY	MICH/ ONT	OUTFALL NAME(S)	FLOW $10^3 m^3/d$	AVERAGE CONCENTRATION[2] (ug/L)	kg/d	% TOTAL POINT SOURCE CONTRIBUTION
Total Mercury	0.0001	Mt. Clemens WWTP	M	Final effluent	13.3	0.878	0.009	70.3
	0.0001	Warren WWTP	M	Final effluent	109	0.027	0.0023	18.0
	0.025	Chatham WPCP	O	Final effluent	39.4	0.033	0.0013	10.2
	0.025	Wallaceburg WPCP	O	Final effluent	7.88	0.025	0.0002	1.5
						TOTAL	0.0128	100
Total Copper	5.0	Wallaceburg WPCP	O	Final effluent	7.88	311	2.45	58.5
	1.0	Warren WWTP	M	Final effluent	109	5.7	0.619	14.8
	1.0	Pontiac WWTP	M	Final effluent	46.9	8.6	0.404	9.6
	1.0	Mt. Clemens WWTP	M	Final effluent	13.3	29.9	0.400	9.5
	5.0	Chatham WPCP	O	Final effluent	39.4	3.6	0.147	3.5
						TOTAL	4.42	95.9
Total Nickel	4.0	Warren WWTP	M	Final effluent	109	28.4	3.09	51.0
	5.0	Wallaceburg WPCP	O	Final effluent	7.88	309	2.44	40.3
	5.0	Chatham WPCP	O	Final effluent	39.4	10.5	0.42	7.2
						TOTAL	5.95	98.3
Total Cobalt	0.001	Warren WWTP	M	Final effluent	109	1.8	0.195	97.5
	0.001	Mt. Clemens WWTP	M	Final effluent	13.3	0.29	0.0041	2.5
						TOTAL	0.1991	100

TABLE VIII-13. (cont'd 3)

PARAMETER	MDL(s) (ug/L)	FACILITY	MICH/ ONT	OUTFALL NAME(S)	FLOW $10^3 m^3/d$	AVERAGE CONCENTRATION[2] (ug/L)	kg/d	% TOTAL POINT SOURCE CONTRIBUTION
Oil and Grease	100	Chatham WPCP	O	Final effluent	39.4	2,090	82.2	41.9
	2,000	Mt. Clemens WWTP	M	Final effluent	13.3	3,610	48.0	24.5
	100	Wallaceburg WPCP	O	Final effluent	7.88	2,990	23.6	12.0
	100	Belle River WPCP	O	Final effluent	5.47	3,860	21.1	10.8
	2,000	Rochester WWTP	M	Final effluent	8.7	2,400	20.9	10.7
						TOTAL	196	100
Total Cadmium	0.2	Warren WWTP	M	Final effluent	109	0.6	0.0652	69.0
	5.0	Wallaceburg WPCP	O	Final effluent	7.88	2.52	0.0199	21.1
	0.2	Mt. Clemens WWTP	M	Final effluent	13.3	0.7	0.00933	9.9
						TOTAL	0.0944	100
Total Lead	5	Chatham WPCP	O	Final effluent	39.4	11.2	0.443	42.3
	1	Mt. Clemen WWTP	M	Final effluent	13.3	20.3	0.271	25.9
	1	Warren WWTP	M	Final effluent	108.6	1.5	0.163	15.5
	1	Pontiac WWTP	M	Final effluent	46.9	2.1	0.0986	9.4
						TOTAL	0.976	93.1
Total Zinc	2	Warren WWTP	M	Final effluent	109	52.0	5.65	56.6
	2	Pontiac WWTP	M	Final effluent	46.9	38.2	1.79	17.9
	2	Mt. Clemens WWTP	M	Final effluent	13.3	84.0	1.12	11.2
	5	Wallaceburg WPCP	O	Final effluent	7.88	79.8	0.629	6.3
	2	Rochester WWTP	M	Final effluent	8.7	29.8	0.26	2.6
						TOTAL	9.45	94.6

TABLE VIII-13. (cont'd 4)

PARAMETER	MDL(s) (ug/L)	FACILITY	MICH/ ONT	OUTFALL NAME(S)	FLOW $10^3 m^3/d$	AVERAGE CONCENTRATION[2] (ug/L)	kg/d	% TOTAL POINT SOURCE CONTRIBUTION
Ammonia as N	100	Chatham WPCP	O	Final effluent	39.4	5,710	225	41.5
	10	Mt. Clemens WWTP	M	Final effluent	13.3	1,000	133	24.5
	100	Wallaceburg WPCP	O	Final effluent	7.88	12,800	101	18.6
	10	Rochester WWTP	M	Final effluent	8.7	6,200	54.0	10.0
						TOTAL	513	94.6
Total Iron	14.0	Mt. Clemens WWTP	M	Final effluent	13.3	1,030	13.7	27.2
	5.0	Wallaceburg WPCP	O	Final effluent	7.88	1,410	11.2	22.2
	5.0	Chatham WPCP	O	Final effluent	39.4	239	9.01	17.9
	14.0	Warren WWTP	M	Final effluent	109	60.0	6.52	12.9
	14.0	New Baltimore WWTP	M	Final effluent	5.11	840	4.29	8.5
	14.0	Rochester WWTP	M	Final effluent	8.7	269	2.34	4.6
	5.0	Belle River WPCP	O	Final effluent	7.9	220	1.73	3.4
						TOTAL	48.8	96.7
Chloride	1,000	Warren WWTP	M	Final effluent	109	76,000	8,260	31.6
	1,000	Pontiac WWTP	M	Final effluent	46.9	12,000	5,630	21.6
	500	Chatham WPCP	O	Final effluent	39.4	12,000	4,400	17.1
	1,000	Rochester WWTP	M	Final effluent	8.7	46,000	4,000	15.3
	1,000	Mt. Clemens WWTP	M	Final effluent	13.3	11,000	1,470	5.6
	500	Wallaceburg WPCP	O	Final effluent	7.88	16,700	1,320	5.1
						TOTAL	25,000	96.3
Phosphorus as P	10	Warren WWTP	M	Final effluent	109	370	40.2	32.4
	10	Mt. Clemens WWTP	M	Final effluent	13.3	2,400	32.0	25.8
	10	Pontiac WWTP	M	Final effluent	46.9	460	21.6	17.4
	100	Chatham WPCP	O	Final effluent	39.3	328	12.9	10.4
	100	Belle River WPCP	O	Final effluent	7.9	1,000	7.9	6.4
	10	Rochester WWTP	M	Final effluent	8.7	680	5.9	4.8
						TOTAL	121	97.2

[1] > 95% of total unless sources diffuse (based on data collected in 1985-86).

[2] Flow weighted.

3 Canadian sources not analyzed.

i) Polychlorinated Biphenyls (PCBs): Although detected at only two Michigan sources, Mt. Clemens WWTP and Warren WWTP, the loading of 9.3 g/day to Lake St. Clair was high compared to the loadings estimated for the other UGLCCS areas. Both sources were discharging comparatively large concentrations, 0.019 ug/L at Warren WWTP and 0.540 ug/L at Mt. Clemens WWTP. Although PCBs were not detected in the Canadian sources, the analytical method detection limit was 1,000 times less sensitive for Canadian samples than for the U.S. samples.

ii) Total Phenols: The total loading was 1.73 kg/d. The elevated concentration at Mt. Clemens WWTP, 77 ug/L, was much higher than a comparable objective in Ontario of 20 ug/L for industrial discharges.

iii) Total Cadmium: The Wallaceburg WWTP effluent exceeded the Ontario Industrial Effluent Objective of 1 ug/L in two of the three samples collected. The concentration in both samples was 4 ug/L. The total loading from all sources was 94.4 g/d.

iv) Total Mercury: Mt. Clemens WWTP had an unusually high effluent concentration of 0.878 ug/L. The concentration was more than four times the Great Lakes <u>ambient</u> water quality objective for filtered mercury. The total loading from all sources was small, 12.8 g/d.

v) Total Copper: The Wallaceburg WWTP had effluent concentrations of 196 to 500 ug/L, 10 times larger than any other point source and two orders of magnitude greater than the Great Lakes Agreement ambient objective of 5 ug/L. The combined loading from all sources was 4.18 kg/d.

vi) Total Nickel: The Wallaceburg WWTP had effluent concentrations of 225 to 452 ug/L, well above existing ambient objectives such as the Great Lakes Agreement objective of 25 ug/L. The total loading from all sources was 6.06 kg/d.

vii) Total Phosphorus: Mt. Clemens had an effluent concentration of 2.4 mg/L during the survey, above the 1.0 mg/L permit limit and the Great Lakes Water Quality Agreement Effluent Objective. Facility self-monitoring reports indicated the 1.0 mg/L objective was frequently exceeded in 1986. The plant's interim permit did not contain a phosphorus limitation. Total loading from all sources surveyed was 123 kg/d.

viii) Ammonia-nitrogen: The Wallaceburg WWTP had two of three effluent concentrations above the Ontario industrial objective of 10 mg/L, i.e., 12.2 and 18.6 mg/L. The combined loading from all sources was 541 kg/d.

No significant contributions of non-UGLCCS parameters were identified.

2. Industrial Point Sources

There were 38 known point sources discharging to the Lake St. Clair Basin in 1986, and all were minor facilities. All industries were indirect dischargers to Lake St. Clair, except the Mt. Clemens, Michigan, water filtration plant, which discharged filter backwash directly to the Lake. The total flow from industries was not available. However, the majority of the industrial flow was once through cooling water or storm water. The ten Canadian industries were predominantly food processors and cement plants while the majority of the 28 Michigan plants were automotive parts manufacturers, with process water usually discharging to municipal WWTPs and cooling waters discharging to surface waters. Because there were no direct industrial dischargers to Lake St. Clair, no industrial sources were sampled as part of the UGLCC Study.

3. Urban Nonpoint Sources

Intermittent Stormwater Discharges

PCB concentrations on the U.S.(west) side of the head of the Detroit River were found to be greater than on the Canadian side (28). This finding was consistent with the observations of Pugsley *et al*. (38) that the highest concentrations of PCBs in clams and sediments from Lake St. Clair were found along the western shore. Johnson and Kauss suggest that the single high value of 1,630 ng/g that was observed on a single survey may be related to an episodic point or nonpoint source discharge that occurred during the survey. High total organic carbon (TOC) concentrations were also observed during the same survey, which may have resulted in increased adsorption of hydrophobic compounds.

Some municipal storm drains exist in Michigan communities on Lake St. Clair (39). New Baltimore has a single 8" drain that enters Frog Creek, a minor tributary to the lake. In Mt. Clemens, 13 storm drains, ranging in size from 12" to 54" in diameter, discharge into the Clinton River. Impacts of these drains on the receiving water quality have not been documented. However, seven of the drains in Mt. Clemens have received a preliminary "high priority" ranking by Michigan Department of Natural Resources (MDNR). Discharge priority ranking was based on indicators such as basin land use, basin area, and diameter of discharge. The process included many assumptions and estimation of relative impacts. Therefore, the ratings should be regarded as only an indication of potential impacts.

Estimates of the annual contaminant loadings to Lake St. Clair from Canadian urban runoff (stormwater and combined sewer overflow) are presented in Table VIII-14. These estimates were based on the mean measured concentration of contaminants in urban runoff from April 1985 to November 1986 in Windsor, Sarnia and Sault St. Marie, Ontario, and on previous estimates of the volume of urban runoff in the Canadian Lake St. Clair basin. Because of the uncertainties involved in the data used in the calculations, these estimates should be considered only as approximations. No similar loadings were calculated for the Michigan urban areas.

Combined Sewer Overflows

None of the U.S. municipalities have combined sewers, while three of the larger Canadian municipalities do have combined sewer systems. The larger urban centre, London (population 277,000) is serviced by 25% combined sewers. Chatham (population 36,000) and Wallaceburg (population 12,000) each have 37% combined sewers. Chatham and Wallaceburg are the largest major urban centers on the two largest Canadian tributaries of Lake St. Clair, Thames and Sydenham Rivers, respectively. The impacts of either the storm water discharge or of any combined sewer overflows on the quality of the receiving waters have not been documented.

4. Rural Nonpoint Runoff

Nutrients

Major sources of nutrients within the Lake St. Clair drainage area are fertilizer (commercial and manure spreading), livestock operations and soil erosion. Nutrients removed by leaching or transported by sediment and runoff may produce two pollution problems: groundwater contamination and accelerated eutrophication of surface waters.

Commercial fertilizer (and to a lesser extent, livestock manure) is applied to approximately 50% of the land in the Lake St. Clair geographic area. Approximately 90% of this land is situated in Ontario and receives approximately 300,000 tonnes (429 kg/ha) of commercial fertilizer annually. Over-fertilization has been identified for both Michigan and Ontario agricultural areas. Analysis of soil fertility and crop nutrient requirements relative to fertilizer applications reveal that many farmers are applying up to 3 times more phosphorus fertilizer than required in Canada, and up to two times the required rate in the U.S.

Livestock operations in the Lake St. Clair geographic area consist of dairy, beef, hog, sheep, chicken and horse operations. Beef and dairy cattle are the biggest producers of phosphorus, followed by hogs. A total of 61 tonnes/yr of phosphorus are

TABLE VIII-14

Estimate of contaminant loading to Lake St. Clair from Canadian urban stormrunoff[a].

UGLCCS Parameter	Loading kg/yr	Loading kg/d[b]
PCB	6.4	0.02
HCB	0.06	0.0002
OCS	0.11	0.0003
Phenols	693	1.9
PAHs(17)	282	0.8
Cyanide	139	0.4
Oil and Grease	219,000	600
Cadmium	320	0.9
Zinc	15,500	42.5
Mercury	3.3	0.009
Lead	10,700	29.3
Copper	2,700	7.4
Nickel	1,800	4.9
Cobalt	187	0.5
Iron	378,400	1036.7
Chlorides	7,995,000	21,904.1
Phosphorus	12,000	32.9
Ammonia-N	24,000	65.7

[a] Estimates calculated from average measured concentration in urban runoff from Windsor, Sarnia and Sault Ste. Marie (51) and from estimated volume of urban runoff in Lake St. Clair basin (52).

[b] Expression of contaminant loadings from urban runoff on a daily basis is somewhat artificial, since loadings are seasonally dependent. However, expression in these terms allows comparison with daily point source loads.

estimated to be delivered to the water courses from the livestock operations, 65% of which comes from Ontario counties.

Soil erosion contributes approximately 3.2 tonnes/yr of phosphorus from Michigan to the water courses. Based upon the percent of total cropland erosion occurring from wind, Macomb and St. Clair Counties should be targeted for accelerated conservation assistance.

Pesticides

Lake St. Clair geographical area is a region of potential problems regarding the movement of pesticides into the water course. These problems are a result of an estimated 3.5 million kg being applied to land in both Canada and the U.S. which has a high potential to transmit the chemicals via surface runoff, fine particulate matter carried by wind or water, and infiltration to groundwater. Based on soil texture and drainage, approximately 70% of the St. Clair geographical area in Canada has been identified as potential problem areas with respect to surface water contamination, and approximately 60% of the area possesses a high risk for pollutant transfer to groundwater systems (5).

5. Atmospheric Deposition

Loadings of contaminants to Lake St. Clair from the atmosphere are a nontrivial portion of the total estimated load of lead and phosphorus (see section E, modeling and mass balance considerations, for further discussion). The major sources of phosphorus are soil dust, leaf and insect debris, and industrial activity. A large percentage of the loading may be derived from entrainment of phosphorus-containing particles in agricultural areas. Lead and cadmium are introduced through combustion of fossil fuel, including exhaust from burning leaded gasoline in automobiles. From measurements in urban and rural locations close to Lake St. Clair, atmospheric deposition of lead was estimated to range from 4 to 8 kg/d and for cadmium from 0.8 to 1.1 kg/d (17).

The atmospheric loadings of P, NO_3, NH_3, Cd, Pb, Zn and Cl to Lake St. Clair for the years 1982 - 1985 were estimated from data collected at the Mt. Clemens station of the Great Lakes Atmospheric Deposition network. The thirty-year mean precipitation average was used to convert concentration values into loadings, as displayed in Table VIII-15.

Quantitative estimates of loadings of organic contaminants to Lake St. Clair are not available. Given the quantity of inorganic materials introduced to the lake from the atmosphere, however, an atmospheric source for organic pollutants is also likely to be important.

TABLE VIII-15

Atmospheric loadings of selected parameters to Lake St. Clair for 1982 - 1985. Mt. Clemens GLAD station is the source of data. Lake surface area is 1101.178 km^2 (430 mi^2).

	kg/yr		
	Nitrate(NO_3)	Ammonia(NH_4)	Total Phosphorus(TP)
1982	301,723	180,593	3,402
1983	441,810	342,466	5,952
1984	514,250	427,257	5,102
1985	445,242	305,124	3,928
AVERAGE	425,756	313,860	4,596

	Cadmium	Chloride	Zinc	Lead
1982	--	436,067	30,909	--
1983	226	252,170	14,773	5,179
1984	254	322,645	23,393	5,509
1985	299	323,492	13,769	3,825
AVERAGE	260	333,594	20,711	4,838

6. Groundwater Contamination/Waste Sites

Surface Waste Sites

Active and inactive waste sites within 19 km of the Connecting Channels were identified as part of this investigation. The majority of sites were landfills, hazardous waste disposal sites, and regulated storage sites. Other waste sites included transportation spills, leaking underground storage tanks and contaminated water wells. Underground injection wells were also identified.

Ranking of sites was based on their potential for contributing contaminants to the Connecting Channels via groundwater. Sites in the U.S. were ranked using the U.S.EPA DRASTIC System with additions and minor modifications. This system assesses the impact by evaluating the hydrogeology, waste material and the distance from Lake St. Clair for each site. Nine U.S. sites were ranked as confirmed or possible contamination sites within the Lake St. Clair groundwater discharge area (Table VIII-16). In general, these sites are in areas of sandy unconsolidated surficial materials and are near to the Connecting Channels. The water table is generally less than 4.6 m below land surface and priority pollutants and/or inorganic contaminants are on site or in the groundwater.

Waste disposal sites in the Ontario study area were also identified. Emphasis was placed on identifying sites that require monitoring or remedial investigations. Criteria for ranking and prioritization of the sites included geologic, hydrologic, hydrogeologic and geochemical information, on-site monitoring, waste characterization and containment, and health and safety. No sites in Kent County were identified that require immediate investigation or that posed a definite potential for impact on human health and safety. Three waste disposal sites in the area contain only building refuse, domestic waste and commercial garbage. These sites are small and not close to the lake. Therefore, no significant impact is expected from them.

Deep Well Injections

The Safe Drinking Water Act (SDWA) of 1974 requires U.S. EPA to provide for the safety of United States drinking water. The act contains a set of requirements which involves the protection of underground sources of drinking water from contamination by injection well activities. Seven U.S. injection facilities are presently authorized in the Lake St. Clair area, five of which are salt water disposal wells and two of which are hydrocarbon storage wells. Of the salt water disposal wells, two are currently in operation: Consumers Power injects to the Dundee Formation at 957 m and Lakeville Gas Association injects to the

TABLE VIII-16

Confirmed or possible contamination sites in the U.S. within the Lake St. Clair groundwater discharge areas.

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1. Hwy M-29 and Michigan St. This site is a gas station with a leaking underground tank on sandy materials near the St. Clair River and a shallow water table.

2. Clay Township Sanitary Landfill This landfill has accepted household and commercial wastes, and is near to the north Channel of the St. Clair River distributary system, sandy surficial deposits, and a shallow water table.

3. Selfridge Air National Guard Base (CERCLIS/RCRA/ACT 307) The Base site consists of 7 individual groundwater contamination sites: 3 landfills, 2 fire training areas and 2 ramps. The landfills contain residential and industrial wastes, solvents, and waste oils. The fire training areas contain flammable waste (JP-4), solvents, strippers and thinners. There have been fuel spills at the two ramps.

4. Metro Beach Incinerator This closed incinerator handled general refuse (most likely from the Metropolitan Beach Park), and is located on the Clinton River Delta within one-half mile from Lake St. Clair over a shallow water table and on silty-sandy surficial material.

5. G and L Industries (Act 307) Phthalate and lead are listed as pollutants for this fiberboard manufacturer in Mount Clemens, Mi., and groundwater contamination is indicated. The site is located on sandy soil near to a shallow water table and aquifer.

6. County Line Landfill This landfill accepted household, commercial and industrial wastes.

7. Henning Road Landfill (Act 307) The Landfill accepts domestic waste. Groundwater contamination is not indicated in the Act 307 listing.

8. Sugarbush Road Dumpsite (CERCLIS/Act 307) This site is a solid waste landfill with pollutants of concern being Pb, Ni, Cr, Cu and Zn. Surface water, air and soil contamination are indicated in the Act 307 listing. Groundwater contamination is not indicated, but there are no monitoring wells.

9. Rosso Highway SAFB - Avis Ford This landfill accepted foundry sand.

CERCLIS:	Site is listed within the information system for Superfund and is considered for clean-up under the comprehensive Environmental Compensation and Recovery Act of 1980 (CERCLA).
RCRA:	Site has current activity under the Resource Conservation and Recovery Act.
Act 307:	Site is listed on Michigan's compilation of sites of known and possible environmental degradation.

Sylvania Sandstone at 733 m in Oakland county. One additional well is presently under construction in Oakland County. Two wells are temporarily abandoned: one to the Detroit River Group of formations at 276 m and one to the Sylvania Formation at 588 m Consumers Power Co. operates the two gas storage caverns in the Salina Formation Group.

Estimates of Groundwater Discharge to Lake St. Clair

Groundwater discharges to Lake St. Clair from three hydrogeologic units termed the shallow glacial (or shallow plus intermediate units), glacial-bedrock interface (or regional, freshwater aquifer), and bedrock units. The shallow glacial unit consists entirely of Pleistocene Age glacial deposits. In southeastern Michigan these are mostly silty-clay till and glaciolacustrine deposits that contain discontinuous stringers of sand and gravel. Base flow of perennial streams largely represents groundwater discharge from this unit.

The glacial-bedrock interface unit occurs between the shallow glacial unit and the bedrock. In general, the glacial-bedrock interface unit discharges less water to the Connecting Channels than does the shallow glacial unit. Environmental concerns, however, are that high head pressures from deep waste injection practices could cause waste fluids to migrate through fractures or more permeable horizons in the rock. The glacial-bedrock interface unit could thus be one pathway by which waste fluids could reach the channels or contaminate adjacent groundwater. No evidence exists at present that this has occurred in Michigan.

The bedrock unit is defined as the first bedrock aquifer lying directly beneath the Connecting Channels. In the Lake St. Clair study area, the bedrock unit includes all carbonate rocks of the Traverse Formation which lie at depths of 30 to 91 m beneath the Antrim shale.

Total discharge from the three units to the Lake St. Clair study area was estimated to be 1,315 L/s.

More direct measurement of groundwater flow to Lake St Clair was also undertaken. Recognizing that all flow entering the lake from groundwater must pass through its bed, the flow was calculated using the lakebed area, hydraulic gradients, and hydraulic conductivities established by an electrical survey of the lake sediments. The advantage of the electrical survey approach to calculating groundwater flux is that it produces continuous measurements of the hydraulic conductivity, as long as sediment is present over the bedrock, allowing both detailed resolution of the locations of groundwater inflow and an alternative method to calculate the quantity. Summations of groundwater fluxes for the entire lakeshore show a total groundwater discharge of 886 L/s.

This estimate agrees well with that from above, estimated from fluxes within geologic units.

Groundwater Contamination

In order to determine the concentration of contaminants in groundwater in the Lake St. Clair area, and subsequently to calculate loads from groundwater to the lake, eight monitoring wells were installed in four groundwater discharge areas on the Michigan shore of Lake St. Clair. Analyses of water from the wells were made for volatile, base neutral, acid extractable and chlorinated neutral extractable hydrocarbons, trace metals, and other chemical substances.

Volatile hydrocarbons, if present, were consistently less than the detection limit of 3.0 ug/L. Benzene was detected in water from one well near Mt. Clemens at a concentration of 3.1 ug/L. Concentrations of base neutral and acid extractable compounds, and 13 chlorinated pesticides, were also generally below the analytical detection limits of 0.1 to 30 ug/L and 0.01 ug/L respectively. Phthalates were found in the water from all but one well, with concentrations up to 170 ug/L (for bis (2-ethyl hexyl) phthalate).

Some pesticides were found in four wells at levels exceeding U.S.EPA Ambient Water Quality Criteria for Chronic Effects and the GLWQA Specific Objectives. Lindane and total DDT were found down-gradient from the Clay Township Landfill near the St. Clair River delta. DDT was found also in wells near New Baltimore and St. Clair Shores. Heptachlor was found in a well near the Selfridge Air National Guard Base (ANGB).

Most wells exceeded the GLWQA Specific Objectives, the Ontario (Provincial) Water Quality Objectives or the U.S.EPA Drinking Water Primary or Secondary Maximum Contaminant Levels for total phenols, phosphorus, pH and some heavy metals. The elevated metals concentrations may have been due to the inclusion of fine particulate matter in the samples, and if so, the concentrations of metals dissolved in the groundwater may be much lower than those reported. The well near the Selfridge ANGB contained the highest levels of phosphorus, phenols, dissolved solids and specific conductance.

A computation of the loading of chemical substances transported by groundwater to Lake St. Clair does not seem feasible based upon the data currently available. Concentrations of organic compounds were generally less than their respective limits of analytical detection, and concentrations of trace metals were reported higher than they would have been had the finely divided particulate matter been excluded from the analyses.

7. Spills

Spills reports from Michigan and Ontario information systems were reviewed and indicate that a limited number of spills to surface water occurred in 1986. However, in many cases the volume of the amount spilled was not known and it is not possible to compare point source effluent loadings with the loadings due to spills.

8. Contaminated Sediments

Identification

i) Organics

Depth-integrated samples (interval composites) were prepared from sediment cores collected in 1985 (Figure VIII-5) and analyzed for organics in order to estimate the mass of contaminants stored in the sediments. Horizontal distributions in total storage have patterns which are essentially congruent with the thickness of recent sediments and form the basis for estimating total storage in the lake by contour integration. For the sandy nonaccumulating area, where cores were not collected, a value of 5 ng/cm^2 was used for PCBs and HCB, and a value of 0.5 ng/cm^2 was used for OCS. These approximations were not critical since the sandy areas contributed less than 5% of the contaminant mass for these chemicals. Lake St. Clair sediments presently contain about 960 kg of HCB, 870 kg of PCBs and 210 kg of OCS.

These values are much higher than the contaminant masses found by Oliver and Pugsley (40) for the St. Clair River sediments (3 kg HCB, 20 kg OCS) indicating that Lake St. Clair is a more significant repository for chemicals than the river itself, in part due to the much greater mass of sediments in the lake. Recent loading estimates for HCB and OCS in the combined dissolved and particulate fraction at Port Lambton in the St. Clair River were 180 kg/yr for HCB and 11 kg/yr of OCS. At these rates, Lake St. Clair sediments contain the equivalent of 5 years loading of HCB and 20 years loading of OCS. Thus, the sediments retain significant fractions of these chemicals and, given the uncertainties in the calculation, accumulation is consistent with sediment reservoir residence times derived from historical studies of metal and organic chemicals in the system and from the response of sediments to particle-associated radionuclides.

ii) Metals

In order to estimate the total mass and anthropogenic mass of each metal stored in Lake St. Clair sediments, the sediment cores collected at each station in 1985 were designated to be representative of a region of the lake. The anthropogenic mass of each metal stored in each sediment type was calculated by subtracting background metal concentrations from all concentrations in post-settlement sediments. In general, metal concentrations increased above the glacial deposits.

Within the lake and its marshes, 30 to 64% of the mass of metals stored in post-settlement sediments is anthropogenic. Storage of anthropogenic metals is highest in the silts and clays (48-70%), second highest in the sands (32-35%), and lowest in the marshes (5-29%). An exception to these general statements is the high fraction of anthropogenic lead stored in the marshes (29%), based on the one core used to represent the marshes.

Lake St. Clair appears to be a temporary trap for some metals (Table VIII-9). Thus, sediments and their associated contaminants, appear to be transient and will eventually be transported down the Detroit River to Lake Erie.

Classification

Using the OMOE and U.S.EPA pollution guidelines, the sediments underlying the open water of Lake St. Clair can be classified as only lightly polluted. Sediments at the mouths of some tributaries are more contaminated.

9. Navigation

As a result of the Rivers and Harbors Flood Control Act of 1970, which authorized the U.S. Army Corps of Engineers to construct facilities for containment of polluted dredge spoil from the Great lakes harbors and waterways, two diked facilities were constructed on Dickinson Island adjacent to North Channel in the St. Clair delta. Both sites were located on the high pre-modern delta deposit and did not infringe on the wetlands. These disposal sites were designed to accommodate dredgings produced during a 10 year period, and they presently receive the materials dredged from the St. Clair system. Navigation-related dredging, which removes contaminated sediments and deposits them in confined disposal facilities could be considered beneficial in that the total contaminant load within the system is reduced. Impacts of the dredging due to resuspension of contaminated sediments during the dredging operations, and the subsequent temporary increase in bioavailability of the contaminants, have not been documented.

Commercial vessel operations through the shipping channel are also believed to cause some local sediment resuspension. The extent of influence and effects of the contaminants associated with the resuspended particles have not been documented.

D. DATA LIMITATIONS

A detailed discussion of data quality management for the UGLCC Study can be found in Chapter IV. The information presented below reflects concern for some data quality pertaining specifically to Lake St. Clair.

1. Sediment Surveys

References in the text to a "1983 sediment survey" in Lake St. Clair refer to a study conducted by the OMOE. The data have not yet been published, nor have the methods, results or any interpretation of the data been peer reviewed. Discussions with the principal investigators, however, indicate that the samples were obtained by bottom grab sampler, and the top 3 cm of each of 3 grabs were composited. The samples were then sent to a laboratory for analysis by "standard techniques". This study has the appearance of being a valuable contribution to the knowledge of the distribution of contaminants in Lake St. Clair sediments. However, the data must be considered "preliminary" at this time, and used only to support the findings of other documented surveys, particularly the 1985 surveys conducted by Environment Canada and by U.S. Fish and Wildlife Service.

2. Tributary Loadings

Accuracy of estimates of tributary loadings of chemical parameters is dependent on the responsiveness of the stream to storm events and on the frequency of sampling. Data from a program employing infrequent sampling will generally be biased low for substances which increase in concentration with increasing stream flow, such as nutrients from agricultural runoff (41). Of various sampling strategies, flow-stratified sampling, i.e., emphasizing storm events, and calculations provide the most accurate results. Loading data for phosphorus, nitrogen, chlorides, lead and cadmium from the Clinton, Thames and Sydenham Rivers were based on a combination of monthly and storm-event sampling and included from 15 to 72 samples per year. Data for the Ruscom, Puce and Belle Rivers were based on only 14 or fewer samples per year, and may therefore be subject to considerable error.

A recent analysis of the flow responsiveness of Great Lakes tributaries, i.e., their potential for change in rate of flow in relation to storm events, indicated that the Clinton River was "stable", the Sydenham River was "event responsive", and the Thames was intermediate between the other two (42) Estimates of loads of phosphorus, Cd and Pb for the Thames River, with the greatest number of annual samples, and the Clinton River, with the most stable flow, may be expected to have about the same accuracy, although confidence intervals were not reported. The estimate for the Sydenham, with the about the same or fewer samples and more variable flow response, may under represent the true load by some unknown amount.

The difficulty in calculating loads from small data sets created the need to make loading calculations using several methods. For Canadian tributaries, the Beale Ratio Estimator was used to arrive at loads for P, Cd, Pb, and Cl. Loading calculations for these parameters plus NO_3 were also made from the same data set by plotting P concentration vs flow. A "best line fit" was then drawn, and concentrations were then read off the graph for days on which no samples were taken. Phosphorus loads on the remaining Canadian tributaries were calculated using a two-strata method. A "cut-off" line was determined by doubling the annual mean flow. An average concentration was found for days when flow exceeded the cutoff, and another was found for days with flow below that value. Loads for unsampled days were calculated by multiplying the average concentration by the flow for that day. The values presented in this report represent an arithmetic average of results obtained by the two methods.

Concentrations of lead, cadmium, chloride and nitrogen in Canadian streams did not exhibit a variation with respect to flow. Therefore, loads were calculated by averaging all samples and multiplying by the flow.

For the Clinton River, loads were calculated using the Stratified Ratio Estimator (43). This method is essentially a modification of the Beale Ratio Estimator.

The average annual loads for Canadian tributaries as displayed in Table VIII-1 represents a mixture of included data. For P, the average unit area load is based only on data from the Sydenham and Thames Rivers, which comprise 57% of the Lake St. Clair watershed. Were an arithmetic average of all estimates of loadings from all Canadian tributaries to be used, the unit area loading would have been reported as 3.18 kg/ha instead of 2.26 kg/ha.

For NO_3 and Cl, the loadings include an average unit area loading from the Ruscom River, which was approximately 10 times that of the other rivers in 1985. The average unit area loading for the Sydenham and Thames Rivers combined for NO_3 and Cl was 20.5 kg/ha and 160 kg/ha, respectively, instead of the reported 40 kg/ha and 287 kg/ha. The cause for the Ruscom River concentrations and loads may need investigation, but the data should not be considered typical of the unit area loads for the Lake St. Clair watershed.

3. Point Sources

The point source monitoring data in general were developed with a rigorously defined quality assurance program. Due to constraints on the sampling frequency and quantity, however, a number of shortcomings in the point source survey data limit the inferences that can be drawn from the results of the study. Most facilities in the Lake St. Clair basin were not sampled. The major facilities closest to the lake itself, as opposed to those furthest upstream, were surveyed, however.

One deficiency, that of a small data base consisting of one day sampling by the U.S. and 3 to 6 day surveys by Canada, prevents precise determination of annual loadings. The timing of the surveys reduced the comparability of the data. The U.S. surveys were carried out during May and August of 1986, while the Canadian data was collected on October 1985 and March and November of 1986. The sampling methods were also different. The U.S. composited four grabs (one per six hours) for each facility. Canadian samples were collected by automatic composite samplers (one portion per 15 min.). Differences in the analytical methods and the method detection limits used by the U.S. and Canada for several parameters also reduced data compatibility. This deficiency was particularly pronounced for PCB analyses.

Despite these limitations, the data were considered adequate for identifying major sources of contaminants, and were used to make conclusions and recommendations concerning specific point sources.

4. Fish Consumption Advisories

The data upon which the fish consumption advisories for Lake St. Clair are based were derived primarily from Canadian analyses of samples of the edible portions of fish. This method generally returns concentrations of contaminants less than those found in larger skin-on fillets that the U.S. uses for its analyses of contaminants in fish. One implication, therefore, is that if the U.S. method for assessing contaminants in fish were used, the fish consumption advisories may become more restrictive. Although the impacts to humans of contaminants other than mercury in fish flesh for commercially marketed fish are not quantified, the advisories remain useful as a general guide for use by the public who consume fish from Lake St. Clair.

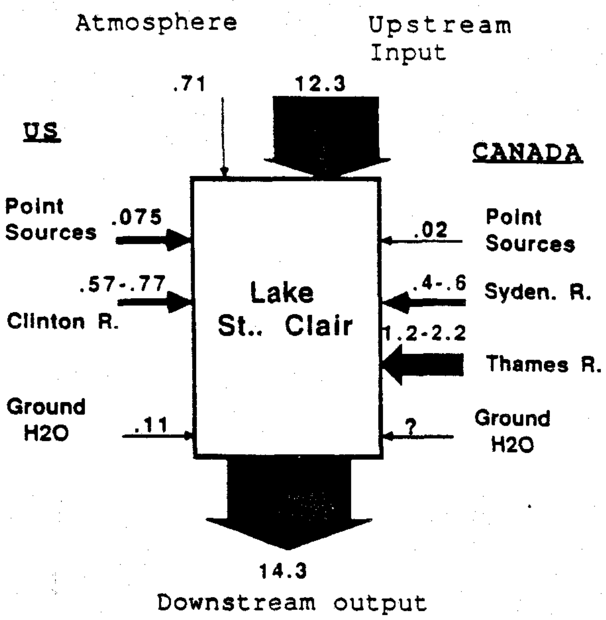
E. MODELING AND MASS BALANCE CONSIDERATIONS

1. Mass Balance Models

Four days prior to the onset of the System Mass Balance measurements in the Detroit River, measurements of contaminants entering Lake St. Clair from the St. Clair River were initiated. The intent of starting four days before making measurements on the Detroit River was to allow for passage of most of the St. Clair River water through the lake. By doing so, upstream and downstream contaminant fluxes could be compared and conclusions could possibly be drawn concerning whether Lake St. Clair is a source or a sink of contaminants. It must be emphasized that the validity of comparing upstream and downstream measurements in this mass balance calculation depends on how well the same parcel of water was sampled at the head and mouth of Lake St. Clair. Given winds that existed during the sampling time, and output from a particle transport model (developed at the National Oceanic and Atmospheric Administration - NOAA) discussed below, we estimate that 60-80% of the water that entered the lake, exited it on day four. Therefore, downstream contaminant fluxes that are 20-40% different from upstream fluxes cannot be argued to be significant. On the mass balance diagrams that follow (Figures VIII-6 through VIII-13), best estimates of point and nonpoint source inputs have also been noted. If estimates were not available, they are indicated with a "?" on a diagram. Loading information was compiled with data provided by the Point and Nonpoint Source Workgroups. Groundwater loading estimates are extremely preliminary and should be treated as such. These diagrams should therefore be used only to suggest possible issues that may require further investigation. This is because of uncertainty about time lags between the head and mouth of the Lake, and the "long term average" character of some of loading information.

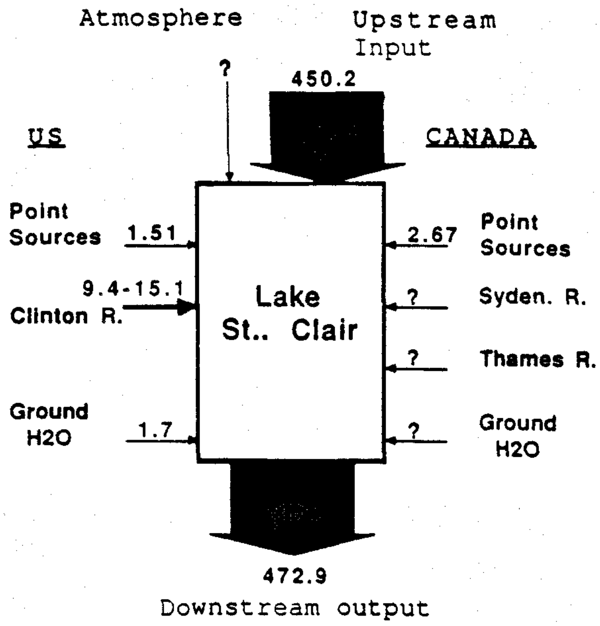
In most cases, the downstream contaminant fluxes do not differ widely from the contaminant flux entering the lake via the St. Clair River. In the cases of cadmium and particularly lead, it appears that a significant portion of the lake's total load could be coming from its tributaries. If the Thames River lead loads are reasonably accurate, then a regulatory problem may exist. Sediment records that indicate a net storage of lead over the years would corroborate these observations.

A total phosphorus budget was developed for Lake St. Clair for 1975-1980 (Figure VIII-13). Phosphorus load estimates were made for point sources and hydrological areas (Figure VIII-14). During this period Lake Huron accounted for 52% of the total annual load, while hydrologic area loads accounted for 43% (13). The remaining load came from the atmosphere, shoreline erosion and direct point sources. The Thames hydrologic area contributed 58% of the total hydrological area load, followed by the Sydenham (17%), the Clinton (9%), the Ruscom (7%), and the Black (6%).



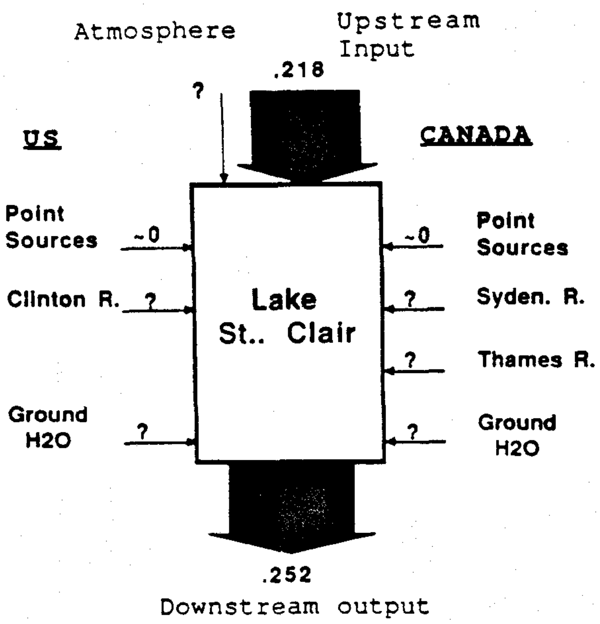
In=15.4-16.8
out=14.3
sink=1.1 - 2.5?

FIGURE VIII-6. Lake St. Clair total cadmium (kg/d).



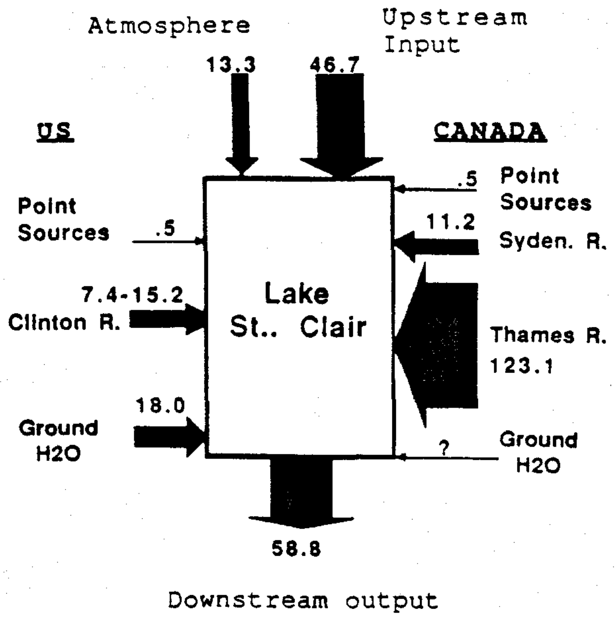
In=465.5-471.2
out=472.9
source=7.4-1.7?

FIGURE VIII-7. Lake St. Clair total copper (kg/d).



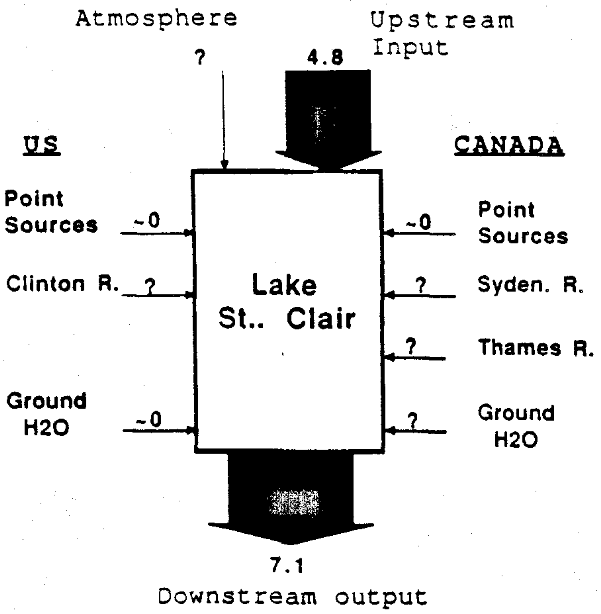
In=.218
out=.252
source=.034?

FIGURE VIII-8. Lake St. Clair HCB (kg/d).



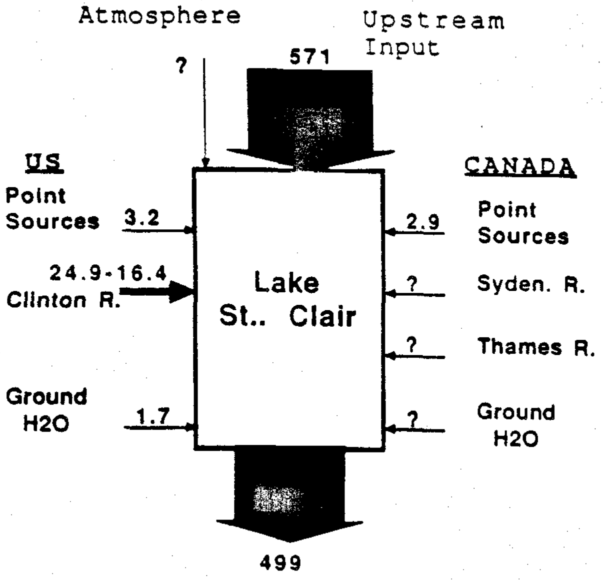
In=220.7-228.5
out=55.8
store=161.9-169.7?

FIGURE VIII-9. Lake St. Clair total lead (kg/d).



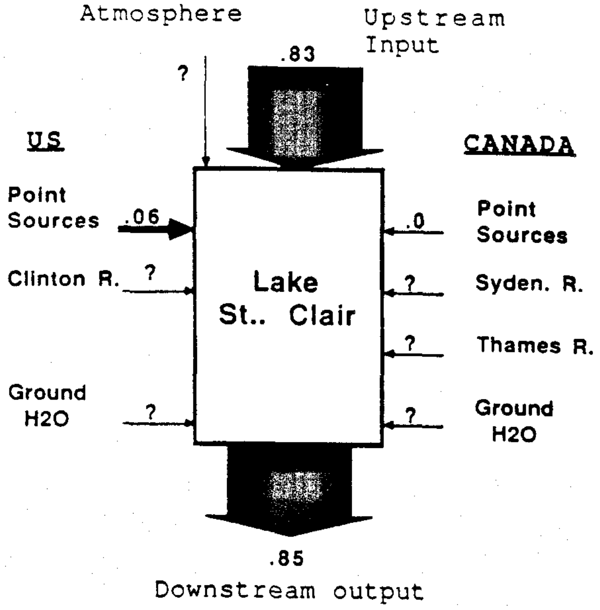
in=4.8
out=7.1
source=2.3?

FIGURE VIII-10. Lake St. Clair total mercury (kg/d).



in=595.2-603.7
out=499
sink=96-105?

FIGURE VIII-11. Lake St. Clair total nickel (kg/d).



in=.89
out=.85
store=.04?

FIGURE VIII-12. Lake St. Clair total PCB (kg/d).

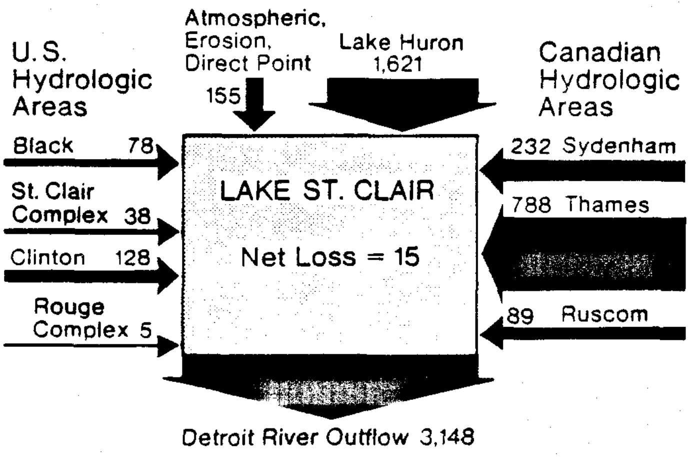


FIGURE VIII-13. Lake St. Clair average phosphorus loads and losses during 1975-80 (mt/yr).

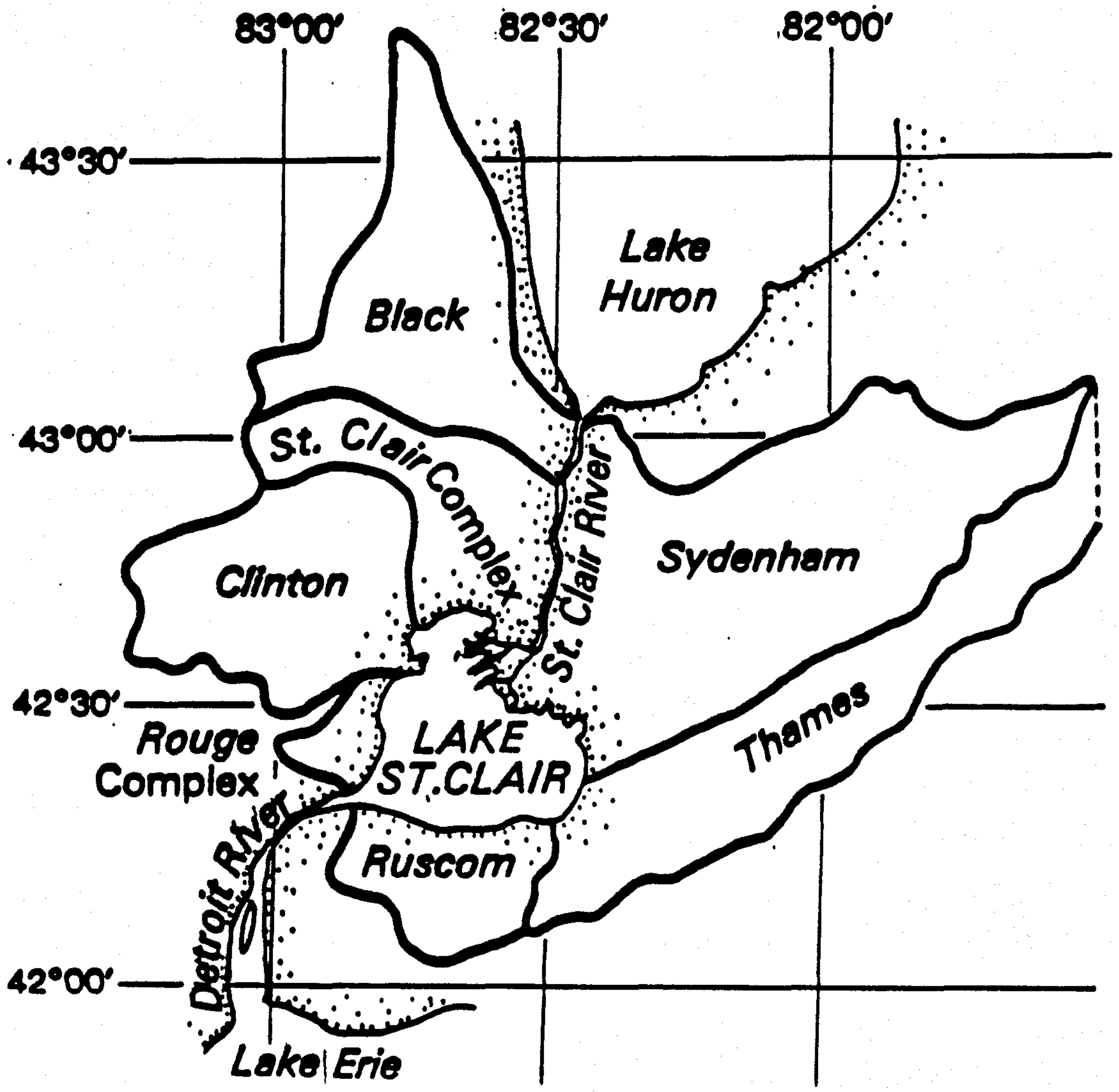


FIGURE VIII-14. Hydrological areas used in determining mass balances.

Over the six year period examined, the lake's total input and output of phosphorus were nearly equal. Therefore, there was no significant net source or sink of phosphorus in the lake during that period.

2. Process-Oriented Models

Changes of water level caused by wind are most pronounced in shallow lakes such as Lake St. Clair. The ability to predict wind-induced water level changes would therefore be useful, since these changes can affect shorelines and contingent properties. A hydrodynamic model was developed to investigate the effects of bottom drag and wind stress on computed lake setup, and to determine the efficacy of hydro-dynamic or purely empirical approaches to predicting water measurements. Empirical approaches by-pass many of the calculations that are used in the hydrodynamic approach. No essential difference between the two approaches was found, but for an empirical model to be developed, an adequate historical data base for the site of interest must exist. The strength of the hydrodynamic approach is that it is transferable among lake systems.

To predict the fate and transport of contaminants in any body of water, the movement of that water, as affected by winds or tributaries, must be known or predictable. Because of this need, several models were developed by Canadian and U.S. scientists to predict and understand currents in Lake St. Clair. In addition, models were developed for predicting and understanding wave dynamics in Lake St. Clair since waves can resuspend sediments and associated contaminants.

Simons and Schertzer, (Environment Canada - EC) developed a model that predicts mean daily currents in Lake St. Clair. They found that an important consideration in developing the model was accounting for the effects of a shallow bottom on currents. Lack of information regarding these effects has been a major impediment to the application of hydrodynamic models to shallow lakes. They were able to develop a tentative relationship between eddy viscosity and wind stress that aided in shallow water model development.

Schwab and Clites (NOAA) developed a particle transport model for Lake St. Clair to answer the following questions: 1) What path does water entering Lake St. Clair from one of the tributaries follow through the lake before leaving the Detroit River? 2) How long does it take? 3) How is the particle path changed by wind-induced circulation in the lake? 4) For the meteorological conditions during the summer and fall of 1985, what are the typical statistical distributions of these pathways? The model they developed calculates currents on a 1.2 km grid and yields results that are similar to those of Simons and Schertzer above. Their model can be used to make preliminary estimates of the spatial distribution, transport and residence times of conservative, hazardous spills in Lake St. Clair. This model, however, only tracks conservative, nondispersive tracers from the mouths of the tributaries through the lake under various wind conditions.

Even though the average hydraulic residence time for Lake St. Clair is about nine days, the residence time for conservative particles entering the lake from the individual tributaries ranges from 4.1 days for the Middle Channel to over 30 days for water from the Thames River, depending on the wind conditions. If significant contaminant loads were to enter the lake from tributaries that have long residence times, the impact of these contaminants might be greater than if they entered the lake from other tributaries.

Most of the water from the St. Clair River enters the lake through the North Channel (35%). According to the calculations, this water tends to flow down the western shore of the lake and never gets into the central or eastern parts of the basin. Water from the Middle Channel tends to remain in the western third of the lake, almost never entering the eastern half. Water from St. Clair Flats and the St. Clair Cutoff can be dispersed almost anywhere in the lake to the south of the shipping channel which connects the St. Clair Cutoff with the Detroit River. A small amount of the St. Clair inflow (5%) enters through Bassett Channel. This water can pass through any part of the eastern half of the lake depending on the wind conditions. The Thames inflow tends to be confined to the eastern and southern shores before reaching the Detroit River and it can take a very long time to get there. Water from the Clinton River and the Clinton Cutoff is most likely to follow the western shore of the lake southward with the most probable paths within 3 km of the western shore.

Water quality measurements made in Lake St. Clair by Leach (44, 45) showed two distinctly different areas in the lake. In the southeastern part of the lake, the water quality was dominated by the Thames inflow, which is a major source of phosphate and other dissolved and suspended material. The central and western parts of the lake possessed water quality similar to Lake Huron than to the southeastern part of the lake. The pattern of water mass distribution (45) is very close to the combined patterns of the four main St. Clair River inflows and the Thames inflow. Bricker et al. (46) examined the distribution of zooplankton in the western half of the lake. They distinguished an area of biological and physiochemical similarity along the western shore of the lake that appeared to be influenced more by the Clinton River than the St. Clair River. The shape of this area matches quite well with the modelled distribution pattern for water from the Clinton River.

To verify the circulation model and lend credulity to currents calculated by Schwab and Clites, their model was tested by comparing model output to actual current data measured in Lake. St. Clair in 1985. Two separate current data bases were gathered. One involved the use of 5 drifting buoys which were repeatedly launched and tracked in the lake. The other was the result of several synoptic current surveys utilizing electromagnetic current meters. Currents predicted by the circulation model were used to simulate 16 drifter tracks. Most of the tracks were about 2 days in length from various portions of the lake. In most cases, the model simulated the tracks extremely well as did a similar study by Hamblin et al., (26). For the entire data set, the mean root mean square (rms) of the drifter was 25% greater than that of the calculated current track. The directions compared favorably except for a few tracks near the mouth of the Bassett Channel, where the model prediction was over 90 degrees different in direction when compared with the observed track. The comparisons between current meter measurements and model-predicted currents were even better. In nearly 100 comparisons, 60% of the variance is explained by the model prediction. The model again seems to under-predict the current speeds, here by about 30%.

Contaminant transport depends in large part on the movement of suspended particles. Therefore, accurate computation of horizontal sediment transport should rely upon the accurate simulation of the vertical structure of the horizontal flow field. Hamblin et al., (26) developed such a three dimensional finite element model for Lake St, Clair. Model agreement with observations was good near the lake bottom but poorer near the surface and suggested that a more elaborate model would be needed to accurately model vertical velocity profiles. The more elaborate model would include the effect of surface waves.

An empirical model was developed to describe and understand the relationship between waves and sediment settling and resuspension (25). The importance of these relationships to our ability to predict and understand the transport of contaminants is evident. Statistical relationship between suspended matter and concentration and wave orbital velocity was computed. Integration of computed resuspension rates provided an estimate of sedimentation in sediment traps. The model-generated sedimentation rates compared rather well with the sediment trap data.

Present Status of Physical-Chemical-Biological Models

To predict the fate and behaviour of contaminants, models that integrate physical, chemical, and biological processes are often needed. Two such synthesis models were developed for predicting contaminant fate in Lake St. Clair. Halfon (EC) utilized TOXFATE and Lang, Fontaine and Hull (NOAA) utilized the U.S.EPA TOXIWASP model. TOXFATE was used to predict the spatial distribution of seven halocarbons in Lake St. Clair, and the fate of perchloroethylene in the St. Clair - Detroit River system. The TOXIWASP model was used to predict and understand the fate of the contaminant surrogate Cs-137, as well as PCBs and OCS. Neither of these models could be fully tested for Lake St. Clair applications due to a limited test data set. However, these models are based on well documented cause and effect relationships, and as such, could be used to forecast the fate and behaviour of contaminants introduced to the lake in the future. Representative results of Halfon's Lake St. Clair TOXFATE model is demonstrated in Figure VIII-15.

Lang and Fontaine (NOAA) developed a multi-segment, generic contaminant fate and transport model for Lake St. Clair. The TOXIWASP code upon which it was based was streamlined to make it more specific to Lake St. Clair. Because evidence of biological mixing in Lake St. Clair was extensive, this capability was added to Lake St. Clair version of TOXIWASP. An extremely fast version was created that calculates steady state contaminant concentrations in seconds rather than hours. Numerous programming errors in the original code were found, corrected and passed on to the U.S.EPA-Athens modeling group.

Lang and Fontaine (NOAA) calibrated the transport mechanisms of TOXIWASP using chloride and meteorological data that were collected during a series of cruises in Lake St. Clair during 1974. After obtaining reasonable agreement with the conservative chloride ion, calibrations of contaminant dynamics was carried out using Cesium-137. Cesium-137 was used to calibrate the model's contaminant dynamics since Cesium-137 adsorbs to particles in a manner similar to that of many hydrophobic, organic contaminants. Most importantly, the source function of Cesium-137 to the lake is well known (Figure VIII-16). This information, coupled with knowledge of the spatial and depth distributions of Cesium-137 in the sediments of the lake, provided an excellent calibration and verification data set. Verification results are acceptable (Figure VIII-17).

Having calibrated the TOXIWASP model for Lake St. Clair, it was used to hindcast possible loadings of octachlorostyrene and PCBs to Lake St. Clair. The model predicted that about 3.9 MT of OCS had to have been loaded to the lake over a period of 12 years to produce measured sediment concentrations (Figure VIII-18). This finding implies that OCS was first loaded in the latter part of 1970 and is consistent with speculation to that fact. The model also estimated that 3,400 kg of PCBs had to have been loaded to produce measured PCB sediment concentrations (Figure VIII-19). The model tended to under-predict the PCB values along the eastern and western segments of the main lake, which may indicate additional or increased PCB sources in these areas.

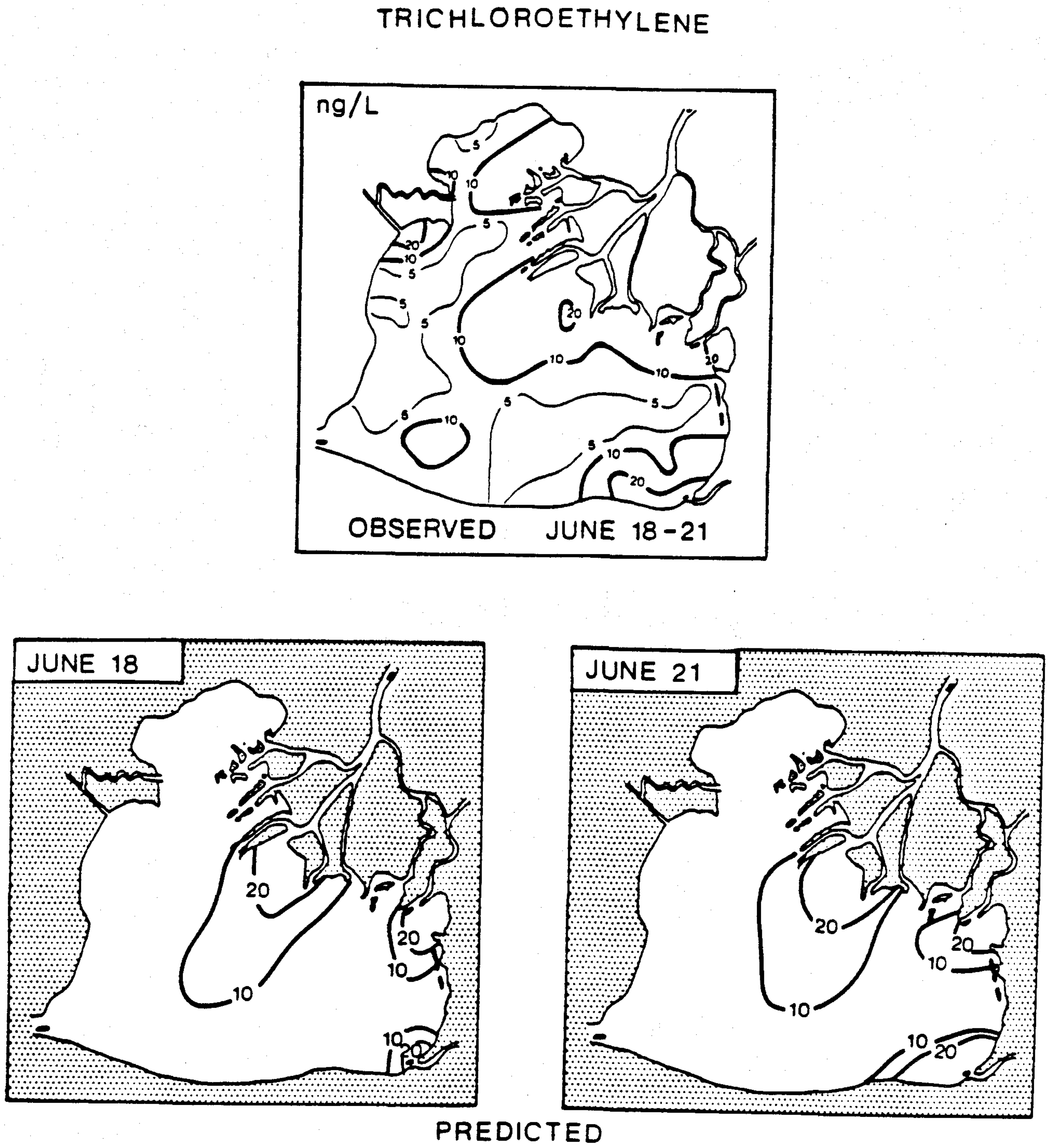


FIGURE VIII-15. Modelled and observed distributions of trichloroethylene 1984.

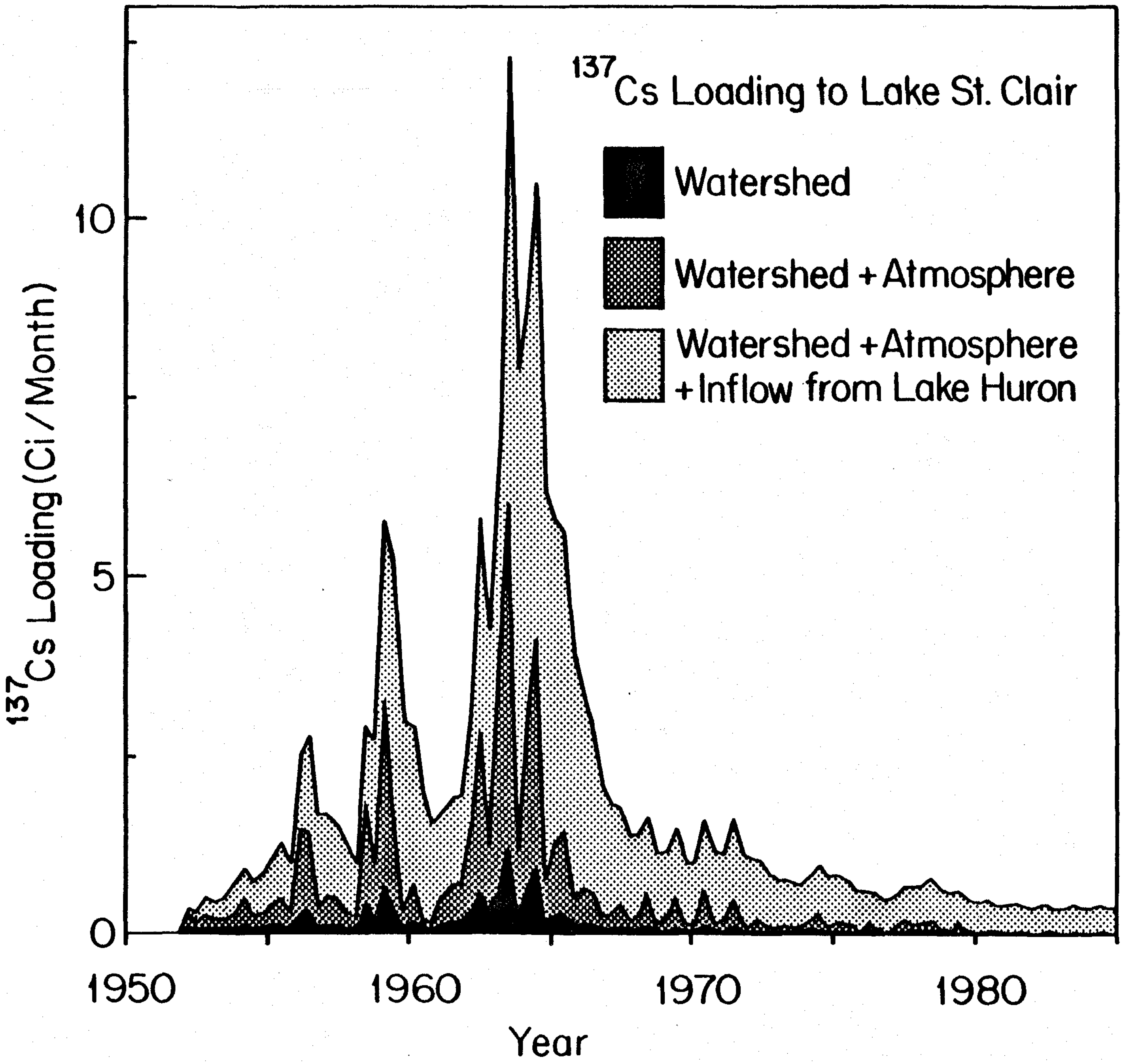


FIGURE VIII-16. ^{137}Cs loadings to Lake St. Clair.

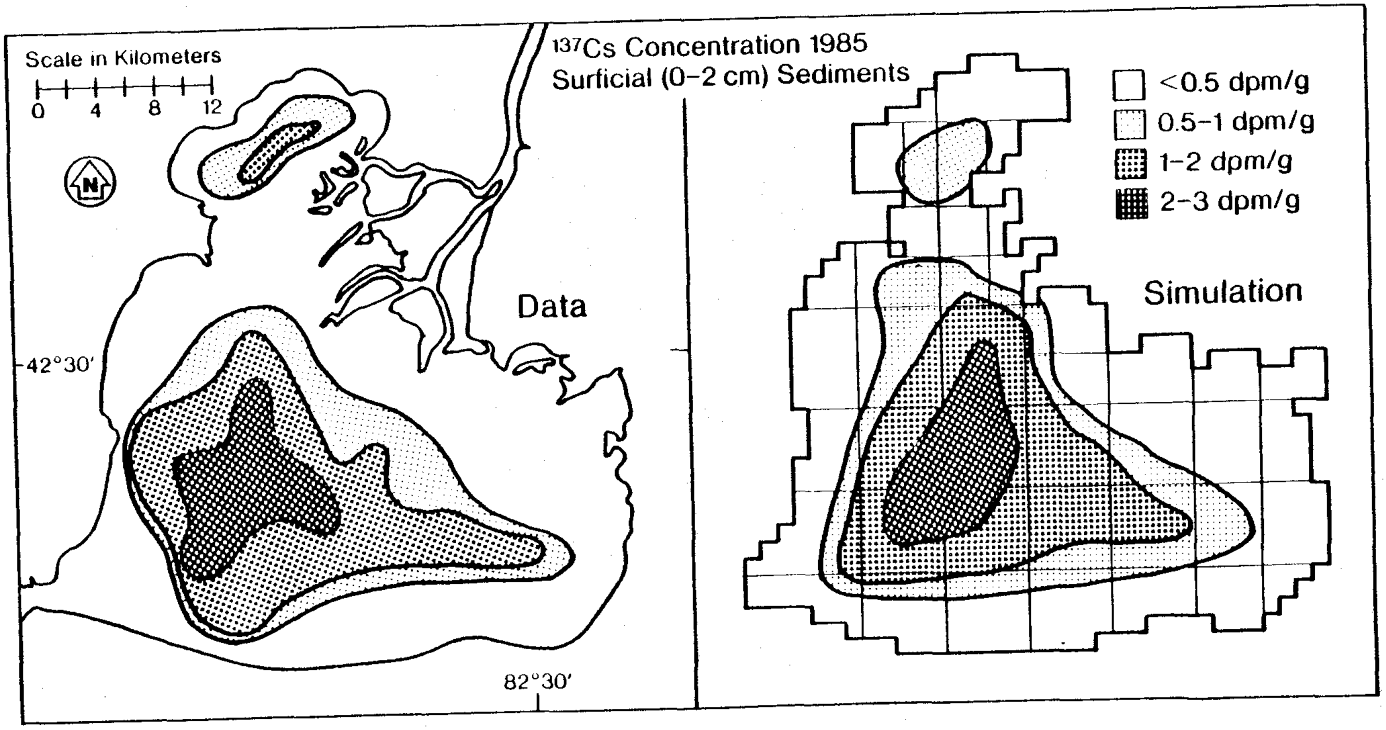


FIGURE VIII-17. ^{137}Cs concentration 1985 surficial (0-2cm) sediments.

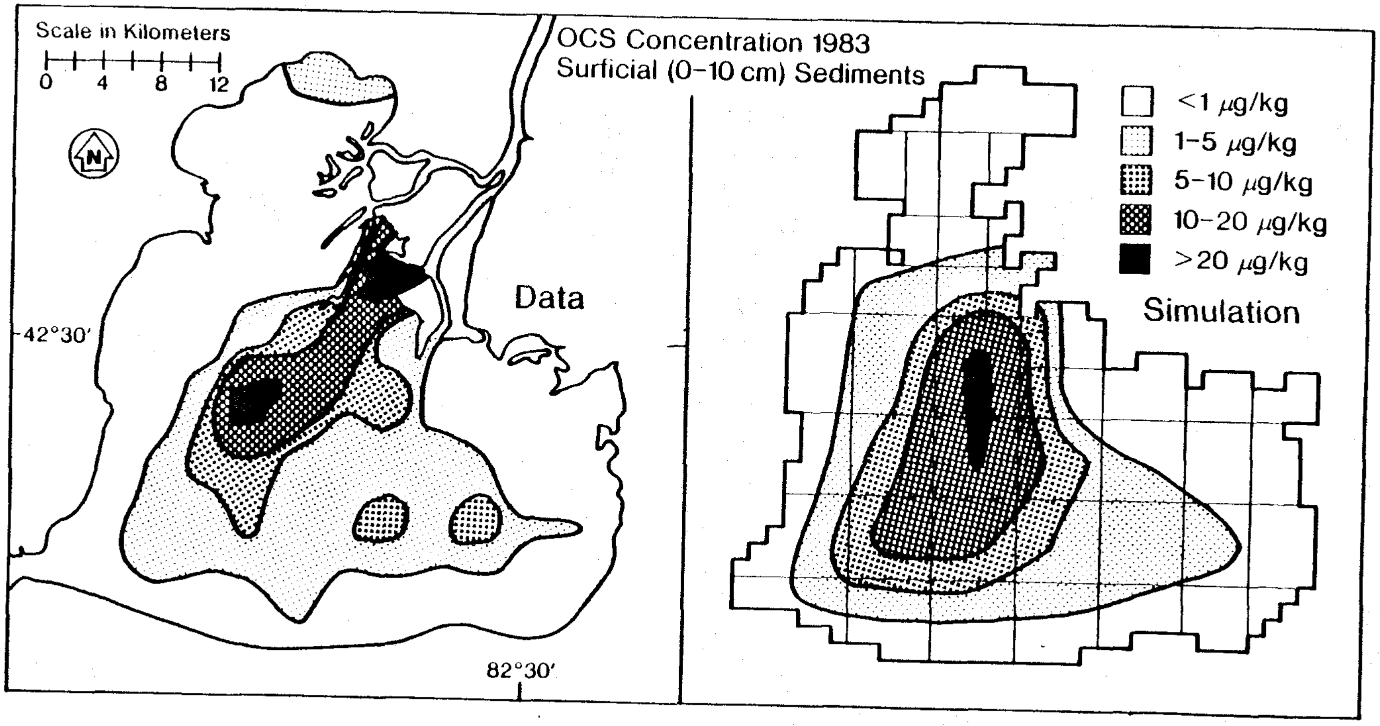


FIGURE VIII-18. OCS concentrations 1983 surficial (0-10cm) sediments.

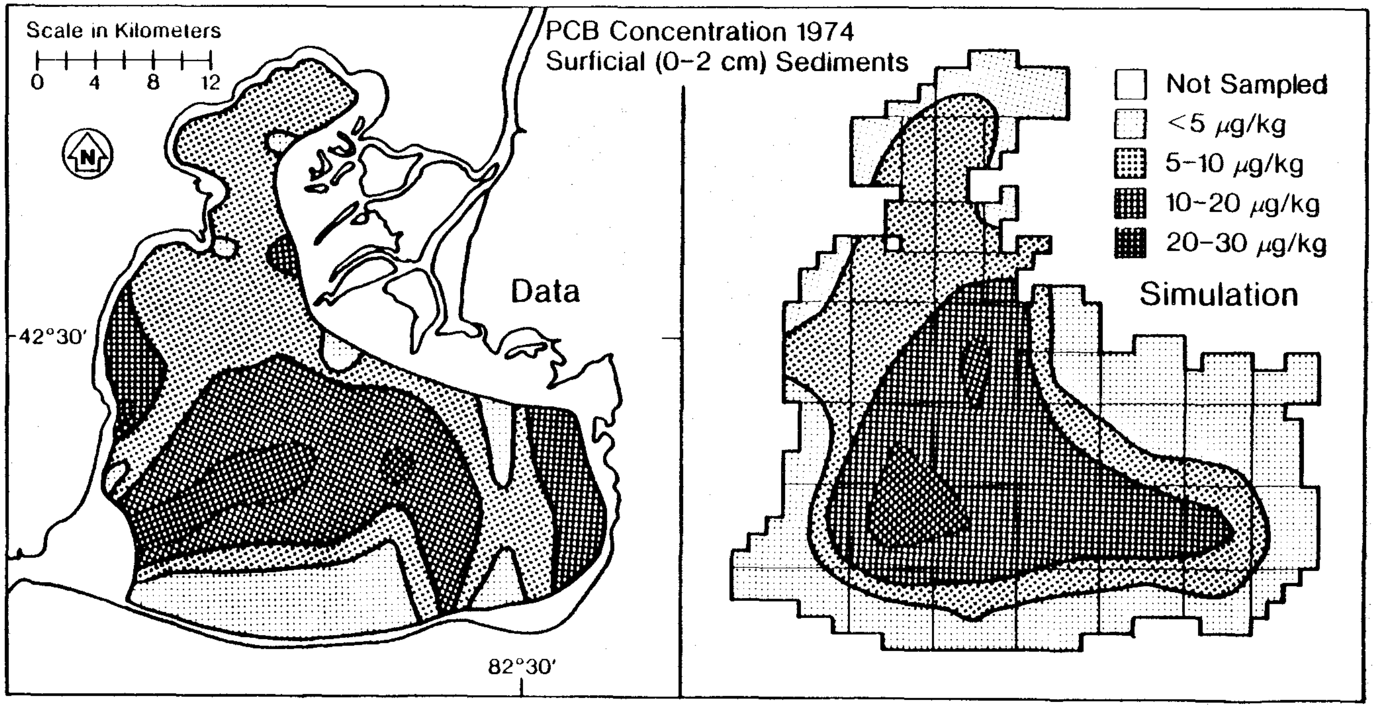


FIGURE VIII-19. PCB concentration 1974 surficial (0-2cm) sediments.

TOXIWASP assumes a local equilibrium between the dissolved, particle-adsorbed and bio-adsorbed chemical. Hull, Lang and Fontaine (NOAA) modified the TOXIWASP model so that kinetic, instead of equilibrium, reactions were simulated. This was done to determine whether the equilibrium approach was valid in all circumstances. Equilibrium models assume implicitly that incoming contaminant loads are at local equilibrium between dissolved, adsorbed, and bioaccumulated phases. When the same load conditions were assumed for the kinetic model, greatest deviations between the two models occurred when predicting the fate of highly hydrophobic contaminants ($K_{OW}>10^6$). The kinetic model not only required a longer time to reach steady state contaminant concentrations, but also required a longer time to flush out the resident contaminant mass after the input load was shut off. Generally, one would expect problems with an equilibrium approach when the time to equilibrium is longer than the residence time of the water body in question.

Halfon (EC) used TOXFATE to predict the fate of perchloroethylene (PERC) in the St. Clair - Detroit River system. The model suggested that about 82% of the PERC would be volatilized, and the remainder, less 1% that would remain in sediments, would enter Lake Erie. Comparison of simulated and measured PERC concentrations show reasonable agreement. Since so much of the PERC is volatilized before it reaches the open lake, Halfon's model does not realistically demonstrate what may happen to a nonvolatile spill entering the lake.

In the case of a nonvolatile spill travelling the lake from the St. Clair River to the Detroit River outflow, the dilution of the concentration would be determined mainly by the strength of horizontal turbulent mixing. There were no direct measurements of horizontal diffusion in Lake St. Clair reported by any of the UGLCCS activities. However, two investigations (17,53) have employed a vertically integrated model of transport and diffusion of a conservative substance, chloride, to infer an effective horizontal diffusion coefficient of 10^{+5} cm^2/s. Because this quantity has been deduced from vertically averaged concentration in the possible presence of current shear over the water column, these authors have termed the diffusion coefficient as a dispersion coefficient.

The particle trajectory measurements and models reported for August 12, 1985 by Hamblin (47) and by the Modeling Workgroup Report (53) for September 1985 demonstrated that particles would take about four days to cross the lake. If a slug of contaminated river water had dispersed longitudinally to a length of 5 km in the St. Clair River, then in the four day transit to the outflow region it would have grown by about 7 km to a characteristic patch size of 12 km under the assumptions of average meteorological conditions and horizontal Gaussian diffusion. In turn, this patch would take about two days to pass across the water intakes near the outflow. Finally, the average concentration would be about 20% of the original concentration entering the lake.

3. Summary

The modeling work on Lake St. Clair has made much progress during the study period from the water level fluctuation models (storm surge) to the coupled contaminant-circulation models. However, more work is required before the models could be used as effective water management tools. Testing of the models with parameters additional to PCB and OCS, more realistic treatment of sediment water interaction, and linkage of the models to lake biota are seen as necessary steps before the models can reliably assess the ecological responses to reductions in loadings to the lake. Although not developed for operational purposes, the models TOXFATE and TOXIWASP, with modest additional effort, could be used to predict the trajectories and dilutions of spills of either volatile or nonvolatile substances occurring on the lake or entering from the rivers.

F. OBJECTIVES AND GOALS FOR REMEDIAL PROGRAMS

The following objectives and goals are grouped according to media. However, remedial actions are likely to have multimedia effects. For example, elimination of point and nonpoint sources of contaminants can be expected to reduce concentrations in water, sediments and biota, even though direct remediation of contaminated sediments or biota may be infeasible. Some objectives may be reached, therefore, upon attainment of one or more others.

1. Water Quality

Since the water quality of Lake St. Clair is dominated by that of the St. Clair River, remedial programs directed towards the St. Clair River will also improve water quality in Lake St. Clair.

Objective 1. **Full implementation of recommendations for the St. Clair River presented in Chapter VII of this report for the elimination of industrial, municipal and nonpoint sources of contaminants to the St. Clair River, particularly HCB, HCBD, OCS, Hg, and Pb.**

Excluding input from the St. Clair River, phosphorus loadings to Lake St. Clair are dominated by nonpoint sources. For example, in the Thames River 93% of the loading was of the nonpoint source type. In water samples from Lake St. Clair tributaries, nearly all contained phosphorus in excess of the PWQO of 30 ug/L. Improved agricultural practices such as conservation tillage, elimination of over-fertilization and control of feedlot effluents are identified as actions relevant to reduction of nonpoint source loadings.

Objective 2. **Reduction of phosphorus loadings from point and nonpoint sources in Michigan and Ontario to assist in meeting target load reductions for Lake Erie.**

The Mt. Clemens WWTP was identified as having average phosphorus concentrations in its effluent exceeding the GLWQA objective of 1.0 mg/L for municipal water treatment facilities. Municipal treatment plants discharging to the Thames River in excess of this guideline in 1986 were Chatham, Ingersoll (new), City of London (Adelaide, Greenway, Oxford, Pottersburg and Vauxhall) and the Strathroy Town Plant.

Objective 3. **Necessary and sufficient technology and operation procedures at all wastewater treatment facilities to meet the target concentration of phosphorus in the effluent of no more than 1.0 mg/L.**

Excessive unit area loading of pesticides from agricultural lands into tributaries of Lake St. Clair was identified. Some areas were identified to be of particular concern.

Objective 4. **Reduction in the loadings of pesticides from all tributaries.**

Objective 5. **Identification and elimination of the source of DDT and metabolites to the Milk River.**

Water quality in several tributaries was reduced by the presence of heavy metals. Cadmium concentrations generally exceeded the GLWQA specific objective and PWQO of 0.2 ug/L, and some were greater than the chronic AWQC of 1.1 ug/L in the Belle, Sydenham, Thames and Clinton Rivers. Also, some lead concentrations were in excess of the chronic AWQC of 3.2 ug/L in the Belle and Sydenham Rivers, and in the Thames River some exceeded the acute AWQC of 82 ug/L.

Objective 6. **Identification and elimination of all point sources of Hg, Pb and Cd in the watersheds of the Clinton, Thames and Sydenham Rivers.**

Objective 7. **Elimination of combined storm sewer overflows which will reduce contributions of P, Pb, Cd, Hg and PCBs to Lake St. Clair tributaries.**

2. Sediment Quality

Reductions in industrial loadings of mercury in the St. Clair River have resulted in dramatic improvements since 1970 in the bottom sediments. However, surface concentrations in bottom sediments still exceed the IJC and OMOE guidelines of 0.3 ppm and contain values classified as "polluted" by the U.S.EPA Classification Guidelines. Since recent mercury concentrations of bottom sediment samples do not appear to be reducing as quickly as in the earlier studies there is some concern that unknown tributary sources exist. The mass balance studies of Section E indicate a net outflow of mercury from Lake St. Clair. Since the tributary loadings are not known, it is impossible to determine the source of the mercury.

Objective 8. **Identification and elimination of continuing sources of Hg to the St. Clair River.**

Objective 9. **Identification and elimination of point and non-point sources of Hg to Lake St. Clair tributaries.**

Of the other metals, only zinc and copper exceed the OMOE guidelines in the sediments of the open lake and would result in a classification of sediments as moderately polluted.

Objective 10. **Reduction in heavy metals concentrations in surficial sediments of Lake St. Clair to levels supporting a classification of "not polluted" by OMOE, U.S.EPA and IJC Guidelines.**

The sediment surveys revealed that PCBs did not exceed the guidelines in the open lake. However, guideline concentrations were exceeded in some of the tributary sediments including the Cottrell Drain, the mouth of the cutoff channel of the Clinton River and the Sydenham River. Other organic contaminants with specific guidelines such as HCD, OCS and pesticides were identified in sediments from the open lake and tributaries. In general, the sampling of all tributary sediments was incomplete, so there could be cases of excesses of certain compounds not reported or cases of compounds that were sampled which have no guidelines.

Objective 11. **Elimination of DDT in sediments at the mouth of the Milk River.**

Objective 12. **Identification and elimination of sources of PAHs in sediments from the Milk River, Cottrel Drain, Clinton River and Frog Creek.**

Objective 13. **Reduction in PCB concentrations at the mouths of Lake St. Clair tributaries such that the sediments would be classified as "not polluted" by OMOE, U.S.EPA and IJC Guidelines.**

3. Biota and Habitat

The most significant impaired use of Lake St. Clair waters is the restriction in the consumption of sports fish. A joint fish consumption advisory between Ontario and Michigan remains in effect for the larger specimens of 18 species of sports fish (33). Levels of mercury in excess of Canadian governmental guidelines have been identified as the main contaminant responsible for restricted fish consumption. Because the concentrations of mercury in the tissues of sports fish have declined dramatically since 1970, programs to control the major historical sources of mercury appear to be satisfactory. However, since tributaries were not monitored, smaller, uncontrolled sources could be contributing to the loading.

Objective 14. **Reduction in mercury concentration in Lake St. Clair fish to less than 0.5 mg/kg, and subsequent elimination of the fish consumption advisory based on mercury contamination.**

Objective 15. **Continued reduction in PCB concentrations in fish to meet the GLWQA specific objective of 0.1 mg/kg for protection of birds and animals which consume fish.**

In addition to being an important sports fishery, Lake St. Clair is a major duck hunting area. The habitat necessary for wildfowl resting, feeding and breeding is provided by the extensive wetlands around Lake St. Clair particularly in the Lake St. Clair Delta. More than 9,000 km of wetlands were lost to shoreline development in Lake St. Clair between 1873 and 1968. Losses are most evident in the Clinton River, the St. Clair River Delta and the eastern shore of the lake. In 1979 the state of Michigan prohibited the modification of a wetland over 5 acres in size to restrain encroachment into the wetland areas. In Ontario, subsidies for engineering projects still encourage drainage of wetlands and their conversion to agricultural use. However, tax relief that favors retention of the wetlands has recently (1987) been granted to wetland owners. Although diked Ontario wetlands are effectively managed for waterfowl hunting, there is a loss of other wetland functions, particularly those related to fish production.

Objective 16. **Preservation of remaining wetlands surrounding Lake St. Clair, and protection of them from further diking, filling or other forms of destruction.**

4. Management Issues

In the Clinton River, the concentration and impact of contaminants are sufficiently severe for the area to be recognized as an IJC "Area of Concern". A Remedial Action Plan is in the process of being developed by the State of Michigan for restoring beneficial uses of the area. This plan will contain details of the problems, their extent and causes, and a schedule for remedial actions to be implemented. Plans for further monitoring for results of the actions will also be included.

Objective 17. **Full implementation of the Remedial Action Plan by Michigan and other responsible agencies for clean-up and restoration of uses in the Clinton River.**

Although the Thames River is not presently one the IJC Areas of Concern, many agricultural and industrial contaminants have been identified in the water and sediments, and impaired uses were identified that are similar to those for the Clinton River. The absence of the Thames River on the AoC list should not imply that the area is contaminant-free.

Objective 18. Preparation and implementation by Ontario of a Plan for the restoration of impaired uses in the Thames River. The Plan should address issues of agricultural runoff of nutrients and pesticides, CSOs in the watershed, and sources of heavy metals in the tributary.

G. ADEQUACY OF EXISTING PROGRAMS AND REMEDIAL OPTIONS

1. Projection of Ecosystem Quality Based on Present Control Programs

In general, the ecosystem quality in Lake St. Clair is adequate for the maintenance of a desirable biological community that includes the production of sport fish. Impairment of the biological communities due to contaminants appears to exist only in localized areas around the mouth of some tributaries (although some contaminant levels in fish are sufficient to force the issuance of a fish consumption advisory by Michigan and Ontario), and the loadings of agricultural nutrients have not caused severe eutrophication problems. Loss of habitat due to wetlands destruction, however, has been extensively documented.

The specific concerns addressed in Section B, above, relate mostly to contaminants in the Lake St. Clair basin, and can be grouped into three major categories: nonpoint source loading of contaminants and nutrients, contaminants in tributary water and sediments, and contaminants in fish. Of these categories, insufficient data exist to determine trends in the loading of contaminants from nonpoint sources, including tributaries. However, the concentration of mercury in the edible portions of northern pike, white bass and yellow perch from Lake St. Clair, and of PCBs in walleye from 1970 through 1984 have been declining at a geometric rate (7), indicating that control programs for these two contaminants have been at least partially effective. Evidence for continuing loadings of nutrients, pesticides, PCBs, and heavy metals implies that the rate of decline in contaminant burdens in fish could be greater were no additional contaminants entering the system.

Although the impact of the loading of the UGLCCS parameters to Lake St. Clair directly may appear to be minimal, consideration must be given to the ultimate impact on Lake Erie populations. Lake St. Clair may be storing HCB and HCBD, but it is a source for PCBs and total phosphorus. These contaminants are then transported through the Detroit River and should be accounted as loadings to Lake Erie.

2. Assessment of Technical Adequacy of Control Programs

Present Technology

In 1985, inputs of nine of the UGLCCS parameters were determined to be significant, resulting in impacts to either water, sediment or biota quality. These were cadmium, copper, cyanide, lead, mercury, nickel, PCBs, phosphorus and zinc. In general, discharge of these parameters from point sources was not controlled by limitations or objectives. All of the surveyed point sources were municipal facilities, and all were subject to discharge limitations mainly for conventional parameters. However, for many of the parameters, point sources were not the most significant contributors. Rather, the largest loading was obtained from unidentified sources discharging through tributaries.

The control of phosphorus has been the main approach of the U.S. and Canada to remediating the eutrophication of the Great Lakes. All municipal plants surveyed in the Lake St. Clair basin had average concentrations less than 1 mg/L, except the Mt. Clemens WWTP. The GLWQA Objective, the Canadian Municipal effluent Objective, and the standard Michigan permit limit for phosphorus is 1.0 mg/L monthly average in sewage plant effluent. The Mt. Clemens WWTP exceeded the 1 mg/L average frequently in 1986 according to self-monitoring data. An expansion and improvement of the facility is underway (1987) which will enable the plant to meet the limitation.

Excluding input from the St. Clair River, the Thames River provided the largest loading of phosphorus to Lake St. Clair, exceeding the contributions made by the point sources by a factor of about 16. Similarly, the Sydenham and Clinton Rivers exceeded the point source loadings by factors of 7 and 3 respectively. Atmospheric loading to the lake was less than 5% that from the Clinton River. This indicates that these rivers were receiving substantial inputs of phosphorus from other sources, and that controls were not adequate or effective. The most probable route is drainage of phosphorus from agricultural uses and livestock operations. The application rates in Michigan and Ontario were found to be 2 and 3 times the recommended rates, respectively, and the use of conservation tillage techniques were not widespread.

Likewise, excluding input from the St. Clair River, the Thames River provided the largest loading of cadmium to Lake St. Clair, almost twenty times greater than all point sources combined. Of the three point sources that were found to discharge cadmium, none did so to the Thames River. The loading from the Sydenham River was 34 times greater than accounted for by the Wallaceburg WWTP, and the loading from the Clinton River was 11 times that of the two WWTPs that discharged Cd. None of the facilities had site-specific permit limits or objectives for Cd. However, the evidence indicates that all three rivers were receiving significant inputs of cadmium from other sources, perhaps from air deposition or use of cadmium-contaminated phosphate fertilizer (48). Estimated loading of Cd to Lake St. Clair from the atmosphere was approximately the same at that from each of the Sydenham and Clinton Rivers.

The Thames River also provided over 100 times the loading of Pb than all the surveyed point sources combined, and three times the loading from the St. Clair River. The Clinton and Sydenham

Rivers each contributed more than 10 times the quantity of lead than did the point sources, and the atmospheric loading was estimated to be similar to that of the Clinton and Sydenham Rivers. Clearly the loading of lead to Lake St. Clair from unidentified sources in the tributary basins was more significant than from the point sources, which did not have effluent limitations or objectives for lead.

Mercury contamination in Lake St. Clair has resulted largely from historical inputs through the St. Clair River. However, inputs may still be occurring, as evidenced by sediment surveys and by the mass balance calculations presented in Section E, above. Although none of the point sources surveyed had effluent limitations or objectives for the discharge of mercury, point source loadings accounted for only 0.0157 kg/d of an estimated 2.3 kg/d source in the Lake St. Clair basin. The source could include the contaminated sediments themselves. Loading estimates from the tributaries and atmosphere were not available for this study.

The Clinton River also contributed significant loads of PCBs to Lake St. Clair. Both the Warren WWTP and Mt. Clemens WWTP serve large communities with substantial industrial bases, and both had industrial pretreatment programs in place. Neither reported specific sources of PCB in their service areas, and neither had permit limits for PCB at the time of the survey. PCBs were not found in three Ontario WWTPs. Although the Canadian MDL was 1,000 times greater than that in the U.S., the PCB concentrations in the U.S. sources were much higher than the Canadian MDL.

Michigan and Ontario both recommend zero discharge of PCB. Michigan is now using a water quality based effluent limit of 1.2 X 10^{-5} ug/L in some NPDES permits, the allowable effluent guideline calculated using the State's Rule 57(2). The level is below any current MDL, so the permits also contain an interim limit of detection at 0.2 ug/L, the MDL commonly achieved with routine monitoring methods. The permittee is further required to develop a plan to meet the water quality based limit.

The Warren WWTP, Mt. Clemens WWTP, Rochester WWTP and Pontiac WWTP all operate an industrial pretreatment program, receiving waste water from industries in their area. Due to the quantities of contaminants coming from these facilities, however, the pretreatment requirements of these facilities and/or the compliance by the contributing industries with the requirements may be suspect.

Similarly, the Chatham WWTP receives industrial waste water, and it provided the largest loading of oil and grease and the third largest loading of nickel to the Lake St. Clair Basin. The quality of the waste water it receives may also be suspect and not in compliance with the Ontario By-Law to control the receipt of contaminants from industrial sources.

Best Available Technology

Discussions concerning the adequacy of "best available technology" (BAT) for reducing or eliminating loadings of contaminants to Lake St. clair are premature until specific sources of the loadings are defined. No direct industrial discharges occur to Lake St. Clair, but elevated levels of contaminants were found in the water and sediments of many tributaries, implying that sources may exist upstream. Should specific sources of contaminants be identified, then an assessment of the impact of BAT may be made for that industry on the receiving stream and on Lake St. Clair.

Because phosphorus is found to be coming from agricultural practices, the implementation of conservation tillage and reduced fertilizer application rates should greatly reduce the magnitude of the loadings of P to the system. Likewise, reductions in phosphorus loadings from municipal and industrial effluent, if needed, can be achieved with improved facility design and operations. Urban nonpoint source runoff, however, may be more difficult to control.

Additional efforts are needed to identify the sources of mercury loadings to Lake St. Clair. If internal loadings from the contaminated sediments are found to be significant, active control technology might be infeasible. Techniques for dealing with in-place polluted sediments is a topic for current research, and demonstration projects are expected to be established within the next several years by U.S.EPA. However, technology for treating contaminated sediments is expected to be applicable to localized areas, including harbors and restricted tributary mouths, but not appropriate for a whole lake basin. Given the rather short residence time of sediments in Lake St. Clair, in the order of 10 years, the problem of contaminated sediments could be resolved for Lake St. Clair through natural processes. However, continued problems would be expected in the western basin of Lake Erie.

3. Regulatory Control Programs Applicable to Lake St. Clair

A detailed discussion of regulatory programs in the UGLCCS regions may be found in chapter III. The following programs have particular impact on Lake St. Clair. The Clinton River is one of the Areas of Concern as designated by the International Joint Commission. As part of the effort to develop and implement a Remedial Action Plan (RAP) for the river basin, the State of Michigan has begun intensive remedial activities in the area (49). All major NPDES permits in the Clinton River basin were reviewed and new water quality based or technology based effluent limits (whichever was more restrictive) were developed in 1985. Metals, organics and conventional pollutants were included. A pretreatment program for process industrial wastewater was implemented throughout the Clinton River basin as of 1987, and upgrades to four WWTPs were completed in 1986 and 1987. Full details of the remedial programs and schedule for implementation will be included in the RAP, which is expected to be submitted to the IJC in 1988.

Where stormwater is determined to impact water quality in Michigan, the stormwater provisions (section 405) of the U.S. Water Quality Act of 1987 will be implemented to correct the problem. The State 305 (b) report will be reviewed in 1988 to determine if any of the Upper Great Lakes Connecting Channels areas are impacted by stormwater runoff.

Some technical and educational programs for farmers are in existence. For example, a Canadian Federal and Provincial effort called the Soil and Water Environmental Enhancement Program (SWEEP) encompasses all aspects of soil and water conservation. Within the SWEEP program, a provincial program called the Ontario Soil Conservation Environmental Protection Assistance Program exists which will financially assist the farmer in implementing soil and water conservation practices with up to 67% funding. A Land Stewardship Program has also recently been announced to assist farmers in the implementation of conservation techniques. All of these programs should assist in achieving reduced phosphorus and pesticide contamination in streams.

The preservation of wetlands in Lake St. Clair has been assisted by three relatively recent laws enacted by the State of Michigan: 1) The Great Lakes Submerged Lands Act (1955) which prohibits constructing or dredging any artificial body of water that would ultimately connect with a Great Lake, and which requires a permit from MDNR to fill any submerged lands, including Lake St. Clair; 2) Shorelands Protection and Management Act (1970) which designates wetlands adjacent to a Great Lake as environmental areas necessary to preserve fish and wildlife; and 3) The Goemaere-Anderson Wetland Protection Act (1979) which regulates wetlands through several laws relating to shorelands and submerged lands (36).

H. RECOMMENDATIONS

A. Industrial and Municipal Point Source Remedial Recommendations

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

2. The City of Mt. Clemens should determine the source of PCBs, total phenols and mercury in the WWTP effluent and, through pretreatment or in-plant controls, reduce the concentrations of these pollutants to acceptable levels. Effluent limitations for these parameters should be considered. Phosphorus concentrations in the effluent should be lowered to meet the 1 mg/L Great Lakes Water Quality Agreement objective.

3. Site specific effluent limitations for total cadmium, total copper, total chromium and total nickel to protect the water quality for the Sydenham River and Lake St. Clair should be developed for the Wallaceburg WWTP. The operation of the plant should be optimised to meet the Ontario industrial effluent objective of 10 mg/L for ammonia.

4. The Warren WWTP should determine the source of PCBs in its effluent and take the necessary steps to reduce the concentration to acceptable levels.

B. Nonpoint Source Remedial Recommendations

5. Agricultural areas with high rates of wind erosion need to be targeted for assistance due to the characteristics of wind transported soil (fine textured, high enrichment ratio, and high organic matter content) and its ability to transport nutrients and agrichemicals. The relatively low erosion rates and high percentage of wind erosion in combination make conservation tillage the most practical conservation practice to be recommended. The primary reasons for this are the effectiveness of residue cover in reducing wind erosion and the low cost of implementing the practice. Conservation tillage is recognized as being highly cost-effective and physically effective in areas of sandy soils where wind erosion is a problem. If conservation tillage were applied to all cropland eroding over the soil tolerance level, with a resulting compliance with the tolerance level, a 32% reduction in phosphorus loading from cropland could be achieved.

6. Rural landowners need to implement, with the assistance of Federal, State and Provincial governments, a comprehensive

soil and water management system in order to control, at source, the contribution of conventional and organic pollutants including manure and pesticides to surface and groundwater. Specifically:

a. Agricultural and conservation agencies need to accelerate the implementation of control technologies through technical, financial and information/education programs. There is a need for extension, education and incentives to persuade farmers to implement conservation management systems including cropping, tillage and structural practices, nutrient and pesticide management technology, thereby reducing the movement of soil, conventional pollutants and contaminants off their land into the waterways.

b. Environmental and agricultural agencies should assess the adequacy of existing controls, regulations and permits for the use of fertilizer and pesticide products.

c. Specific programs, especially in Macomb County, MI, should be directed at reducing the excessive levels of phosphorus fertilization, improving the management of animal waste disposal and storage, and educating pesticide users with respect to handling, application and storage of pesticide products.

7. Future assessment and control of agricultural nonpoint sources of pollution would be facilitated by compatible Federal, State and Provincial monitoring data and more frequent flow-weighted tributary monitoring data. The small water quality monitoring data set available for tributaries indicated the need for increased sampling for all parameters, especially flow weighted data. The lack of samples in high flows created difficulty in calculating representative loads as well as understanding seasonal patterns of pollutant transport. More samples on high flow days would improve the basis for pollution control strategies.

8. Macomb and St. Clair Counties, Michigan, should be targeted for fertilizer management. U.S.EPA Region V has requested the USDA-SCS Michigan State Office to develop standards and specifications for a nutrient, best management practice that would protect ground and surface waters as well as sustain crop production. The Michigan Departments of Agriculture and Natural Resources are developing a joint action plan to manage livestock waste problems that includes best management practices for proper animal disposal that gives attention to air and water pollution from concentrated animal operations. This program may require a system of

permits for concentrated feeding operations.

9. The CSOs from municipal wastewater treatment plants should be intensively surveyed to determine their contribution of pollutant loadings to the surface waters. In the long term (due to enormous cost) combined sewers in all municipalities should be eliminated. In the interim, the municipalities should institute in-system controls to minimize the frequency and volume of overflows.

10. The Michigan Pollution Emergency Alerting System and the Ontario Spills Action Centre spills reports should be improved so that all information on recovery, volume (if known) and final resolution are fed back to the central reporting system to complete each report for inventory purposes.

11. The Superfund Site Investigations to be undertaken at Selfridge ANGB should focus on groundwater and surface water runoff impacts upon Lake St. Clair and the Clinton River. In the event that this site is not included on the U.S. National Priorities List, the State of Michigan should place high priority upon cleanup on this site.

12. Michigan should require groundwater monitoring as a permit condition for the Sugarbush solid waste landfill.

13. Michigan should include groundwater monitoring as part of the RCRA Generators permit for G and L Industries.

C. Surveys, Research and Development

14. Data interpretation would be facilitated by the development of more complete water quality objectives for the organic pollutants and pesticides that are used extensively by the agricultural industry. Currently, water quality objectives do not exist for many parameters that are measured. Although meeting water quality objectives does not guarantee "no impact" of a contaminant, the objectives do provide a point of reference for assessing the relative potential for negative impacts of various contaminants in the aquatic system.

15. The presence of organic contaminants (PCBs, HCBs and OCS) in the Canadian tributaries illustrates the need to locate the contaminant sources.

16. The cadmium content of the phosphate fertilizer that is being used on agricultural lands should be determined.

17. A study of atmospheric deposition of organic contaminants, particularly PCBs, to Lake St. Clair and to the tributary watersheds would provide quantitative information on loading of these contaminants to the lake. The loading estimates are important for mass balance calculations and the identification of unknown sources of the contaminants.

18. Urban runoff was identified as being a potentially major nonpoint source of many parameters,including PCBs, oil and grease, zinc, mercury, copper and nickel. The loadings from urban runoff, however, were based on contaminant concentrations from Canadian urban areas outside of the Lake St. Clair basin. Therefore, the loading information provide only a general potential for urban runoff to contribute contaminants to Lake St. Clair. A study should be performed to determine the contribution actually made by urban runoff on the Michigan shore where the shoreline is more urbanized than is that of Ontario.

19. The sediments near the mouth of the Clinton, Sydenham and Thames Rivers contain contaminants that may be impairing benthic communities. Studies are needed to document possible impairment of benthic communities of these sites. Appropriate actions to remedy any observed problems will need to be defined. Techniques and technologies for remediating in-place polluted sediments should be developed.

20. Recognizing that the biological effects of a substance are dependent in part on the chemical species of that substance, studies should be conducted to identify the chemical species and valances of the heavy metals in Lake St. Clair and its tributaries. For those forms which are present but for which toxicity information is lacking in the literature, toxicity and bioaccumulation experiments should be conducted on appropriate target organisms.

21. The evaluation of the point source data has been conducted on a parameter by parameter basis. In order to assess the quality of whole effluents, it is recommended that biomonitoring studies, both acute and chronic, be conducted at the major facilities (Wallaceburg WWTP, Chatham WWTP, Warren WWTP, and Mt. Clemens WWTP).

22. An inventory of all point sources, hazardous waste sites, urban and rural runoff, and spills discharging or potentially discharging to the Clinton River should be collected. These facilities, sites or incidents should then be examined for their potential to contribute chemicals to the Clinton River.

23. A more complete analysis of sediment, water and biota quality along the entire stretch of the Clinton River is

needed. Such information would establish the locations of sources of contaminants.

24. The Thames and the Sydenham Rivers were found to be major contributors of phosphorus, ammonia, lead and cadmium. An inventory of all point sources, hazardous waste sites, urban and rural runoff and spills discharging to these rivers should be collected. These facilities, sites or incidences should then be examined for their potential to contribute chemicals to the rivers.

I. LONG TERM MONITORING

1. Purposes for Monitoring and Relationships Between UGLCCS and Other Monitoring Programs

A presentation of the purposes for monitoring and surveillance activities is included under Annex 11 of the 1978 GLWQA, and a discussion of considerations for the design of a long term monitoring program can be found in Chapter 7 of the Report of the Niagara River Toxics Committee (50). Because the focus of the UGLCC Study was toward remedial actions to alleviate impaired uses of the Connecting Channels System, long term monitoring recommendations will likewise focus on the evaluation of trends in environmental quality in order to assess the effectiveness of remedial actions. In general, post-UGLCCS monitoring should be sufficient to 1) detect trends in system-wide conditions noted by the UGLCCS, and 2) detect changes in ambient conditions which have resulted from specific remedial actions. Monitoring programs should be designed to specifically detect the changes intended by the remedial actions so as to ensure relevance in both temporal and spatial scales.

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

Lake St. Clair is not one of the AoCs, although the Clinton River in Michigan is, and a RAP is being developed by Michigan for the Clinton River. The RAP will present details of uses impaired, sources of contaminants, specific remedial actions, schedules for implementation, resources committed by Michigan to the project, target clean-up levels, and monitoring requirements. Results and recommendations coming from the UGLCC Study will be incorporated extensively into the RAP, which will then be the document that influences Michigan programs in the Clinton River. The recommendations for long term monitoring that are presented below are intended for consideration and incorporation into either or both the GLISP for the Upper Great Lakes Connecting Channels, and the RAP for the Clinton River.

2. System Monitoring for Contaminants

Water

Knowledge of the concentrations of the principal contaminants in the water of Lake St. Clair should be used to indicate general exposure levels for the biota, to identify changes and trends over time in the concentration levels, and to be used for general assessment of contaminant impacts. The parameters to be monitored include phosphorus, PCBs, mercury, lead, and cadmium. Near tributary mouths, concentrations of ammonia, total phenols, pesticides, Cu, Ni and PAHs should also be determined. Monitoring stations should be located to coincide with identified water use areas, such as biota habitat, and with contaminant entry points to the lake. Suggested locations include the mouth of the St. Clair River at Port Lambton, around the St. Clair Delta, at the mouth of the Clinton, Sydenham, and Thames Rivers, and at the head of the Detroit River. Sampling frequency should be influenced by the variability in contaminant sources. Spring high flow conditions and late summer low flow conditions would be expected to bracket the normal seasonal variability in flow that could influence measured contaminant concentrations.

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

1) Head and mouth transects. The number and location of stations should relate to measured and predicted plume distributions. Suggested locations include the mouth of the St. Clair River at Port Lambton and the head of the Detroit River. Dispersion modeling and past sampling results should be used to predict contaminant concentrations and therefore to establish appropriate collection and analytical methodology. Both dissolved and particulate fractions should be analyzed. The quantity of suspended sediment flux should also be measured.

2) Municipal and industrial point sources. No direct industrial sources are considered to be major contributors of contaminants to Lake St. Clair. The principal municipal sources all discharge to tributaries. Thus, special monitoring consideration should be given to the Sydenham, Thames and Clinton Rivers to fully address municipal loadings of the contaminants.

3) Tributaries. Efforts should be focused on seasonal and storm event loadings of contaminants to Lake St. Clair from the Clinton, Sydenham and Thames Rivers. Tributary mouth stations should be sampled and analyzed for both dissolved and sediment-associated contaminant loadings.

4) CSOs and Urban Runoff. To provide an estimate of contaminant mass loadings expected during storm events, occasional studies on selected urban drainage areas should be conducted, particularly for the Michigan shoreline.

5) Groundwater inflow. The quantity and quality of potential contaminant releases from waste disposal sites adjacent to Lake St. Clair or its tributaries should be determined.

6) Sediment transport. Efforts to measure and model sediment transport to, within and from Lake St. Clair should be continued. The quantity of contaminants being desorbed from the sediments should be determined in order to assess loadings from these in-place polluted sediments.

7) Atmospheric deposition. Monitoring of wet and dry atmospheric deposition to Lake St. Clair should continue, and should be expanded to include organic contaminants. Volatilization losses of organics should also be quantified.

Sediments

Monitoring of sediments for concentrations of contaminants should be conducted periodically throughout Lake St. Clair in order to assess both the trends in surficial contaminant concentrations and the movement of sediment-associated contaminants within the Lake. The grid used by the U.S. Fish and Wildlife Service during the 1985 survey would be appropriate for consistency in sampling sites and sediment composition. An analysis of sediment chemistry including bulk chemistry, organic and inorganic contaminants, and particle size distribution should be conducted every five years, in conjunction with a biota survey (see "habitat monitoring" below).

In Lake St. Clair, particular attention should be given to sediment concentrations of PCBs and mercury. Additional stations should also be established at the mouth of the Clinton, Sydenham and Thames Rivers and at Chenal Ecarte to track effects of remedial actions in the tributary watersheds to reduce loadings of these materials.

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

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

Biota

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

i) Annual or Bi-Annual Monitoring of Sport Fish.

This program should focus especially on PCBs, mercury and/or other contaminants (e.g. dioxins and dibenzofurans) that are considered to be known or suspected health hazards. The monitoring should be continued regardless of the differences that may be observed between acceptable concentrations or action levels that may be established by governmental agencies and the measured contaminant concentrations in the fish flesh. As a link between human health concerns and integrated results of remedial programs to reduce contaminants in the UGLCCS system, this program is critically important.

ii) Spottail Shiner Monitoring Program.

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

iii) Caged Clams Contaminants Monitoring.

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

3. Sources Monitoring for Results of Specific Remedial Actions

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

For Lake St. Clair, seven actions were recommended that would affect specific sources of contaminants, and that would require site-specific monitoring for compliance or other effects of the action at the following locations: Macomb and St. Clair Counties, Michigan (fertilizer management); Mt. Clemens WWTP (PCBs, phenols, mercury, phosphorus); Wallaceburg WWTP (Cd, Cu, Cr, Ni, ammonia); Warren WWTP (PCBs); Selfridge Air National Guard Base (several contaminants); Sugarbush landfill, Michigan (groundwater monitoring); and G and L Industries, Michigan (groundwater monitoring).

Other recommendations for specific contaminant sources involve an assessment of the present conditions or a study to quantify concentrations or loadings: quantify CSOs from municipal waste water treatment plants, identify sources of organic contaminants in tributaries; determine Cd content of phosphate fertilizer, measure atmospheric deposition of organic contaminants; measure loadings of contaminants from urban runoff; conduct biomonitoring studies at WWTP's; inventory point sources and waste sites discharging to the Clinton River; analyze sediment, water and biota quality along the Clinton River; and inventory point sources and waste sites discharging to the Sydenham and Thames Rivers. Each of these items requires a specific program of data collection and analysis. Additional needs for longer term monitoring may be identified as a result of these studies.

4. Habitat Monitoring

Habitat monitoring should be conducted to detect and describe changes in the ecological characteristics of Lake St. Clair through periodic analysis of key ecosystem elements. The following items are recommended:

a) The abundance and distribution of the mayfly Hexagenia should be determined every five years. The grid used by the U.S. Fish and Wildlife Service during the 1985 survey would be appropriate for consistency in sampling sites each survey. An analysis of sediment chemistry, including bulk chemistry, organic and inorganic contaminants, and particle-size distribution, should be conducted for samples taken concurrently with the Hexagenia survey. These data will provide information on the quality of the benthic habitat for a common pollution sensitive organism that would serve as an indicator species of environmental quality.

b) Quantification of the extent of wetlands along Lake St. Clair should be conducted every five years, in conjunction with the Hexagenia survey. Aerial photography or other remote sensing means would be appropriate to discern both emergent and submergent macrophyte beds that are important as nursery areas for larval fish and other wildlife. Verification of areal data should be conducted by inspection of selected transects for plant species identification and abundances. Changes in wetland areas should be correlated with fluctuating water levels and other natural documented influences so that long term alterations in wetlands can be tracked and causes identified.

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