LAKEWIDE MANAGEMENT PLAN FOR LAKE ONTARIO

Stage 1: Problem Definition

May 1998

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ACRONYMS

AOC	Area of Concern
ARCS	Assessment and Remediation of Contaminated Sediments
ARET	Accelerate Reduction/Elimination of Toxics
BCC	Bioaccumulative Chemicals of Concern
CEPA	Canadian Environmental Protection Act
COA	Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem
CSO	Combined Sewer Overflow
CWS	Canadian Wildlife Service
DFO	Department of Fisheries and Oceans (Canada)
EEM	Environmental Effects Monitoring
EC	Environment Canada
GIS	Geographic Information System
GLIMR	Great Lakes Information Management Resource
GLIN	Great Lakes Information Network
GLRC	Great Lakes Research Consortium
GLWCAP	(Canada's) Great Lakes Wetlands Conservation Action Plan
GLWQA	Great Lakes Water Quality Agreement
GLWQG	Great Lakes Water Quality Guidance
IJC	International Joint Commission
LaMP	Lakewide Management Plan
LOTMP	Lake Ontario Toxics Management Plan
MISA	Municipal and Industrial Strategy for Abatement
MNR	Ontario Ministry of Natural Resources
MOU	Memorandum of Understanding
MOE	Ontario Ministry of the Environment
NPDES	National Pollutant Discharge Elimination System
NRTMP	Niagara River Toxic Management Plan
NYSDEC	New York State Department of Environmental Conservation
OLMC	Onondaga Lake Management Conference
OMAFRA	Ontario Ministry of Agriculture, Food, and Rural Affairs
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PISCES	Passive In-Situ Chemical Extraction Samplers
PPA	Performance Partnership Agreement
PSL	Priority Substances List
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
SPDES	State Pollutant Discharge Elimination System
TSDF	Transfer, Storage and Disposal Facility
USACE	U.S. Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USF&WS	U.S. Fish and Wildlife Service

Note: Please refer to the glossary in Appendix A for definitions of technical terms. For your convenience, each term appearing in the glossary is italicized the first time it is used in the text.

CHAPTER 1 INTRODUCTION

1.1 Background and Purpose

In 1987, the governments of Canada and the United States made a commitment, as part of the Great Lakes Water Quality Agreement (GLWQA), to develop a Lakewide Management Plan for each of the five Great Lakes. The purpose of a Lakewide Management Plan (LaMP) is to identify the actions necessary to restore and protect the lake. There are a number of important principles that guide the development of LaMPs. According to the 1987 Agreement, "LaMPs shall embody a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses in ... open lake waters", including consultation with the public. LaMPs will also provide an important step towards the virtual elimination of persistent toxic substances and the restoration of "physical, chemical, and biological integrity" (IJC, 1987) of the lakes. Through a LaMP, efforts will be coordinated among governmental agencies to reduce amounts of contaminants entering the lake and address causes of lakewide environmental problems. Plans are being developed in four stages: problem definition (Stage 1), schedule for load reduction activities (Stage 2), selection of remedial measures (Stage 3), and successful results as documented by monitoring (Stage 4).

***The 1987 Great Lakes Water Quality Agreement* calls for achieving common water quality objectives, improved pollution control throughout the basin, and continued monitoring. It focuses on restoring and maintaining "the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem...the interacting components of air, land, and water and living organisms including man within the drainage basin of the St. Lawrence River."**

This Stage 1 LaMP for Lake Ontario has been developed by Region II of the U.S. Environmental Protection Agency (USEPA), Environment Canada (EC), the New York State Department of Environmental Conservation (NYSDEC), and the Ontario Ministry of the Environment (MOE) (the Four Parties) in consultation with the public. It identifies the progress seen to date in the lake as a result of actions already implemented and proposes future actions that the Four Parties can take, individually or jointly, to address identified problems.

One of the challenges of the LaMP is to understand the state of Lake Ontario as it exists today and how it may change in the near future and over the long term. Concentrations of toxic substances in water, sediment, fish, and wildlife respond at different rates to changes in loadings and changes in biological or physical conditions. Programs in place today which have already reduced critical pollutant loadings may not have an impact on environmental levels for decades, particularly in fish and wildlife. This time lag must be considered when evaluating data which were often collected several years before being reported and which reflect loadings which occurred many more years before data collection. Organisms accumulate chemicals or metals that have been in the ecosystem for long periods of time, either in sediment or in organisms which are lower on the food chain. Estimating if current programs will eventually resolve some of these ecosystem issues and over what time frame is an important step in understanding what additional measures are necessary to accelerate the cleanup of Lake Ontario.

The Plan will build on existing programs that are being implemented in the Lake Ontario basin to manage toxic substances. Additional information beyond that which is required for Stage 1 has been included where available (i.e., some remedial measures have been or are being implemented and monitoring programs have indicated improvements). The Four Parties will continue to develop Stages 2 through 4 with public input over the next several years.

This report has taken a number of years to produce. As part of this process, the Four Parties agreed that the cut-off date for adding new information would be November 1996. It is therefore recognized that, in some cases, the background information requires updating. In other cases, new information needs to be reviewed and assessed relative to the conclusions expressed in this report. The binational workplan acknowledges this need and presents a schedule for updating the current data base.

1.2 Physical and Environmental Features of the Lake Ontario Basin

Lake Ontario is the last of the chain of Great Lakes that straddle the Canada/United States border. Its shoreline is bordered by the Province of Ontario on the Canadian side and New York State on the U.S. side (see Figure 1-1). Lake Ontario is the smallest of the Great Lakes, with a surface area of 18,960 km2 (7,340 square miles), but it has the highest ratio of watershed area to lake surface area. It is relatively deep, with an average depth of 86 meters (283 feet) and a maximum depth of 244 meters (802 feet), second only to Lake Superior. Approximately 80 percent of the water flowing into Lake Ontario comes from Lake Erie through the Niagara River (USEPA *et al.*, 1987). The remaining flow comes from Lake Ontario basin tributaries (14%) and precipitation (7%). About 93 percent of the water in Lake Ontario flows out to the St. Lawrence River; the remaining 7 percent leaves through evaporation. Since Lake Ontario is the downstream Great Lake, it is impacted by human activities occurring throughout the Lake Superior, Michigan, Huron, and Erie basins.

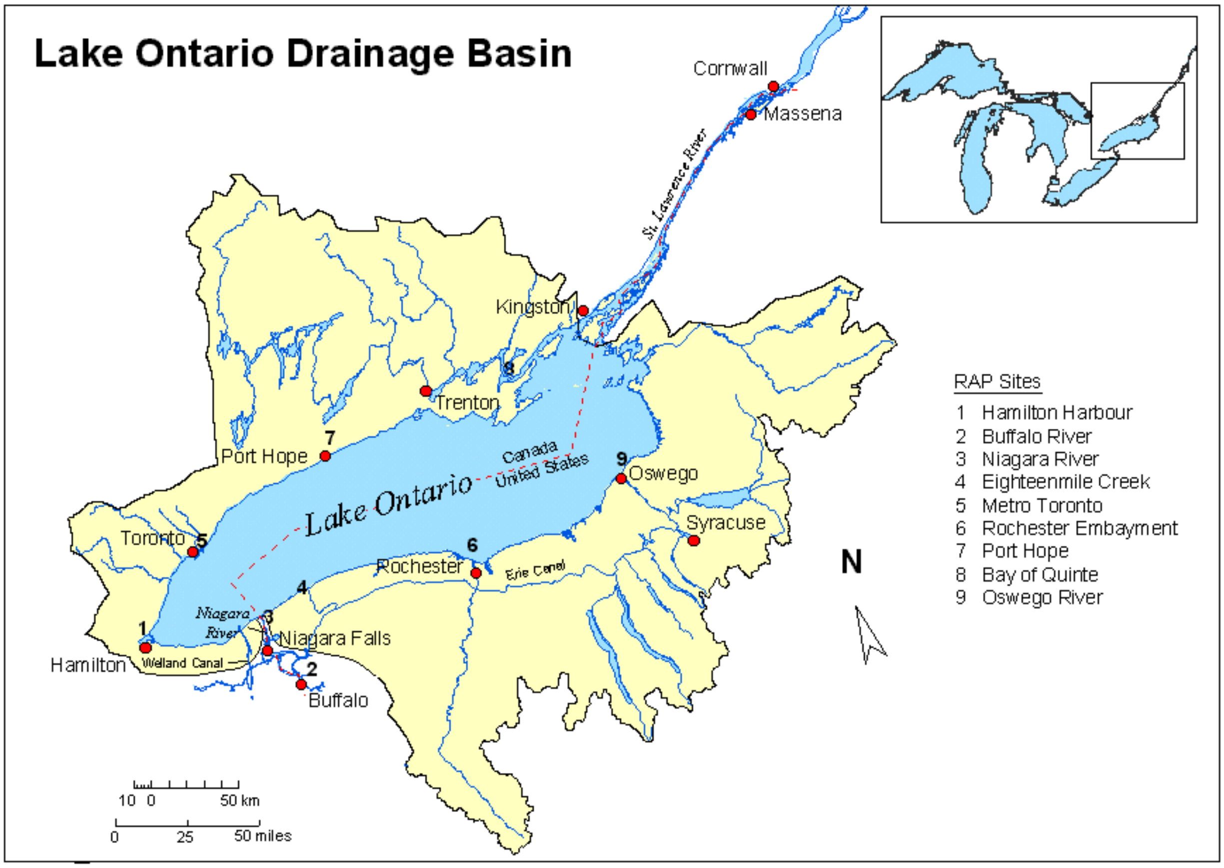


Figure 1-1. Lake Ontario Drainage Basin

Climate

The climate of the entire Great Lakes basin is characterized as humid and temperate (USEPA *et al.*, 1987). The position and size of each lake, together with the effects of outside air masses, further influence climate. Each lake acts as a heat sink, absorbing heat when the air is warm and releasing it when the air is cold. This results in more moderate temperatures at nearshore areas than other locations at the same latitude. The influence of external air masses varies seasonally. In the summer, the Lake Ontario basin is influenced mainly by warm humid air from the Gulf of Mexico, whereas in winter the weather is influenced more by Arctic and Pacific air masses.

Physical Characteristics and Lake Processes

There are two main sedimentary basins within Lake Ontario: 1) the Kingston Basin, which is a shallow basin located northeast of Duck-Galloo Island; and 2) a deeper main basin that covers the rest of the lake (see Figure 1-2). Within the main basin there are three deep sub-basins: the Rochester, Mississauga, and Niagara Basins. These basins are bordered by a shallow inshore zone that extends along the perimeter of the main basin.

Lake Ontario has a seasonally dependent pattern of both horizontal and vertical *thermal stratification*. In the spring, nearshore water warms more quickly than the deep offshore waters. The density of water varies with temperature, resulting in little mixing between these waters. The lake becomes stratified vertically between the nearshore and the offshore zones (except in the Kingston Basin which is shallow throughout). This thermal stratification lasts until around the middle of June when offshore waters warm and mixing occurs between offshore and nearshore waters. For the rest of the summer, there is horizontal stratification between the warm surface waters (epilimnion) and cool deeper waters (hypolimnion). The depth of the *thermocline* varies between sub-basins. Summer water temperatures are generally warmer in the southwest end of the lake and cooler in the northwest end. Mixing of the waters in the epilimnion and the hypolimnion begins during September, when the surface waters have cooled, and continues until *isothermal* conditions occur. During the winter months, inshore areas freeze (including Kingston Basin) but deep waters remain open.

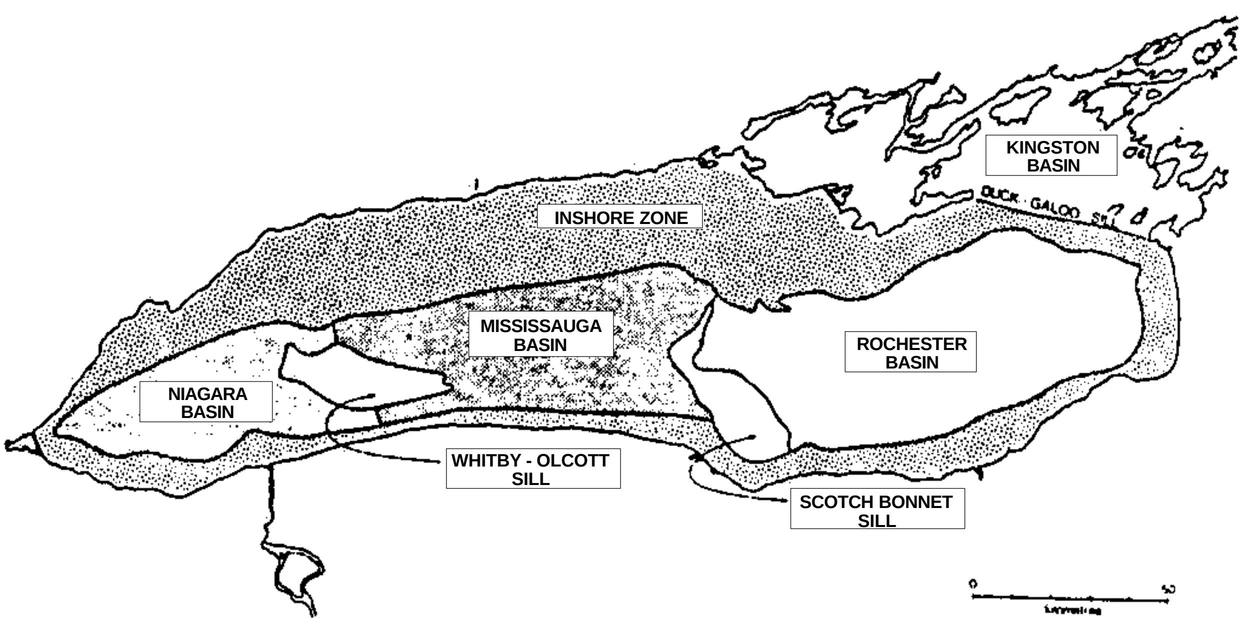


Figure 1-2. Sedimentation Basins in Lake Ontario (Thomas, 1983).

The prevailing west-northwest winds combined with the eastward flow of water from the Niagara River are the most important influences on lake circulation resulting in a counter-clockwise motion (Sly, 1990). Circulation of water generally occurs along the eastern shore and within sub-basins of the main lake. There is very little net flow along the north inshore zone.

Circulation patterns, sedimentation rates, and thermal stratification influence the effects of human activities on the lake. Although water retention time in the lake is estimated to be about seven years, based on inflow and outflow rates it may take much longer for substances such as toxic chemicals to leave the lake (Sly, 1991). Contaminants may bind to sediments on the lake floor, be covered over, and remain indefinitely. Alternatively, contaminants may be resuspended to the water column or ingested by benthic organisms and be introduced to the food chain. In the summer when the lake is stratified, only water from the epilimnion flows out into the St. Lawrence River, but during the winter months when the water is thoroughly mixed, water from the deeper parts of the lake reaches the St. Lawrence. MacKay (1989) suggests that, for some persistent toxics, the lake will actually cleanse itself quicker than reported by Sly.

The trophic status of the lake has been influenced by human activities. Prior to European settlement, Lake Ontario was *oligotrophic*. In the 1960s and 1970s, excess nutrients in the form of phosphorus (from household detergents, for example) caused excess algae growth. The trophic status of the main basin changed from oligotrophic to *mesotrophic*, and many nearshore areas became *eutrophic*. Phosphorus controls were implemented in the 1970s and have been successful in reducing the amount of nutrients entering the lake. Phosphorus levels, which were over 20 ug/L in the 1970s have dropped to less than 10 ug/L since 1986 (Neilson *et al.,* 1994) indicating that the lake is returning to its original oligotrophic condition. The filtering action of zebra and quagga mussels are also thought to have had a role in improving the trophic status of the lake.

Aquatic Communities

The aquatic communities of Lake Ontario are indicative of the trophic status of the lake. Benthic communities in the Kingston and main basins are dominated by the aquatic crustacean, *Diporeia*, a species characteristic of oligotrophic conditions. Benthic communities in most nearshore areas are now totally dominated by zebra and quagga mussels, although oligochaete worms dominate this community in some nearshore areas, reflecting the eutrophic status of these areas. Zooplankton communities are dominated by side-swimmers, and water fleas (cladocerans and cyclopoid copepods). *Diatoms* and green algae are the most common types of phytoplankton. Mysis, a form of freshwater shrimp, is a very important part of the pelagic *food web*.

The fish communities of Lake Ontario have changed significantly since the 1700s when Europeans first settled along the shores of Lake Ontario. These changes have resulted primarily from human activities including destruction of habitat, overharvesting, the introduction of exotic species, and increased nutrients. Historically, as an oligotrophic lake, Lake Ontario's top predators were lake trout, Atlantic salmon, and burbot. The main forage species were lake herring, lake whitefish, and deepwater sculpin. As early as the 1830s, concerns existed about the decline in Atlantic salmon populations, and this species had disappeared by the late 1800s. Lake trout and burbot populations were almost eliminated in the 1940s. By the 1950s, natural populations of lake trout and deepwater sculpin no longer existed in Lake Ontario.

Charter Fishing
(Michigan Sea Grant)

In addition to severe declines in a number of fish populations, other fish community changes have occurred, resulting from the introduction (both accidental and intentional) of exotic species. Over the past 100 years, exotic forage fish such as alewives, rainbow smelt, and white perch became established and filled open ecological niches. Government stocking programs have also influenced the fish communities of the lake. Stocking of lake trout began as early as the 1890s, but it was not until the 1970s that effective sea lamprey control and expanded stocking programs for several salmonid species resulted in the development of a significant sport fishery for salmon and trout in Lake Ontario and many of its tributaries.

Presently, chinook salmon, coho salmon, and brown trout populations are maintained primarily through stocking programs; very limited natural reproduction of these species has been documented in a few tributary systems. Stocking programs for lake trout and Atlantic salmon are directed at rehabilitation of these two native species. While the Atlantic salmon program is still at an early stage, there are encouraging signs of natural reproduction by lake trout in recent years. Rainbow trout have been very successful in establishing wild populations in a large number of tributaries, particularly on the north shore. Rainbow trout are also stocked into the lake in areas where natural reproduction of this species contributes little to the sport fishery.

In the early 1990s, concerns were raised about the long term stability and sustainability of the openwater fish community. Populations of alewife and smelt have declined due to the lower productivity of the lake and the increased stocking of trout and salmon that feed on these species.

Beginning in 1994, U.S. and Canadian natural resource management agencies reduced stocking rates in recognition of these changing predator-prey relationships in the lake.

Over the past two decades, there have been dramatic improvements in the status of formerly depleted stocks of native species. Beginning in the late 1970s, walleye and lake whitefish populations began to recover in eastern Lake Ontario; populations of these species have now reached historically high levels in the eastern end of the lake. In the 1990s, fisheries assessment programs have documented increasing numbers of lake herring, lake sturgeon, and burbot. In 1996, assessment gear captured several specimens of deepwater sculpin, a native prey species, no longer thought to exist in the lake.

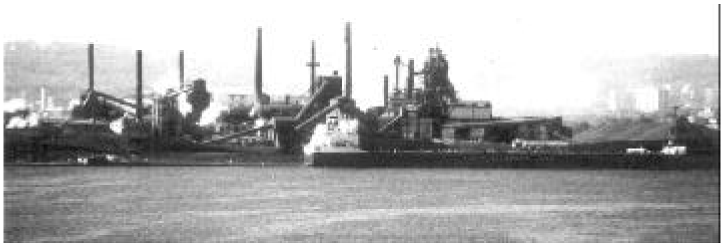
Alewife declines in recent years are believed to be an important factor in the resurgence of native species. Predation and competition by alewife on the juvenile life stages of native species had formerly suppressed their recovery. As a consequence of zebra and quagga mussel invasion, benthic pathways will become more important in the aquatic food web, which should favor benthic and deepwater fish species such as lake trout, burbot, lake sturgeon, and sculpin.

In light of the many changes occurring in the Lake Ontario ecosystem over the last decade, the Ontario Ministry of Natural Resources (MNR) and NYSDEC have initiated a review of the fisheries management direction for the lake, involving fisheries professionals and stakeholders. The draft Fish Community Objectives will be available for formal review in the spring of 1998.

1.3 Demographics and Economy of the Basin

The present day demographics of Lake Ontario are a result of the historical patterns of settlement which were closely tied to the physical and environmental features of the basin. Native people have lived along the shores of the Great Lakes for over 10,000 years. They fished the waters, grew crops on the land, and used the rivers for transportation. Europeans first settled along the shores of Lake Ontario in the 1700s. Cities and towns sprung up near tributaries because of the abundant water supply and transportation opportunities. The mixed hardwood forests provided a rich resource. Logging became a major activity, both for the valuable timber and to clear the land for agriculture. The Lake Ontario basin has an ideal climate and soil types for agriculture. Some areas, such as the Niagara region, are highly specialized in the growing of fruit and vegetable crops.

Lumber camp, c. 1900
(Douglas County Historical Society)



Hamilton, Ontario

Shipping is a major activity on the lake and has led to the growth of manufacturing and population increases in port communities. Major steel mills, that rely on shipping, were established at Hamilton. In the 1900s, the chemical industry was established near Niagara Falls due to the abundant supply of hydroelectric power generated by the Falls.

Commercial fishing yields in Lake Ontario were never as high as more productive lakes such as Lake Erie. Ontario does, however, currently support a Canadian commercial fishery for lake whitefish, American eel, yellow perch, and bullheads that was worth $1.5 million (CDN) in 1996 (Hoyles and Harvey, 1997). The U.S. commercial fishery for Lake Ontario was valued at $68,000 (US) in 1995 (Cluett, 1995). The recreational fishery is based primarily on salmon and trout species in the open lake and tributaries, walleye in the eastern lake, and smaller numbers of perch, smallmouth bass, and panfish species in embayments. The economic value of recreational fishing to local communities is estimated to range from $100 million to over $200 million per year (USEPA *et al.*, 1987; Kerr and LeTendre, 1991).

The Lake Ontario basin, its major sub-basins, and communities are shown in Figure 1-1 (see page 3). At the present time, over 5.4 million people live on the Canadian side of the basin (Statistics Canada, 1994). The northwestern part of the shoreline is a highly urbanized and industrialized area referred to as the "Golden Horseshoe". This area extends from Coburg in the east, around the western end of Lake Ontario to St. Catharines and Niagara Falls. The U.S. side of the lake is not as heavily populated, with approximately 2.2 million residents (NYSDED, 1991). There are, however, concentrated areas of urbanization at Rochester, Syracuse, Oswego, and Watertown, New York.

Land use in the basin and along the shoreline is presented in Tables 1-1 and 1-2, respectively. Forested areas are mainly in the northernmost and southernmost areas of the watershed. Nearer to the lake, forest habitat is highly fragmented.

Table 1-1. Basin Land Use (%)

	Agriculture	*Residential*	*Forest*	*Other*
Canada	49	6	42	3
U.S.	33	8	53	6
Total	39	7	49	5

Table 1-2. Shoreline Land Use (%)

	Residential	*Recreational*	*Agricultural*	*Commercial*	*Other*
Canada	25	15	30	18	12
U.S.	40	12	33	8	7

Rural and urban land use activities in the watershed influence the environmental health of Lake Ontario. Herbicides, pesticides, and excess nutrients from agricultural runoff are types of non-point source contaminants. Sources of pollution from urban areas include stormwater runoff from paved streets, effluent from sewage treatment plants, and *combined sewer overflows* (CSOs).

1.4 The Lake Ontario Toxics Management Plan and Progression to the LaMP

In response to an identified toxics problem in the Niagara River and Lake Ontario, a Niagara River Declaration of Intent was signed on February 4, 1987, by the Four Parties. This document included a commitment to develop a Lake Ontario Toxics Management Plan (LOTMP). The main purpose of the LOTMP was to define the toxics problem in Lake Ontario and to develop and implement a plan to eliminate the problem through both individual and joint agency actions. The Four Parties developed a draft Toxics Management Plan which was presented for public review in 1988. The completed LOTMP was published in 1989 (LOTMP, 1989). Updates of the LOTMP were completed in 1991 (LOTMP, 1991) and in 1993 (LOTMP, 1993).

Goals of the Lake Ontario Toxics Management Plan:

- *Drinking water and fish that are safe for unlimited human consumption*
- *Natural reproduction, within the ecosystem, of the most sensitive native species, such as bald eagle, osprey, mink, and river otter*

To achieve the goals, four objectives were developed:

- Reductions in Toxic Inputs Driven by Existing and Developing Programs
- Further Reductions in Toxic Inputs Driven by Special Efforts in Geographic Areas of Concern
- Further Reductions in Toxic Inputs Driven by Lakewide Analyses of Pollutant Fate
- Zero Discharge

The LOTMP identified 11 priority toxic chemicals in the lake (see Appendix B) and provided information regarding ongoing load reduction efforts. This program has been the primary binational toxic substances reduction planning effort for Lake Ontario. As such, it serves as a foundation for the development of the Lake Ontario LaMP, which incorporates an "ecosystem approach" through the assessment of "beneficial uses". In May of 1996, the Four Parties signed a Letter of Intent (see Appendix C) agreeing that the LaMP should provide the binational framework for environmental protection efforts in Lake Ontario. The Four Parties have reviewed and incorporated all relevant LOTMP commitments into this Stage 1 Plan.

1.5 Scope of the LaMP

The Lake Ontario LaMP focuses on resolving:

- Lakewide beneficial use impairments as defined in the Great Lakes Water Quality Agreement (Annex 2) and described in Chapter 3 of this LaMP;
- Critical pollutants contributing to, or likely to contribute to, these impairments despite past application of regulatory controls, due to their toxicity, persistence in the environment, and/or their ability to accumulate in organisms; and
- Physical and biological problems caused by human activities.

***Remedial Action Plans** were also required by the GLWQA. These plans address localized environmental problems within an Area of Concern (AOC). AOCs are specific geographic areas where significant pollution problems have been identified as impairing beneficial uses such as swimming, eating fish, or drinking water. (See Figure 1-1).*

The LaMP will address sources of lakewide critical pollutants, which are those substances responsible, either singly or in synergistic or additive combination, for beneficial use impairments in the open lake waters of both countries, as well as those substances that exceed criteria and are, therefore, likely to impair such uses, which require binational actions for resolution. This Plan will be coordinated with Remedial Action Plans within the Lake Ontario drainage basin and other localized efforts which are best suited to address issues of local concern. In addition, this Plan will utilize linkages to other natural resource management activities, such as the development of Lake Ontario fish community objectives by the Great Lakes Fishery Commission and the Lake Ontario Committee of fisheries managers. The LaMP will address impairments found in open waters of the lake and nearshore areas, without duplicating the efforts of localized remedial action plans. Tributaries, including the Niagara River, are treated as inputs to the lake. The St. Lawrence River is treated as an output from the lake.

This report does not provide a complete analysis of the biological and physical problems facing the lake because the ecosystem objectives and indicators needed to evaluate these problems are still being developed and will be reported on as part of the Stage 2 reporting for the LaMP (see Binational LaMP Workplan). The LaMP will provide an assessment of the physical and biological problems after these objectives and indicators have been completed. Recognizing that the development of ecosystem objectives may require a considerable amount of time, the LaMP will move forward with the development of a critical pollutants reduction strategy rather than wait until all physical and biological problems have been defined.

In addition to the Lake Ontario LaMP, there are a number of other environmental planning efforts upstream and downstream of the Lake Ontario basin. Plans are being implemented for the Niagara River, including Remedial Action Plans in both Canada and the U.S. and a binational Toxics Management Plan. The major sources of pollutants within the downstream St. Lawrence River are being addressed through three ongoing planning efforts: Canadian and U.S. Remedial Action Plans for the St. Lawrence River at Cornwall and Massena, respectively, and a St. Lawrence River Action Plan for the section of the river located in the Province of Quebec.

1.6 Human Health and the Lake Ontario LaMP

The Lake Ontario LaMP is concerned with human health issues related to water quality. Other human health issues, such as air pollutants, infectious diseases, and pesticide residues on food are not addressed as part of the LaMP and are under the jurisdiction of other programs. Three of the LaMP's impairment indicators are directly related to human health issues: Restrictions on Drinking Water Consumption, Fish and Wildlife Consumption, and Beach Closings. Of these three, only fish and wildlife consumption advisories have been identified as a lakewide problem.

Localized beach closings due to occasional high bacteria levels are a problem in some areas and are being addressed by several Remedial Action Plans. While some taste and odor problems have been observed, there are no restrictions on drinking water consumption. The LaMP will work with U.S. and Canadian health agencies to assure that health issues are being adequately addressed.

1.6.1 Potential Human Health Impacts

Potential environmental pathways of human exposure to Great Lakes pollutants include inhalation of air, ingestion of water, foodstuffs, or contaminated soil, and dermal contact with water or airborne particulates. Multimedia analyses indicate that the majority (80 to 90%) of human exposures to chlorinated organic compounds and mercury comes from the food pathway, a lesser amount (5 to 10%) from air, and minute amounts (less than 1%) from water (Birmingham *et al.*, 1989; Newhook, 1988; Fitzgerald *et al.*, 1995).

Most of the available data on human exposure to toxic substances in the Great Lakes comes from the analyses of contaminant levels in drinking water and sport fish. The consumption of contaminated sport fish and wildlife can significantly increase human exposure to Lake Ontario critical pollutants. The risks associated with fish consumption are greatly reduced if people follow consumption advisories. Those who are unaware of or do not follow these advisories are at greatest risk. Investigators have demonstrated that blood serum levels of these contaminants are significantly increased in consumers of contaminated Great Lakes sport fish as compared to non-fisheaters (Humphrey, 1983a,b; Kearney *et al.*, 1995; Health Canada, 1997; Fitzgerald *et al.*, 1995).

Even though residents of the Great Lakes basin are exposed to toxic substances from many sources originating within and outside the region, the main routes of human exposure to contaminants from the waters of the Great Lakes are ingestion of fish and, to a lesser extent, ingestion of drinking water (DFO and Health and Welfare Canada, 1991). Also, several investigators have shown that exposure from fish far outweighs atmospheric, terrestrial, or water column sources (Swain, 1991; Humphrey, 1983b; Fitzgerald *et al.*, 1995). These patterns may vary for populations living in the vicinity of industrialized areas.

Several epidemiologic investigations have been conducted on the association between water pollutants in the Great Lakes and the health of people in the Great Lakes basin. These studies have demonstrated increased tissue levels of toxic substances in these populations that may be associated with or potentially result in reproductive, developmental, behavioral, neurologic, endocrinologic, and immunologic effects (Fitzgerald *et al.*, 1995).

Some studies have reported subtle effects in children of mothers who consumed large amounts of Great Lakes fish. At birth, some of the children most highly exposed to the mixture of contaminants present in the fish were slightly smaller, showed slightly delayed neuromuscular development during infancy, and had a reduced ability to deal with stressful situations. A small percentage of such children showed slightly delayed or reduced intellectual development during their school years. Recent epidemiologic and laboratory studies complement and continue to build upon the scientific data gathered over the last two decades that document health consequences associated with exposures to persistent toxic substances. The findings of elevated polychlorinated biphenyl (PCB) levels in human populations, together with findings of developmental deficits and neurologic problems in children whose mothers ate PCB-contaminated fish, have significant health implications. Additional research is necessary to better understand the human health impacts that persistent toxic substances may have on sensitive populations (Johnson *et al.*, draft 1997).

Endocrine disruption has emerged as a major issue in regulatory toxicology with significant human health implications. While human health effects due to endocrine disruption remain controversial, some pesticides and certain industrial chemicals, as well as some naturally occurring substances have been shown to mimic the action of estrogen in tissue cultures and laboratory animal studies. Laboratory and animal studies reveal that fetuses and infants are especially susceptible to bioaccumulating and endocrine disrupting chemicals because exposure occurs during critical periods of early tissue and organ development and growth.

LaMP Human Health Related Issues	Where can I find more information?
Research on potential human health effects (neurological, endocrinological, reproductive, and other effects)	Section 1.6.1
Fish & Wildlife Consumption Advisories	Section 3.3.1
Beach Closings	Section 3.5.5
Drinking Water Quality	Section 3.5.4
Radionuclides	Section 1.6.4
Microbial Pathogens	Section 3.5.5

1.6.2 Wildlife as a Sentinel for Human Health

The health of fish and wildlife provides a good indication of the overall condition of an ecosystem. The dramatic reproductive failure of cormorants on Lake Ontario due to DDT in the 1960s provided a clear indication that something was wrong. Since that time, contaminant reduction programs have succeeded in banning and controlling many toxic substances and, as a result, environmental levels have declined and the cormorants and other sensitive species are reproducing normally. This indicates that the potential risks to human populations posed by persistent environmental contaminants have also declined.

Ongoing fish and wildlife populations can provide an important tool to identify any currently unrecognized contaminant risks that may develop in the future. Given that the metabolisms and diets of fish and wildlife are very different from humans and that these species are exposed to much higher contaminant levels than the general human population, caution must be used when interpreting the significance of fish and wildlife problems for human populations. For example, tumors in fish may reflect high levels of contaminants in sediment or may be the result of natural causes such as viruses or genetic factors. Nonetheless, Canadian and U.S. health agencies [Health Canada and the Agency for Toxic Substances and Disease Registry (ATSDR)] have concluded that the weight of evidence based on the findings of wildlife biologists, toxicologists, and epidemiologists clearly indicates that populations continue to be exposed to PCBs and other chemical contaminants and that significant health consequences are associated with these exposures (Johnson *et al.*, draft 1997; Health Canada, 1997).

LaMP Wildlife Indicators of Potential Health Concerns	Where can I find more information?
Fish Tumors	Section 3.5.1
Degraded Fish and Wildlife Populations	Section 3.3.2
Degraded Benthic Communities	Section 3.4.1
Degraded Phytoplankton & Zooplankton Populations	Section 3.4.2
Bird and Animal Deformities and Reproduction Problems	Section 3.3.2

1.6.3 Indicators of Human Health Trends

Ideally, indicators of human health would gauge trends in any adverse human health effects related to environmental contaminants. Contaminant concentrations in fish tissue, human tissue, and other environmental media can be used as an indication of changes in contaminants levels and that certain human populations are being exposed. However, except in cases where individuals are exposed to relatively high levels of contaminants that can cause clearly recognizable health effects, it may not be possible to separate out any adverse effects due to environmental contaminants from other human health factors, such as diet, lifestyle, work environment, and genetic factors.

There are a number of U.S. and Canadian stakeholders collaborating to define indicators for the basin and the individual Great Lakes. The development of these human health indicators may provide the basis for future monitoring and data gathering efforts.

1.6.4 Other Key Human Health Issues

Potential health risks posed by levels of radionuclides and bacteria in Lake Ontario were also considered by the LaMP.

Radionuclides

There is ongoing debate as to whether *anthropogenic* concentrations of radionuclides in Lake Ontario water should be regarded as a significant human health issue. Current concentrations of radionuclides in water are below existing standards and criteria. Natural sources of radiation contribute on average more than 98 percent of the human radiation dose. Artificial sources, such as nuclear power and medical facilities, add to the radiation levels.

Long term low level exposure to ionizing radiation has been associated with the development of leukemia and other cancers. Effects other than cancer, such as neurological, developmental, and immunological damage, have been observed only at high doses of radiation, and are generally assumed to be threshold effects. It has been suggested that radiation weakens the immune system, and that exposure even at low levels may lower one's resistance to infectious diseases, as there is a depression in the white blood cell count at high levels of radiation exposure. However, there is no clear mechanism linking low level radiation exposure with obvious immune system damage.

Recreational Water

Local beach closings along some of the more populated shorelines due to elevated levels of E. coli (or fecal coliform bacteria) are indicative of fecal contamination and the possible presence of enteric (intestinal) pathogens which can pose a potential health risk. Microbiological water quality indicators are used as surrogates for the presence of pathogenic organisms that may cause illness. In Lake Ontario, a number of local beach closings occur due to microbial contaminants, primarily along the more populated shorelines. Exceedence of microbial standards and criteria typically occurs following a storm event when the treatment capacity of some sewage treatment plants can be exceeded. Given the localized nature of beach closings and their absence along much of the Lake Ontario shoreline, they are not considered a lakewide problem. The frequency of beach closings is expected to decrease as sewage treatment plants continue to improve and upgrade their systems. It should be noted that beaches may also be closed due to other factors such as storm events, excessive turbidity, or lack of funding.

Drinking Water

Newly recognized concerns related to drinking water include microbes resistant to drinking water disinfection, especially encysted forms of protozoan parasites such as *Cryptosporidium* and toxic by-products of drinking water disinfection such as trihalomethanes. These issues have not been identified as a significant concern for residents of the Lake Ontario basin. Although *Cryptosporidium* has not been identified as a significant concern, those supplies without full treatment are potential candidates for outbreaks of cryptosporidiasis (Health Canada, 1997).

1.7 Developing LaMP Ecosystem Goals and Objectives

Ecosystem Goals for Lake Ontario:

- *The Lake Ontario Ecosystem should be maintained and as necessary restored or enhanced to support self-reproducing diverse biological communities.*
- *The presence of contaminants shall not limit the uses of fish, wildlife, and waters of the Lake Ontario basin by humans and shall not cause adverse health effects in plants and animals.*
- *We as a society shall recognize our capacity to cause great changes in the ecosystem and we shall conduct our activities with responsible stewardship for the Lake Ontario basin.*

The earlier LOTMP developed broad ecosystem goals for Lake Ontario which have been incorporated in the LaMP process. The LaMP will expand on these goals by developing more detailed ecosystem objectives and ecosystem health indicators to be used to measure progress in restoring Lake Ontario. A preliminary effort resulted in the following five objectives which will serve as a starting point for a more comprehensive effort to include broader public, private, and governmental input.

- **Aquatic Communities (benthic and pelagic):** the waters of Lake Ontario shall support diverse and healthy reproducing and self-sustaining communities in dynamic equilibrium, with an emphasis on native species.
- **Wildlife:** the perpetuation of a healthy, diverse, and self-sustaining wildlife community that utilizes the lake for habitat and/or food shall be ensured by attaining and sustaining the waters, coastal wetlands, and upland habitats of the Lake Ontario basin in sufficient quality and quantity.
- **Human Health:** the waters, plants, and animals of Lake Ontario shall be free from contaminants and organisms resulting from human activities at levels that affect human health or aesthetic factors such as tainting, odor, and turbidity.

- # **Habitat:** Lake Ontario offshore and nearshore zones and surrounding tributary, wetland, and upland habitats shall be of sufficient quality and quantity to support ecosystem objectives for the health, productivity, and distribution of plants and animals in and adjacent to Lake Ontario.
- # **Stewardship:** Human activities and decisions shall embrace environmental ethics and a commitment to responsible stewardship.

Ecosystem objectives need to consider the ecological possibilities and constraints within the lake. Although there is general agreement that the reduction of bioaccumulative contaminants entering the lake should be a priority, consensus may be lacking for many natural resource issues. An individual's point of view regarding the best or most appropriate use of a natural resource is often based on value judgements. For example, some anglers would like to see naturally sustaining populations of native fish, such as lake trout and Atlantic salmon, established as Lake Ontario's top level predator fish. Other anglers advocate stocking of non-native fish, such as Coho salmon and rainbow trout, to promote sport fishing. These will be difficult decisions. The sharing of viewpoints, learning more about these complex issues, and a willingness to work together to develop solutions that "make sense" will be critical in developing objectives that have broad public, private, and governmental support.

1.8 Management Structure

The Four Parties have the responsibility for developing the Lake Ontario LaMP and have approved a LaMP management structure that consists of a Coordination Committee, a Management Committee, a Lake Ontario Workgroup, and a Lakewide Advisory Network (see Figure 1-3 below). There are other agencies that have an interest in the LaMP, such as natural resource and human health agencies, and their involvement on specific issues is an important component of LaMP decision-making. Responsibility for ensuring this participation lies with the Management Committee.

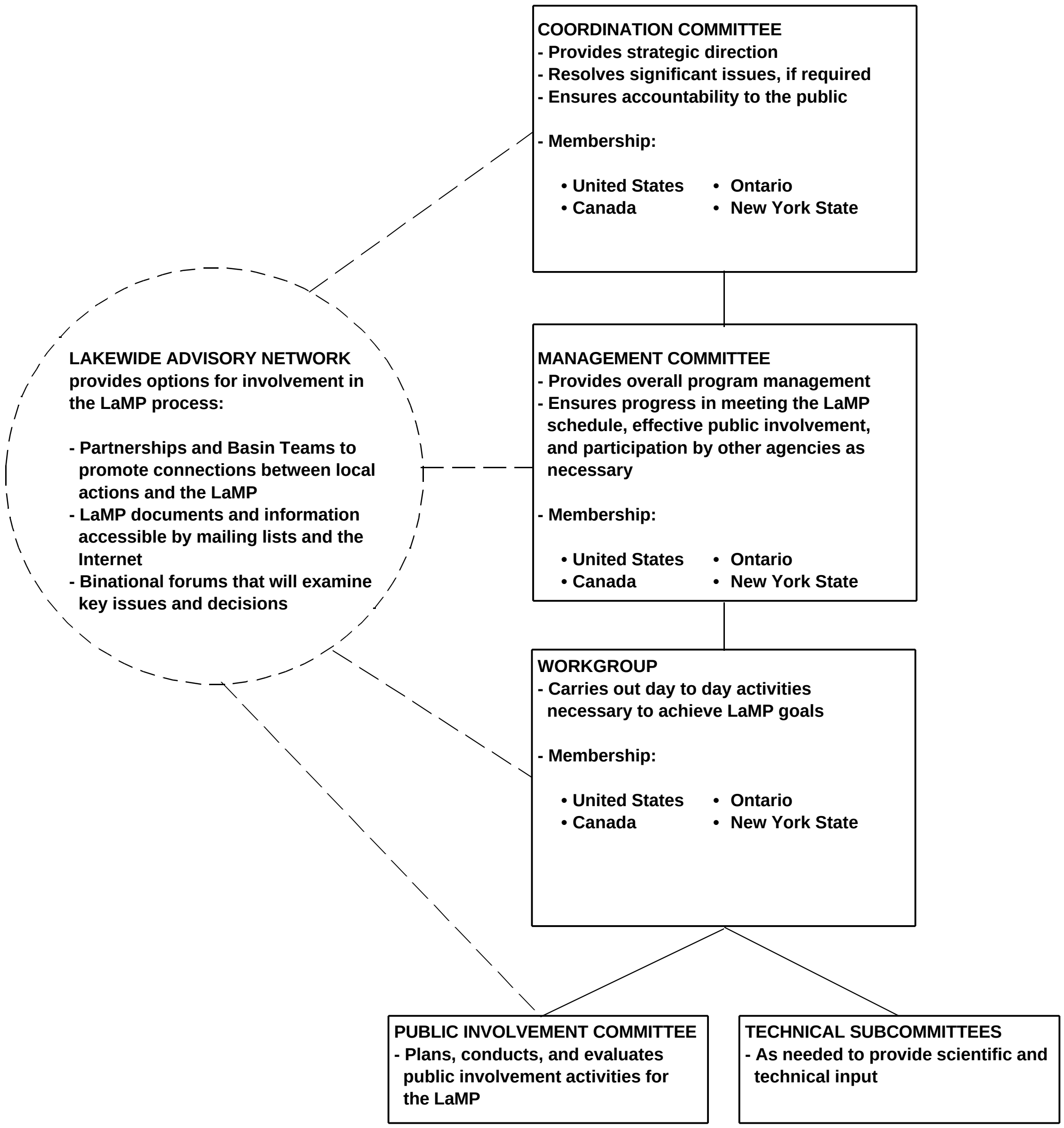


Figure 1-3. Lake Ontario LaMP Management Structure