

INTERNATIONAL JOINT COMMISSION
CANADA AND UNITED STATES

POLLUTION
OF
LAKE ERIE
LAKE ONTARIO
AND THE
INTERNATIONAL SECTION
OF THE
ST. LAWRENCE RIVER

1970

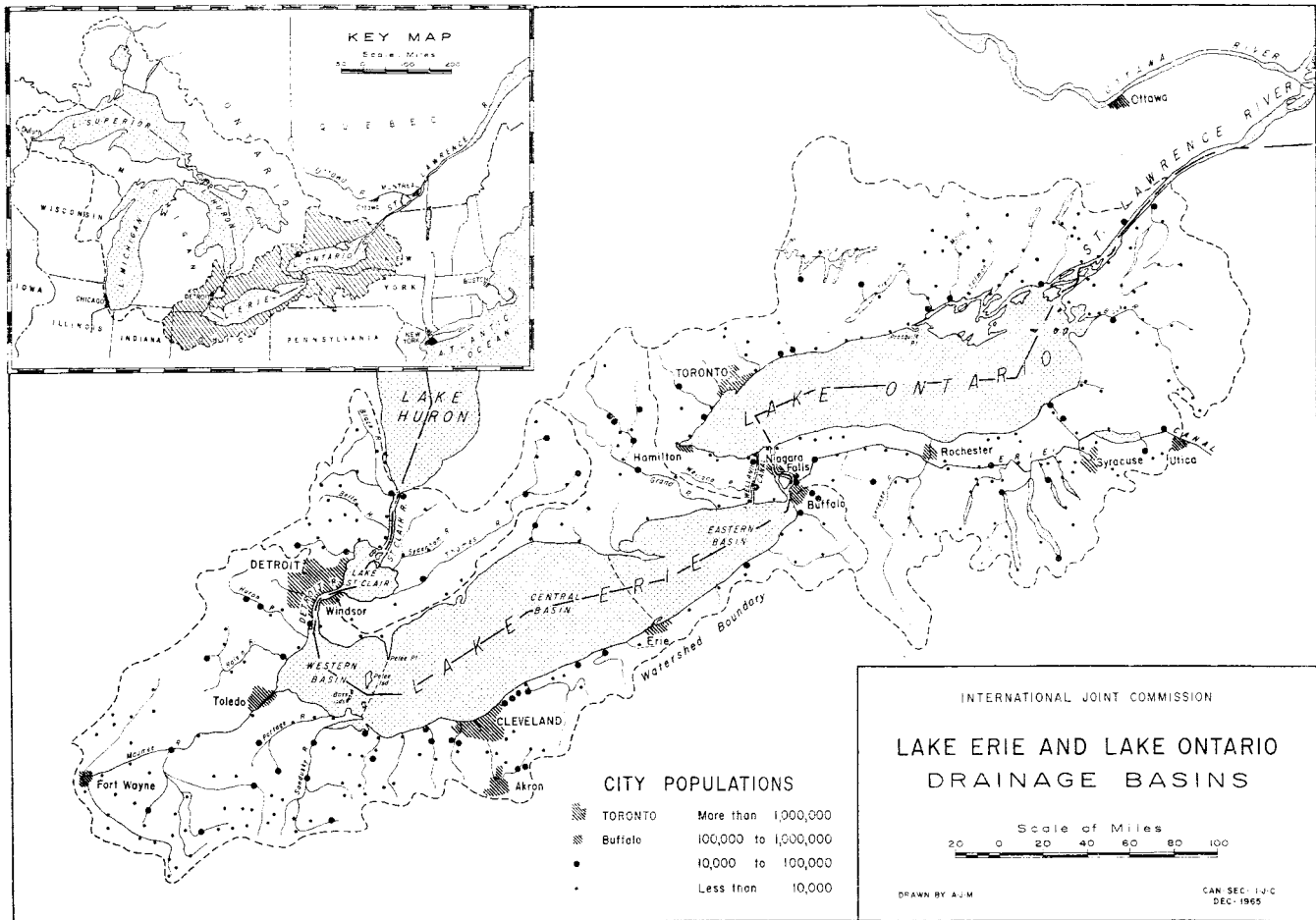


Figure 1

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Chapter I

INTRODUCTION

This is the report of the International Joint Commission on an intensive and extensive inquiry into the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River. It incorporates relevant excerpts from the three interim reports on this undertaking sent by the Commission to the Governments of Canada and the United States.

Lake Erie and Lake Ontario occupy the terminal position of the Great Lakes, the largest fresh water system in the world. They not only receive wastes passed on by the Upper Lakes but are also receptacles for wastes from the municipalities and industries they support. Also, being the smallest of the Great Lakes, they are more sensitive and responsive to the pollution pressures brought about by the activities of man.

Under Article IV of the Boundary Waters Treaty of 1909, Canada and the United States assumed a mutual obligation that "boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other." Lake Erie, Lake Ontario and the International Section of the St. Lawrence River are boundary waters as defined by the Treaty. The current pollution problems in the Lower Great Lakes are now generally recognized as serious from the standpoint of international obligations and the viewpoint of the people, municipal officials and industrial administrators on each side of the boundary.

In 1912 the lamentable prevalence of typhoid fever prompted the Governments of Canada and the United States to request the International Joint Commission to determine to what extent, by what causes and in what localities were the boundary waters between the two countries, including the Great Lakes, polluted so as to be injurious to public health and unfit for domestic and other uses. The Commission's subsequent investigation was essentially a bacteriological study. Regarding the major tributaries to Lake Erie and Lake Ontario, the Commission in its 1918 Report concluded that pollution was "very intense along the shores of the Detroit and Niagara Rivers" and that "conditions exist which imperil the health and welfare of the citizens of both countries in direct contravention of the Treaty."

The Commission in its 1918 Report stated that "it was feasible and practicable, without imposing an unreasonable burden upon the offending communities, to prevent or remedy pollution in boundary waters" and that "it is advisable to confer upon the International Joint Commission ample jurisdiction to regulate and prohibit this pollution." At the request of the two Governments, the Commission in 1920 drafted a "convention" which would accomplish this purpose. The Commission, in forwarding the draft convention, stated, "The Commission is firmly of the view that the best method to avoid the evils which the Treaty is designed to correct is to take proper steps to prevent dangerous pollution crossing the boundary line rather than to wait until it is manifest that such pollution has actually physically crossed, to the injury of health or property on the other side."

With the advent of chlorination of municipal water supplies and in the general belief that there was an inexhaustible supply of clean, fresh water to dilute all wastes, the expenditures of large sums of money on waste treatment facilities did not appear to be urgent. In any event, the proposed convention was not negotiated to a conclusion and the two Governments did not give the Commission further direction or authority with respect to pollution of these waters.

Eventually, in 1946 the two Governments requested the Commission to examine the pollution problems of the Connecting Channels of the Great Lakes (the St. Marys, St. Clair, Detroit and Niagara Rivers) resulting from the new types and greater volumes of wastes discharges by developing industrial complexes and accompanying growth and concentrations of population. This comprehensive study determined through physical, bacteriological and chemical analysis the amount of domestic and industrial wastes in these four receiving streams. The Commission's 1950 Report set forth specific Water Quality Objectives designed to restore and maintain the waters of the Connecting Channels in a condition which would not impair the many uses desired of them. These Objectives, the first of their kind on an international basis, anticipated national action by both countries. The recommendations were approved by the two Governments to satisfy the requirements of the Treaty and subsequently were reflected in whole or in part in the pollution abatement programmes of enforcement agencies in both countries.

Progress in achieving the Objectives for the Connecting Channels in so far as individual communities and industries are concerned has been fairly good. For example, eight years after the Governments had approved the Objectives the total daily discharge of wastes from all industries had been reduced from 13,000 to 2,500 pounds of phenols, from 9,000 to 4,000 pounds of cyanides, from 18,000 to 2,500 gallons of oil, and from 3.1 to 1.6 million pounds of suspended solids. However, the Commission's Water Quality

Objectives are not being met currently in all reaches of the Connecting Channels because the responsible authorities and industries have not provided sufficient treatment facilities to keep pace with the population growth and with industrial expansion.

Pollution problems have changed materially over the last fifty years. The increased quantity and the different composition of municipal and industrial wastes in the last two decades, as well as the residual characteristics of materials discharged into the Lakes, have led to dramatic changes in the biological condition of the Lower Great Lakes System.

Finally, under provisions of the Boundary Waters Treaty the Governments of Canada and the United States in October 1964 requested the International Joint Commission to enquire into and report upon the following questions:

- (1) Are the waters of Lake Erie, Lake Ontario, and the International Section of the St. Lawrence River being polluted on either side of the boundary to an extent which is causing or is likely to cause injury to health or property on the other side of the boundary?
- (2) If the foregoing question is answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?
- (3) If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgement, be most practicable from the economic, sanitary and other points of view and what would be the probable cost thereof?

The full text of the Reference from the two Governments is in the Appendix.

Following a serious oil pollution incident off the California coast, the two Governments on March 21, 1969, requested the Commission as a matter of urgency and within the framework of the on-going pollution investigation, to make a special report on the adequacy of existing safety requirements applicable to underwater drilling and production operations in Lake Erie to prevent oil escaping into the Lake; the adequacy of known methods of confining and cleaning up any major oil spill that might occur in Lake Erie from any source; and the adequacy of existing contingency plans, and their implementation for dealing with such oil spills.

The text of the letter of March 21, 1969, from the two Governments is in the Appendix.

Chapter II

CONDUCT OF THE INQUIRY

In accordance with its usual procedure in such investigations, the Commission on December 2, 1964 established the International Lake Erie Water Pollution Board and the International Lake Ontario–St. Lawrence River Water Pollution Board. The senior officials appointed by the Commission to the two International Boards were experienced scientists and engineers from the Canadian Departments of National Health and Welfare, Fisheries (later Fisheries and Forestry), Mines and Technical Surveys (later Energy, Mines and Resources), the Ontario Water Resources Commission, the Division of Water Supply and Pollution Control of the United States Department of Health, Education and Welfare (later the Federal Water Quality Administration), Michigan Water Resources Commission, Ohio State Department of Health, Pennsylvania Department of Health and the New York State Department of Health (later Environmental Conservation). A list of the members of the Boards, Committees and participating agencies is set out in the Appendix.

The two Boards were directed to review and so far as possible make use of relevant information and technical data which had been or might be acquired by agencies in the two countries. The Boards were also directed to execute the necessary investigations and studies and to advise the Commission on the specific questions set out in the Reference.

In 1960, prior to the Commission's receipt of the Reference from the two Governments, funds were appropriated under the U.S. Federal Water Pollution Act of 1956 for a comprehensive study of the Great Lakes pollution problem in the United States. The study was undertaken by the Division of Water Supply and Pollution Control of the United States Public Health Service with participation of the States bordering the Great Lakes. Work on Lake Erie began in 1963 and on Lake Ontario in 1964. The responsibilities for these short-term studies were transferred in 1965 to the newly formed Federal Water Pollution Control Administration, later called the Federal Water Quality Administration, of the United States Department of the Interior and recently transferred to the Environmental Protection Agency. Additional data were acquired for the International Boards' investigation.

The data gathered for the FWQA study were made available to the two International Boards and incorporated into their report to the Commission.

The Ontario Water Resources Commission commenced its investigation of the Canadian shoreline and tributaries of Lake Erie and Lake Ontario in 1964. The Canadian Department of National Health and Welfare initiated the investigation of the St. Lawrence River in 1965. In addition to the acceleration and expansion of these investigations, the Canadian Fisheries Research Board and the Department of Energy, Mines and Resources initiated extensive programmes to secure the scientific information required by the two Boards. In December 1970 the Public Health Engineering Division of the Department of National Health and Welfare and the water sector of the Department of Energy, Mines and Resources were transferred to the Minister of Fisheries and Forestry and the Canadian Government has introduced legislation to incorporate these units into the Department of Environment.

These massive undertakings of Canadian and United States agencies were conducted in accordance with a programme of surveys and studies approved by the International Joint Commission.

During the course of their investigation the Boards submitted ten semi-annual progress reports and two interim reports. In addition to these formal communications, the Commission was kept informed of the activities of the Boards through correspondence and numerous informal meetings. At the conclusion of the concentrated studies, the Boards in September 1969 submitted to the Commission a detailed Summary Report on the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River. A few months later they provided the Commission with two comprehensive volumes of technical data supporting the findings set out in the Summary Report.

The International Lake Erie Water Pollution Board in response to the Commission's directive of April 1, 1969 and with the concurrence of the Commission, established an ad hoc committee of its members to expedite the examination of drilling regulations and procedures, containment and clean up of oil spills and contingency plans. The ad hoc committee consulted responsible provincial, state and federal agencies in both countries, and in September 1969 the Board submitted its report to the Commission entitled "Potential Oil Pollution Incidents from Oil and Gas Well Activities in Lake Erie — Their Prevention and Control."

Throughout the inquiry the Commission was aware of the active concern of the two Governments and the wide public interest and anxiety concerning the water quality of the Great Lakes. Because of the magnitude and complexity of the problems involved, the Commission realized that completion of the technical investigations would require several years. For these reasons

and to keep the Governments currently informed of urgent matters related to the inquiry and of the progress of the investigation, the Commission submitted three interim reports to the Governments of Canada and the United States.

A year after receipt of the Reference the Commission transmitted its First Interim Report, dated December 1965. It was based on factual information supplied by the Boards and it informed the two Governments that recently acquired data indicated an accelerated rate of deterioration in Lake Erie and that a similar process, though less advanced, was taking place in Lake Ontario. The Commission stated that on the advice of its technical advisers, it was satisfied that the cause of the rapid deterioration was enrichment of the waters by nutrients, and that phosphorus* was one of the essential nutrients involved. Accordingly, the Commission recommended that the Governments of Canada and the United States, as soon as possible and in association with state and provincial governments, take appropriate action to ensure sufficient purification of all municipal and industrial wastes before discharge into these waters and their tributaries to achieve the maximum possible removal of phosphorus.

The same report outlined the three phases of the Commission's programme of investigation. The first phase, short-term concentrated studies was planned to secure factual information on both sides of the boundary as to the extent, origin and location of pollution in these waters. This work was designed to supplement and expand field studies initiated by the United States in 1963 and to undertake the necessary Canadian studies. The first phase of the investigation was completed in 1969.

The second phase, continuing studies, undertaken concurrently with the short-term studies included intensive investigations on lake circulation, mixing and diffusion; the chemistry, physics and biology of the lakes; the changing effects and the relative significance of pollutants in the waters; and continuous assessment of the effectiveness of possible remedial measures.

The third phase consisted of a long-term programme of research to answer fully the questions referred to the Commission by the Governments and to acquire scientific knowledge and understanding of the physical, chemical and biological behaviour of the Great Lakes, particularly in respect to pollutants and their dispersal. Accordingly, the Commission recommended that the two Governments support fully the Commission's programme of

*The term phosphorus in this Report refers to phosphorus as a constituent of various organic and inorganic complexes and compounds, not to elemental phosphorus as a chemical substance. The term phosphorus includes orthophosphates such as trisodiumphosphate, crystalline phosphates such as sodiumtripolyphosphate, and polyphosphates such as sodiumhexametaphosphate. However, in this Report concentrations and loads are given in terms of the element phosphorus as part of any compound to assure uniformity of expression.

investigation and research by provision of the personnel and facilities required from time to time for its effective implementation.

The Commission's Second Interim Report, dated August 1968, briefly outlined the important progress made by the Commission's two Technical Advisory Boards. At that time the Boards were assembling and evaluating data collected by agencies in Canada and the United States. Attached to the Commission's Report was a report from the Boards briefly outlining current and future pollution problems as well as the then current remedial programmes of the enforcement agencies on each side of the boundary.

After an initial review, the Commission made public on October 8, 1969 the detailed Summary Report on the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River submitted to the Commission by the two Technical Advisory Boards. Similarly, on October 27, 1969 the Commission made public the special report entitled "Potential Oil Pollution Incidents from Oil and Gas Well Activities in Lake Erie", prepared by its International Lake Erie Water Pollution Board. Both reports were given wide distribution. Notices of the public hearings to be conducted by the Commission were published in accordance with its Rules of Procedure and were also mailed to many persons known to be interested.

Hearings on potential oil pollution in Lake Erie were held in Toronto, Ontario and Cleveland, Ohio in December 1969. Hearings on the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River were held in Erie, Pennsylvania; Toledo, Ohio; and London, Ontario in January 1970 and in Hamilton, Ontario; Rochester, New York; and Brockville, Ontario in February 1970.

Upon completion of the hearings and consideration of developments the Commission concluded that three items of concern, namely, oil pollution, eutrophication and pollution from watercraft, should be brought to the attention of the two Governments as a matter of urgency.

Consequently, in April 1970 the Commission transmitted its Third Interim Report to the two Governments. This special report on potential oil pollution, eutrophication and pollution from watercraft contained six recommendations which in the opinion of the Commission required implementation at the earliest possible date. The essential material and the recommendations contained in the Third Interim Report are also embodied in this Report.

When the Commission became aware of the mercury and polychlorinated biphenyl (PCB) pollution problems developing in the Great Lakes System, it directed the Boards to report on these subjects as soon as possible. Within a few months the Boards, using a procedure similar to the oil pollution investigation in Lake Erie, submitted detailed reports to the Commission

on these two problems entitled "Mercury Pollution in the Lower Great Lakes" and "Polychlorinated Biphenyls", both dated August 1970.

In order to ensure that the most complete and up-to-date scientific and technical information was taken into account in the Commission's report, individual Commissioners and staff members consulted acknowledged experts in both countries subsequent to the public hearings. In addition, to supplement the testimony received at the public hearings, the Commission has ascertained the preliminary views of the Governments of Canada and the United States with respect to the institutional arrangements needed for an effective international organization for the abatement of pollution of the waters under Reference.

Three of the Commissioners and the two Advisers participated in the Great Lakes Environmental Conference in Toronto on September 9 and 10, 1970. This Conference was convened by the Prime Minister of Ontario and was attended by the Governors of the eight Great Lakes States, or their designated representatives, as well as representatives from the Provinces of Manitoba and Quebec. The Commission has taken cognizance of the discussions which took place during the Conference, the formal re-affirmation by the States and Provinces of their total commitment to achieve improved environmental quality in the Great Lakes Basin, and the recommendations that emerged from the Conference.

During the Commission's deliberations on the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River it has considered all of the reports by its two Boards, the written and oral testimony received at its public hearings, supplementary information obtained from various sources, and representations from the Governments of Canada and the United States.

The Commission at this time wishes to acknowledge with gratitude the valuable assistance and cooperation of those persons who served on the two Boards, their Committees and those who otherwise participated in the Commission's investigation, and of the agencies and departments whose cooperation made their participation possible.

Chapter III

THE LOWER GREAT LAKES BASIN

The Great Lakes, often referred to as the "Heartland of North America", contain the largest concentration of fresh water in the world. In 1966, 30 million people lived on or near the Great Lakes. This is equivalent to one out of every three Canadians and one out of every eight Americans. The Canadian waters of the Great Lakes, their Connecting Channels and the International Section of the St. Lawrence River are all within the boundaries of the Province of Ontario. The United States waters of Lake Erie are shared by the States of Michigan, Ohio, Pennsylvania and New York. The United States waters of Lake Ontario and the St. Lawrence River are within the boundaries of the State of New York. The following paragraphs briefly describe the Lower Great Lakes Basin with respect to population, economy, physical features and water uses.

In 1966, 10.4 million people lived in the United States portion of the Lake Erie Basin while 1.4 million lived in the Canadian portion. By the year 1986 this population is expected to increase to 15.4 and 2.0 million respectively. In the Lake Ontario Basin 2.3 million reside in the United States and 3.8 in Canada. By the year 1986 the populations are expected to increase to 2.8 and 4.8 million respectively. Approximately 156,000 live on or near the shores of the International Section of the St. Lawrence River.

There are two major zones of urban development within the Lake Erie Basin, Windsor-Detroit-Flint and Lorain-Akron-Cleveland; and one in the Lake Ontario Basin, Buffalo-Hamilton-Toronto. These high concentrations of populations, with the concomitant industrial complex, place heavy demands on the water resources of Lake Erie and Lake Ontario.

The Great Lakes region produces one fifth of the United States and half of the Canadian gross national product. The value of industrial output in the United States portion of the Lake Erie basin in 1964 was \$17 billion and of the Lake Ontario basin \$4 billion. In all of the United States it was approximately \$200 billion. Similarly, the value of industrial output in the Canadian portion of the Lake Erie basin in 1964 was \$0.9 billion and of the Lake Ontario basin \$2.8 billion. In all of Canada it was approximately \$16 billion. At the

Great Lakes Environmental Conference in Toronto on September 10, 1970 Governor Rhodes of Ohio stated that 50 percent of the taxes collected in the United States came from the eight Great Lakes States.

Lake Erie has a surface area of 9,900 square miles. Its maximum depth 210 feet; the average depth only 58 feet. The volume of Lake Erie is 110 cubic miles. The land area of Lake Erie's Drainage Basin including Lake St. Clair is 29,700 square miles of which 70 percent lies in the United States. The Detroit River with a mean flow of 188,000 cubic feet per second (cfs) contributes 90 percent of the inflow to Lake Erie.

Lake Ontario has a surface area of 7,500 square miles, a maximum depth of 802 feet and an average depth of 276 feet. The volume of Lake Ontario is 393 cubic miles. The land area of Lake Ontario's Drainage Basin including the Niagara River and the St. Lawrence River above Cornwall is 29,500 square miles. The Niagara River with a mean flow of 195,000 cfs contributes 85 percent of the inflow into Lake Ontario. An additional flow of about 8,000 cfs enters Lake Ontario through the Welland Canal.

The International Section of the St. Lawrence River extends from Lake Ontario to Cornwall, a distance of 112 miles. The water surface width of this part of the River varies from 1 to 4 miles. Over 1,800 islands are in the River. The mean annual flow is 240,000 cfs.

Much of the shoreline of Lakes Erie and Ontario is bounded by bluffs dissected by tributary streams. The eroded shore materials, largely silt and clay, probably contribute a major portion of the sediments in the Lakes.

If one imagines that an inflow of clean water could displace all the water in the Lakes, the replacement time on the basis of the inflows and the volumes of the Lakes, would be two and a half years for Lake Erie and eight years for Lake Ontario. This is physically impossible since the actual situation involves current circulation, mixing and stratification. It has been estimated that the replacement time for 90 percent of the stable contaminants would be approximately three times longer for each lake. Although more realistic, even these estimates should be treated with caution.

Each of the Great Lakes undergoes a yearly cycle of heat storage and heat loss. Solar radiation is the principal source of heat. The thermal structure, that is the temperature of water at various depths and at various locations within the lakes, is in a constant state of flux. Superimposed on the annual temperature oscillations corresponding to seasonal climatic conditions are random changes caused by wind-induced turbulence, barometric pressure, residual currents and internal displacement.

Lake Erie and Lake Ontario are warmed by the action of sun and wind on surface waters from the middle of March to the end of July and are cooled thereafter by a net loss of heat to the atmosphere. The water temperatures in the upper layer of the Lakes vary from approximately 0.5°C to 24°C or 33°F

to 77°F. Water is at its maximum density at 4°C. Warm water being lighter floats on the colder, more dense waters. During the summer months these physical characteristics divide the deeper parts of the Lakes into three zones of thermal stratification. The warm and lighter upper layer of water, called the *epilimnion*, becomes effectively separated from the deep, cold and heavier zone of water called the *hypolimnion*. The transition zone of abrupt temperature change (2 or 3°C per metre) between the lighter and heavier layers is called the *thermocline*.

The formation of the thermocline in the spring and its persistence during the summer is caused by the heating of surface waters by the sun and by the turbulent transfer of this heat to a depth determined by the force of the winds blowing on the lake. Due to the difference in the densities of the epilimnion and hypolimnion, the thermocline is a barrier to the movement of warm water downwards. Dissolved constituents, including pollutants, that enter the lake tend to be retained in the epilimnion for a prolonged period. The supply of atmospheric oxygen to the hypolimnion is cut off as long as the thermocline exists. In the late autumn and early spring the stability associated with the thermocline is lacking and pollutants are then subject to vertical mixing.

The cooling of the surface waters in the late summer and fall months thus making them heavier, coupled with storms that thoroughly mix the epilimnion, forces the thermocline deeper and deeper. The thermocline disappears about the first week in December when the surface temperature drops to 4-6°C. This is called the fall overturn. In the spring when the surface waters reach their maximum density a similar action, called the spring overturn, is induced. Because of these seasonal overturns, pollutants in the epilimnion and hypolimnion are subject to vertical mixing. Pollutants are well dispersed throughout all depths in shallow parts of the lakes, such as the Western Basin of Lake Erie, which are vertically isothermal (equal temperature) at most times of the year.

The waters of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River are used for municipal and industrial water supplies, cooling purposes, recreation, navigation, commercial fisheries and wildlife. In addition these same waters are used for domestic and industrial waste water disposal.

Withdrawals of water for municipal and industrial purposes are heavy and are indicative of the relative use of the Lakes by the two countries. These withdrawals are expected to increase rapidly because the sources of inland water supplies are almost fully developed. Over half of the municipal withdrawals are used for commercial and industrial purposes. Table 1 summarizes the withdrawals by each country for municipal and industrial purposes.

A total of 18,000 acres of parks and beaches are developed along the north shore of Lake Erie; 26,000 on the south shore. Similarly, along the

TABLE 1. MUNICIPAL AND INDUSTRIAL WATER WITHDRAWALS
Millions of Gallons Per Day

	Population Served	Municipal	Industrial	
			Process	Cooling
FROM LAKE ERIE				
Canada.....	87,000	24	4	18
U.S.A.....	3,300,000	634	112	4,491
FROM LAKE ONTARIO				
Canada.....	2,600,000	325	197	1,917
U.S.A.....	302,000	69	1	721
FROM INTERNATIONAL SECTION OF ST. LAWRENCE RIVER				
Canada.....	148,000	25	41	60
U.S.A.....	53,000	6	7	6

shores of Lake Ontario and the St. Lawrence River there are 4,500 acres of recreational land in Canada and 28,500 in the United States. Pleasure boating is popular along the shoreline of the Lower Great Lakes wherever there are good natural harbours and a lake-front free of hazards. The beautiful Thousand Islands Region in the St. Lawrence River is a favourite with boating enthusiasts.

The navigation facilities, channels, locks and harbours make the Great Lakes one of the most sophisticated water transportation systems in the world. Traffic tonnages have steadily increased since the St. Lawrence Seaway was opened in 1959. The cargo carried through the Welland Canal increased from 27.5 million tons in 1959 to 59.1 million tons in 1966. In 1969, 53.6 million tons of cargo were carried through the Welland Canal.

The Lower Great Lakes support a commercial fishing industry of economic importance. The market value of the 1967 commercial catch in Lake Erie was \$4.7 million, and in Lake Ontario \$0.3 million. Sport fishing is popular in the protected areas of the Lakes.

In Lake Erie waterfowl are found in large numbers at Long Point, Pelee Point and Kingsville on the north shore, the marsh areas on the southern shores and in the Western Basin. The wetland areas along the shoreline of Lake Ontario and the St. Lawrence River are also the habitat of waterfowl. Many birds winter near the Detroit and Niagara Rivers. Fur-bearing animals are now relatively scarce.

Chapter IV

THE BOARDS' INVESTIGATIONS

The Commission established two advisory boards, the International Lake Erie Water Pollution Board and the International Lake Ontario-St. Lawrence River Water Pollution Board, to undertake, through appropriate agencies in Canada and the United States, the necessary investigations and studies on behalf of the Commission and to advise the Commission on matters it would have to consider in making its report to the two Governments. The senior officials appointed by the Commission to the two advisory boards were from agencies of the Federal Governments of the two countries, the Province of Ontario and the States of New York, Pennsylvania, Ohio and Michigan.

The Boards' investigation was the most extensive water pollution study to be undertaken anywhere to date. It required the full cooperation and concerted efforts of twelve agencies from two sovereign nations and five other jurisdictions. Several hundred scientific, engineering and technical experts participated in this multi-million dollar study. The team of experts encompassed a wide range of disciplines, including bacteriology, biology, geochemistry, water chemistry, limnology, medicine, oceanography, physics, and several branches of engineering. Several world-acknowledged scientists participated in the study.

This multi-disciplinary investigation conducted under the aegis of the Commission brought together the five State and Provincial regulatory agencies along with Federal agencies concerned with questions of water quality. It permitted prompt exchange of technical information and plans and provided the basis for early implementation of some remedial measures. During the course of the investigation international relationships within the Boards were of a high order, friendships were established, and mutual understanding and respect developed among the participants.

All the data collected for the U.S. Federal Water Pollution Control Administration reports on the pollution of Lakes Erie and Ontario were made available to the International Boards. The additional information required was gathered by the participating agencies. The Canadian Government, recognizing the need to acquire more scientific information on the fresh

waters in Canada including Lakes Erie and Ontario, established the Canada Centre for Inland Waters at Burlington, Ontario and the Freshwater Institute at Winnipeg, Manitoba.

The Boards' investigation required nearly 450 man years of work by scientists, engineers and technical experts. The offshore studies involved over 100 cruises on Lake Erie and 200 on Lake Ontario to obtain on a regular basis, water samples and retrieve data at 13,000 stations. The regulatory agencies identified sources of pollution and collected data along the shorelines and tributaries in their jurisdictions. For example, the Ontario Water Resources Commission alone at various times deployed as many as 12 survey vessels to collect data at 50,000 sampling locations. In all, 600,000 samples were analyzed for a number of constituents.

At the conclusion of their study the Boards submitted to the Commission an 800-page report in three volumes. The Boards' report is a product of four years of intensive study, research and evaluation by acknowledged experts. Their findings and recommendations as well as a summary of the pertinent data are in Volume I. The detailed technical information, which was the basis for the Boards' recommendations is in Volumes 2 and 3. The supporting volumes represent the most comprehensive compendium of scientific information on the Lower Great Lakes. The Boards' report described the physical, chemical and biological characteristics of the Lakes; their present state and trends; the sources, characteristics and quantities of pollutants and their effects on the Lakes; the rationale for phosphorus control programmes; and recommended remedial measures.

The Boards' report is a balanced appreciation by experienced and specially qualified scientists and engineers who collectively are engaged in the solution and control of all aspects of water pollution.

Chapter V

PUBLIC HEARINGS

On October 8, 1969, following receipt of the Boards' Summary Report on pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, the Commission released a statement to the press which indicated the highlights of the Boards' report and announced that public hearings would be held early in 1970. Some 4500 copies of this report were sent to officials of governments, municipalities, companies and concerned persons. Similarly, on October 27, 1969 the Commission made public the Board's special report on potential oil pollution incidents from oil and gas well activities in Lake Erie.

In accordance with the Commission's Rules of Procedure, notice of the public hearings was published in the *Canada Gazette*, the *U.S. Federal Register* and a number of local newspapers in each country. Notices were also mailed to many individuals and associations, to all companies and municipalities mentioned in the Boards' report, and to all elected representatives in the Lower Great Lakes region.

Public hearings on potential oil pollution in Lake Erie were held at Toronto, Ontario and Cleveland, Ohio on December 2 and 3, 1969. Public hearings on the water pollution report were held at Erie, Pennsylvania on January 20, 1970, at Toledo, Ohio on January 20, at London, Ontario on January 23, at Hamilton, Ontario on February 2, at Rochester, New York on February 4, and at Brockville, Ontario on February 6. The eight public hearings were well attended. All those interested were given opportunity to convey relevant information to the Commission and express their views orally or in writing.

Statements were made by elected representatives from all levels of government in each country, officials of governmental agencies, industrial representatives, local organizations and private individuals. Representatives of voluntary groups such as the League of Women Voters and Pollution Probe were prominent at all of the hearings. A number of housewives testified. Secondary school and university students were present in large numbers and some presented statements. Scientists and engineers from both industry and

the academic community spoke on nutrients, eutrophication and substitutes for phosphorus in detergents. In all, about 180 witnesses were heard. A list of persons who gave testimony is in the Appendix of this Report. In addition, over 200 statements and letters were filed on behalf of individuals and organizations either at the public hearings or by mail.

Testimony presented at the hearings disclosed widespread concern about pollution in the Lakes and an increasing awareness of the effects on the Lakes of municipal and industrial discharges and of nutrient enrichment. The following statements indicate the sense of testimony received from individuals and associations:

Safe lakes require a public willing to protect its environment and willing to pay for this protection.

We have become alarmed at the dramatic and shocking changes which are taking place with respect to the condition of this grand waterway.

The Federal Government should increase its financial assistance to the States for waste treatment.

We have heard a lot of words. When is the action going to start, because the longer we procrastinate the worse the problem becomes?

Our community is dedicated to pollution abatement.

Our local officials are more cost conscious than ecology conscious.

Youth is more concerned about the environment than any previous generation.

We must reassess our priorities—roads or pollution control?

The housewife believes phosphorus should be removed from the detergents—we don't care as much about snow white shirts as about cleaning up the Lakes.

Detergent manufacturers have mounted an intensive campaign to induce housewives to believe that "whiter is better". It is time they admit their corporate responsibility for the pollution which they are creating.

It would be useful to have exact phosphate content of detergents clearly shown on the label so that the shopper could choose accordingly.

The soap and detergent companies were represented at six of the hearings and gave testimony at four. Their spokesmen explained that the consumer expects and demands high performance from synthetic detergents and that phosphate builders have been an essential ingredient in their formulation. They did not concur with the Boards' findings and recommendations concerning phosphate removal from detergents but supported nutrient removal at sewage treatment plants. They said a reduction of phosphates would result in lower cleaning results, and that there was no satisfactory substitute for phosphates. It would require years of research to develop one.

Statements were made on behalf of the federal, provincial and state agencies concerned with pollution in these waters. They supported the findings and recommendations in the Boards' report. Several stressed that phosphorus removal must be a two-pronged attack—removal of phosphorus from detergents and also phosphorus removal at waste treatment plants. They reported on the Swedish experience with phosphorus control from the academic, government, research and industrial points of view. One official suggested that the amount of phosphorus allowed to be discharged to the Lakes by each jurisdiction should be clearly delineated.

An official stated that air and water are scarce resources and that we are no more free to contaminate them than we are free to throw garbage into our neighbour's yard. Polluted effluents cross from the United States to Canada and vice versa. The only way to control pollution is to establish standards which apply equally to all the waters under consideration. These standards must be comprehensive, compatible and must be upheld by the federal, state and local levels on both sides of the boundary. Several stated that the IJC, which by Treaty has responsibilities for these boundary waters, should be strengthened and given a major role in coordinating the management of water quality in the Great Lakes. An Ontario official was critical of the pollution control programme of Ohio, especially in the Cleveland area, and of the progress of pollution control programmes of New York State at Buffalo and Niagara Falls.

At the hearings on potential oil pollution, Ontario officials explained their offshore drilling regulations and requirements and their enforcement. Other statements described contingency plans in both countries, drilling and gas production operations in Lake Erie and the relation of ships to oil pollution. In Cleveland, statements indicated a general opposition to drilling, so as to prevent added impairment of an already critical situation. A doctor stated that health is menaced by existing contamination of drinking water supplies by oil products, which are not removed by water treatment plants. An elected representative recommended that Canada limit gas drilling to that portion of Lake Erie east of Point Pelee and that there be a moratorium on oil production.

The Commission was reminded of the practice common many years ago in mines of keeping a small bird in a cage to give warning of possible imminent danger to man. Today it is a common practice to utilize the fish in our water supplies for a similar purpose. Some of the fish in these waters are dying. It is a warning that must not be ignored.

Verbatim transcripts of all hearings are on file at the offices of the Commission.

Chapter VI

POLLUTION PROBLEMS

The Lower Great Lakes System is not only a source of water for the people and the industrial complex located in the basin but is also the final disposal area for the expended resources from the highly developed society they support. We must recognize that this has been for the last century one of the accepted uses of the Lakes and yet at the same time realize this past treatment has transmuted the Lakes so that their capacity to be of use to us has been decreased.

Most of the water used for municipal and industrial purposes is also used to convey wastes from their point of origin to the Lakes. The introduction and accumulation of untreated or partially treated wastes from tributaries, municipalities and industries has limited the legitimate uses of the Lakes, caused unfavourable biological changes, and destroyed much of the general satisfaction and enjoyment that we refer to as the Lake's contribution to the quality of life.

These personal losses are matched by economic costs. Future industrial and urban development will be adversely affected and distracted unless there is prompt implementation of necessary remedial measures to correct the pollution problems briefly described hereunder.

EUTROPHICATION

Eutrophication is the biological response caused by an increase of nutrients into lakes. The biological productivity depends on the supply of essential nutrients. Lakes well supplied with these nutrients tend to be the most productive biologically. This relationship is the basis for the "trophic" system of lake classification.

Oligotrophic lakes are poorly supplied with nutrients and support little plant growth. The biological production is generally low; the waters are clear; and the deeper waters are well supplied with oxygen throughout the year. *Eutrophic* lakes are rich in plant nutrients and support a heavy growth of aquatic vegetation. As a result, biological production is high; the waters are

turbid due to the dense growth of phytoplankton; and the deeper waters during periods of restricted circulation become deficient in oxygen as a result of the decomposition of great quantities of organic material. *Mesotrophic* lakes are intermediate between oligotrophic and eutrophic states. They have a moderate supply of nutrients, moderate plant abundance and moderate biological production.

If the supply of nutrients to an extremely oligotrophic lake is progressively increased, the lake will become mesotrophic in character, and with further enrichment it will eventually become eutrophic, even extremely eutrophic. This whole process of progressively becoming more eutrophic is known as eutrophication. Thus, eutrophication refers to the whole complex of changes which accompany continuing enrichment of waters by the addition of plant nutrients. These include progressive increases in the growth of algae and aquatic weeds, a general increase in biological activity, successive changes in the kinds of plants and animals living in the lake and oxygen depletion in deep water during periods of restricted circulation.

The biological response produced by natural eutrophication is extremely slow. On the other hand, the inputs of man-derived nutrients into a lake can produce in a few decades a biological response similar to that which under natural conditions would take tens of thousands of years.

Increased population, industrialization, intensified agricultural practices and the use of phosphorus-based detergents since the late 1940's have greatly increased the rate of eutrophication of lakes in many parts of the world, including Lake Erie and Lake Ontario. Dense nuisance growths of algae and aquatic weeds degrade water quality. *Cladophora*, an attached alga, piles up on the beaches when dislodged by wave action. Blue-green algae accumulate on the shore creating unsightly odorous scums.

Although a number of elements are required by plants for their growth, phosphorous and nitrogen are recognized as the most important elements responsible for triggering eutrophication because their supply is lowest in relation to nutritional requirements. Phosphorous is more controllable than nitrogen both in terms of present technology for removal at sewage treatment plants and in terms of proportion of the total supply to the lakes that is directly attributable to man.

The phosphorus loading to the lakes can be controlled more effectively than nitrogen for several reasons. The percentage of the total phosphorus supply attributable to municipal and industrial sources (70 percent for Lake Erie, 57 percent for Lake Ontario) is higher than in the case of nitrogen (about 35 percent for Lake Erie, 30 percent for Lake Ontario). Thus, complete removal of phosphorus from municipal and industrial wastes would reduce the overall nutrient supply to a greater extent than in the case of nitrogen.

Appreciable quantities of readily assimilable nitrogen compounds such as nitrates and ammonia are delivered to the lakes in precipitation, whereas the comparable quantities of phosphorus are minute. It has been estimated that approximately 32 million pounds of nitrogen are contributed annually to the surface of Lake Erie and 24 millions pounds to the surface of Lake Ontario by rain, snow and dustfall. Finally, during times of nitrogen deficiency blue-green algae and bacteria can convert atmospheric nitrogen into nitrogen salts readily available for algal growth, thus adding to the overall supply. For these and other reasons, control of phosphorus inputs is likely to be more effective in restricting plant growth than would be the case for nitrogen or any other single nutrient. The Commission is encouraged by the fact that the input of phosphorus into the lakes can be controlled because the concentrations of phosphorus in domestic wastes, certain industrial effluents and runoff from some agricultural operations are of our own making.

Massive growths of algae year after year are dependent on a continuous influx of phosphorus and other limiting nutrients from outside the lake. The resultant biological productivity is proportional to the annual rate of input of these nutrients. Theoretically, plant populations could be controlled by reducing the input of any essential element required for growth. The important feature of phosphorus is that it offers the best combination of a nutrient that is growth-limiting in the lakes and at the same time controllable by man. Phosphorus compounds are highly reactive materials and can be precipitated readily, absorbed or adsorbed by a variety of relatively inexpensive methods that remove 80-95 percent of phosphorus during sewage treatment. Even if technology for the elimination of nitrogen compounds were advanced to a comparable state, there would still remain the uncontrollable nitrogen input from the atmosphere and other natural sources.

OXYGEN DEPLETION

Dissolved oxygen, the oxygen held in solution in water, is derived from contact with the atmosphere and from photosynthetic processes of aquatic plants in a well balanced environment. Equilibrium with the atmosphere is approached or exceeded in thermally unstratified water as a result of mixing. Dissolved oxygen is required for respiration of fish and most living organisms, for effective bacterial decomposition of organic matter, and for chemical oxidation.

Oxygen depletion is likely to occur in the bottom waters of shallow lakes, such as Lake Erie, when they are cut off from the sources of oxygen by thermal stratification. Oxygen depletion is caused by falling organic material synthesized by plants and by contact with bottom muds that have a high content of organic matter and a high chemical oxygen demand. Oxygen depletion is a

consequence of the heavy growths of aquatic vegetation associated with eutrophic lakes. In deeper waters dissolved oxygen is only replenished by the spring and fall overturns.

The top centimetre of the sediment is usually capped by a thin oxidized microzone, often rich in ferric hydroxide. It forms a chemical barrier that keeps phosphate ions in the sedimentary layer below from passing into solution, and also assimilates material falling to the bottom. However, at times of oxygen depletion of the bottom waters, the microzone is destroyed. This permits the release of phosphate, ammonia and other ions to the overlying waters.

Additional problems related to oxygen depletion are discussed further in Chapter X.

BACTERIAL CONTAMINATION

The group of bacteria most indicative of pollution encountered in bacteriological analysis of water is the coliform group. This group is found on plants and grains, in the soil and in the intestinal tract of man and animals. A member of this group, *Escherichia coli*, is predominant in the feces of warm blooded animals. Fecal coliforms provide an index of fecal contamination. Sewage also contains appreciable numbers of fecal streptococci. The latter are found only in feces and in waters polluted by fecal matter. They rarely survive longer than two days.

Although the coliform group is not normally regarded as pathogenic, the presence of members of this group in water does serve as an indication of the possible presence of the scarcer and much more difficult to isolate pathogenic enteric organisms, such as those causing typhoid fever, dysentery and cholera.

Water with coliform counts of 5,000 per 100 ml (millilitres) or less are suitable for water supplies after being given conventional treatment. Water with coliform counts of 1,000 per 100 ml or less are acceptable for bathing and similar water contact sports providing the fecal coliform count is less than 200 per 100 ml.

VIRUSES

Viral diseases can be transmitted by water. They can reach public water supplies from the discharges of pleasure and commercial water craft, from the effluents of municipal sewage treatment plants and from urban and rural runoff. Many of the treatments afforded sewage are not adequate with respect to viruses; viable viruses have been isolated even in effluents from sewage treatment plants employing tertiary treatment, and viruses are not inactivated in lagoons or septic tanks.

Although viruses require the presence of living, susceptible cells in order to grow and multiply, current evidence indicates that they survive outside these cells for considerable periods of time, much longer than bacteria. Apparently viral survival is longest in slightly or moderately polluted waters. Such conditions of pollution prevail in many areas of both Lake Erie and Lake Ontario. The situation is critical because the areas where there is the highest possibility of viral survival, that is, areas near large urban centers, are often the same areas used for recreation and public water supplies.

Since viruses are very different from bacteria, the indicators used as an index of bacterial pollution (the coliform count) do not serve as indicators for viral pollution. There is as yet no suitable agent available which can be used as an indicator of the presence of human or other viruses. As a result large scale investigations have been hampered by the lack of an adequate isolation method which can be applied to waters where only small numbers of viruses would be expected to occur.

Thus there are no data available regarding the extent of the presence of viruses in the Great Lakes.

ACCUMULATING SOLIDS

Lake Erie and Lake Ontario historically have been receptacles for the materials discarded by those who live near their shores and tributaries. The Commission is concerned with present accumulations of solids, suspended materials, dissolved solids and floating refuse.

The post-glacial mud accumulations in the Lakes are a result of erosion of soils in the drainage basin, shoreline recession and reworking of shallow lake bottom deposits. It is claimed by some that the intensified land use has increased the rate of sedimentation in the Great Lakes to 50 times the geologic norm. About 58 percent of the lake bottom in Lake Erie is covered with gray, silty clay or clay mud deposits. The widely distributed clay deposits in the Lakes may be an asset so far as their adsorptive capacity for phosphorus is concerned. However, they destroy sand and gravel spawning areas of the more valuable fish species.

Turbidity, or lack of transparency, is a measure of the interference of suspended particles to the passage of light through water. Turbidity is dependent on the size and number of particles rather than their weight. It is caused by phytoplankton, high silt loads and suspended organic debris.

Game fish which feed by sight are at a disadvantage in dark waters compared with the coarser types such as carp and catfish. Turbidity also impairs the aesthetic quality of beaches. However, the present turbidity levels do not seriously affect the water quality of the Lakes.

Total dissolved solids are a measure of all the dissolved solid substances present in a water sample. The United States Public Health Service drinking water standards list 500 mg/l (milligrams per litre) as the desirable maximum for public supplies. In the last 50 years the dissolved solids have increased from approximately 140 mg/l to 185 mg/l in both lakes. These concentrations of dissolved solids are low in relation to the foregoing potable water supply standards.

Notwithstanding the fact that these levels in themselves do not inhibit use of these waters, the data indicate the changes which are occurring through man's use of the Great Lakes as receiving waters for his wastes.

Floating materials and refuse in the Lakes result from irresponsible dumping of garbage from watercraft and unauthorized disposal of refuse along the shoreline. These wastes are not generally present in quantities large enough to cause chemical or biological deterioration of water quality. However, such wastes pose a problem near water intakes and are not only serious nuisances to swimmers, boaters and shore property owners but also are aesthetically offensive to the entire community.

ORGANIC CONTAMINANTS

Organic contaminants are persistent or biochemically resistant organic compounds. They occur in pesticides, industrial and domestic wastes. Because of their persistent nature and the fact that many of them are toxic at very low concentrations, they pose a serious threat to the health of man and to the aquatic community. Also, because of their persistency, these chemicals can have a synergistic effect with one another; that is to say, organic compounds which might be only slightly toxic as a sole contaminant, in the presence of other compounds can have their toxicity increased many fold.

Many of these organic substances resist conventional water treatment processes as well as natural purification. Organic substances are also produced by algae. Some interact chemically with chlorine to form substances that impart an offensive taste and odour to water. As a result, taste and odour problems are experienced in public water supplies and in the food processing industry. It has been reported that concentrations of certain organic contaminants in some cases have caused fish kills and in other cases have seriously affected fish fertility.

Re-use of contaminated water increases the concentration of stable organic contaminants. Consequently, further deterioration of the water quality of the Lakes can be expected. The Commission is concerned about the lack of information on the levels of these organic compounds in the Great Lakes, on new product formulations and on organic and inorganic interactions which may affect the quality of receiving waters. Analytical techniques for

qualifying and quantifying these contaminants at low levels are at present woefully inadequate, time consuming and cumbersome.

One of the ways of reporting organic compounds in water is in terms of the carbon chloroform extract (CCE) $\mu\text{g}/\text{l}$ (micrograms per litre). Because of the suspected low recovery efficiencies of the CCE test, the reported values must be considered as minima, the actual values being equal to or greater than the reported values. The CCE test does not discriminate among pollutants of varying toxicity. More specific procedures should be used in those cases where they are available and a concerted effort made to develop improved methodologies. This is a matter of urgency.

The most desirable condition is one in which the water supplied to the consumer contains no organic residue. The United States Public Health Services and the Ontario Water Resources Commission have set a maximum limit of 200 (CCE) $\mu\text{g}/\text{l}$. Repulsive taste and odours can be detected in water with a greater CCE concentration. In comparison, clean surface and ground waters contain 25-50 (CCE) $\mu\text{g}/\text{l}$.

Pesticides, which for the purpose of this Report include insecticides and herbicides, are organic contaminants which deserve particular attention because of their persistence and cumulative nature. More than 9,000 commercial preparations are available in the United States. Tests have demonstrated that some of these compounds persist in the soil far more than five years. Pesticides may reach potable water supplies from aerial spraying, from agricultural runoff, from food processing wastes, accidents and thoughtless disposal of surplus pesticides. There is also some direct application of herbicides to water for aquatic weed control. Thus the amount present at any point in the lakes will depend on the sources involved.

A permit and accountability system in Ontario yields information on the kinds, amounts and places of pesticide application throughout the Canadian portion of the watershed. Only Pennsylvania and Michigan on the United States side have a similar permit system and their permits are limited to the direct application of herbicides to water.

Polychlorinated biphenyls (PCBs) are recognized as a potential contaminant. PCBs, like DDT, contain chlorine, hydrogen and carbon. They are not soluble in water, but are soluble in fat, and are extremely persistent in the environment. The chemical similarity suggests that they may have similar effects on fish, birds and perhaps people. It is ironic that PCBs enter the environment mainly through the cleaning and disposal of their containers. Some PCB compounds have been used in flow-through systems where their entry into the environment is not controlled. The sole supplier has recently withdrawn these compounds from the market. The major problems associated with PCBs are unknown sources, toxic effects, analytical methods for their measurement and techniques for their control.

Phenols are another group of organic contaminants. They have been of great concern for the last 25 years because of their taste and odour producing effects in public water supplies. The term phenol as used in this Report refers to phenol and phenolic type compounds which react with 4-amino-antipyrene to produce colour development. Carboic acid is a phenolic compound. Natural phenols are present in the oils secreted by algae. Other phenols accumulate from wastes discharged from the catalytic processes of oil refining, plastic industries and the coking processes of coal. A minute amount of phenol ($1\mu\text{g/l}$) in combination with chlorine can cause a disagreeable taste.

OIL

Oil pollution has plagued the principal tributaries of the Lower Great Lakes for years, notably the Detroit, Cuyahoga, Buffalo and Niagara Rivers. Although oil spills which are discussed in Chapter VII, are spectacular and dramatic, the continuous discharge of oils and greases by industries and municipalities cause much greater damage to the environment. These oils and greases occasionally appear as slicks which disperse a short distance from the outfall. More often they are emulsified in the effluents and are not observed as oil films in the receiving waters.

Notwithstanding the fact that municipal treatment plants rarely create observable oil films, their treated wastes may contain considerable quantities of oils, fats and greases. For example, the International Niagara River Pollution Board reported that of the 29 million pounds of oils discharged in 1967 to the Upper Niagara River, 40 percent came from municipal treatment plants effluents.

The movement and persistence of oil in the lakes and onto their shores are influenced by the nature of the oil, wind, sunlight, temperature, the presence of solids, shore conditions and bacteria. Certain oil fractions evaporate, others undergo autoxidation; some sink to the lake bottom, others are carried to the shores by wind and water movements.

In addition to the continuous injection to the lakes of oils from industries and municipalities, there is a potential risk of oil contamination from severe spills, shipping accidents and offshore drilling.

RADIOACTIVITY

Radioactivity in the Great Lakes has been a concern since the advent of nuclear weapon testing and the increased applications of nuclear energy and nuclides in atomic reactors, medicine, industry and research.

Radioactivity in water can enter the human body either through direct ingestion or through the consumption of fish and other aquatic products.

If the water is used for recreational purposes, prolonged exposure to high radiation levels could also prove injurious. Consequently, radioactivity measurements are made regularly by governments on the raw waters, on the animal and plant life in the water, on bottom sediments and on beach sands from recreational areas.

Alpha and beta activity are the two principal forms of radioactivity encountered in water. Alpha activity is largely due to natural sources, whereas some beta radiation results from man's activities. Generally, beta activity reflects the variable contamination from fallout and discharges from man-made sources. The principal fallout products are strontium-90, caesium-137 and iodine-131.

At various times the main source of increases in the radioactivity in Lake Erie and Lake Ontario has been from fallout following atmospheric nuclear weapon testing. The amount of radioactive materials discharged to surface waters by nuclear reactors, uranium refineries, medical uses and research is carefully controlled by government regulations. This ensures that radioactivity is maintained at levels within prescribed limits.

CALEFACTION

Calefaction, the result of discharges of heated waters to the Lakes, is of growing concern. When or whether it becomes a problem—thermal pollution, or a benefit—thermal enrichment, are matters still to be determined.

The effect of waste heat on the Lakes is not considered at this time to be significant. For example, the total heat input into Lake Erie by power generation and industry is 0.13 percent of the natural heat input for the period of warming, April to August. The perceptible effects of calefaction are local in extent. Near the shoreline local heat inputs stimulate algal growth, deplete the dissolved oxygen and possibly alter the local ecology.

TOXIC MATERIALS IN TRACE AMOUNTS

One of the major problems relating to public water supplies is the false sense of security based on past experience in a far less polluted environment. The infrequency of water borne disease outbreaks does not justify complacency. Conventional water treatment does not remove all dissolved organics and inorganics, to say nothing of its questionable effectiveness in the removal of viruses. There is a parallel situation between a person consuming dissolved materials of unknown toxicity over a long period of time and the concentration in predator fish of the minute amounts of mercury occurring in the aquatic environment. The fact that current epidemiological techniques are inadequate to identify and define these problems is no basis for concluding that they do not exist.

Waters of the Lower Great Lakes contain trace amounts of toxic materials including but not restricted to arsenic, cadmium, chromium, cobalt, copper, lead, mercury, vanadium and zinc. The concentration of these elements in the waters is so small that their minute ambient levels cannot be measured except by special techniques. Often their presence is not detected until highly sophisticated quantitative measurement techniques have been developed. These materials may occur naturally in the lakes or may be introduced by man.

The toxicity limits and toxic effects of relatively small quantities of these elements on the aquatic environment and on human health have not been adequately determined. Some lethal elements, in extremely minute amounts, are essential for good health. The magnification characteristics—that is the ability of various forms of life to concentrate some of these elements—are not fully understood.

The discovery of high levels of mercury in the fish of the St. Clair River illustrates the dilemma. For years metallic mercury was thought to be very stable; so much so that in laboratories it was stored in water. The mercury concentration in the St. Clair River, in all water samples except those taken in the immediate vicinity of the outfalls discharging mercury, was less than the detectable level of 5 $\mu\text{g/l}$.

It was also thought that elemental mercury and the salts of mercury would remain locked up in the sediments. Recent discoveries have proved that this was not the case. Investigations and research demonstrated that under natural conditions bacteria effected a conversion of these compounds into methyl mercury which entered the biological food chain. The mercury manifested itself in high concentrations in predator fish, as much as 3000 times the level found in the water. Recently, methods have been developed to quantitatively lower levels of mercury than was previously possible.

The Commission is concerned with the problem of identifying and quantifying various materials that may be present in these waters. There may be undetermined toxic effects on humans and the environment.

Chapter VII

POTENTIAL OIL POLLUTION

This chapter was originally prepared in response to a request from the two Governments for a special report on the several aspects of oil pollution in Lake Erie. The sections pertaining to current sources of oil pollution, the containment and clean up of oil spills, and contingency plans are equally applicable to Lake Ontario and the International Section of the St. Lawrence River as they are to Lake Erie.

There is no production of oil in Lake Erie. In 1969 four billion cubic feet of natural gas were produced from 234 active gas wells in the Canadian portion of Lake Erie. The production of natural gas has not resulted in a water pollution problem. Although a few wells were drilled in United States waters, there has been no production to date.

There is no production of oil and gas from submerged lands underlying Lake Ontario or the St. Lawrence River, and there are no known plans for exploration activities.

In Lake Erie all of the submerged lands offshore from Ontario have been leased for drilling. Some submerged lands offshore from Pennsylvania were leased for drilling but exploration has not commenced (See Figure 2). New York State's plan for oil and gas exploration is not fully developed. The Ohio programme has been postponed. Pursuant to Michigan's long-standing policy, leases of State owned bottom land in the Great Lakes and their Connecting Channels are not granted for offshore drilling.

SOURCES

Lake Erie is an essential source of fresh water for some ten million people that live on or near its shores. Thus in its concern with the quality of Lake Erie waters, the Commission must take account of potential as well as current sources of oil pollution. The potential for serious incidents of oil pollution includes but is by no means limited to underwater oil and gas exploration and development. In order to place the threat of pollution from drilling in its proper perspective, it is necessary to consider the significant amounts of oil

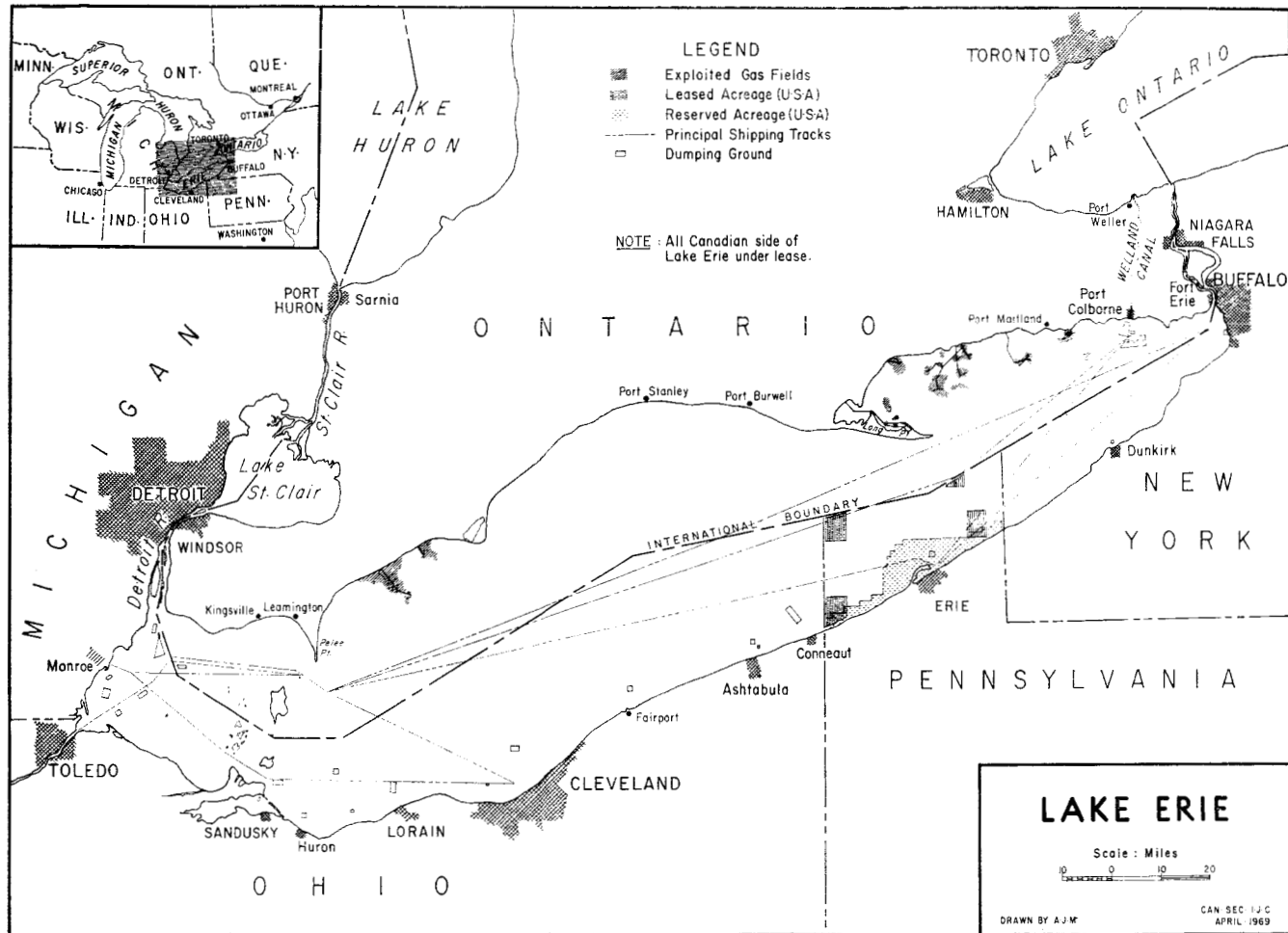


Figure 2

pollution from municipal and industrial sources, shipping, product transfer, shore storage and pipelines.

The Commissioners were appalled at the insidious intrusion of vast amounts of oil from the populous and industrialized communities in the Lake Erie basin. For example, during 1969 more than 1000 barrels per day of oils and greases were discharged into the Detroit River, the major tributary to Lake Erie. The Buffalo River is another significant source of oil pollution of boundary waters. These oils and greases occasionally appear as slicks on the water surface but more often are emulsified in the effluents. Some of these pollutants are adsorbed onto the suspended load in the river and are deposited as sediment. Such is the situation in Cleveland Harbor where it was estimated that 17,600 tons of oil and grease were included in the 660,000 tons of dry solids removed during the 1966-67 dredging operations. (These wastes are currently being placed in a dyked disposal area.)

The Commission is concerned about the numerous accidental spills. In April 1969 it was estimated that 2,300 barrels of cutting oil from one industrial spill in the Trenton Channel of the Detroit River entered the Western Basin of Lake Erie.

The Commission also appreciates the serious implications of the grounding of the ship "Arrow" off the coast of Nova Scotia, the grounding of the "Delian Appollon" off the coast of Florida, the sinking of the barge "Irving Whale" in the Gulf of St. Lawrence and the sinking of the ship "Eastcliffe Hall" in the International Section of the St. Lawrence River, all in 1970.

The Commission was informed that on Lake Erie at any one time during the navigation season 22 lake freighters, 4 lake tankers and 7 deep sea freighters carry an estimated 120,000 barrels of oil as either fuel or cargo. These facts illustrate the gravity of the total oil pollution threat on the lakes and the need for adequate controls over the several aspects which comprise the total threat.

GEOLOGY

Lake Erie is part of a stable geologic basin, the latest movements occurring over 200 million years ago. These structural movements were gentle and did not involve extensive folding and faulting of the strata. The Eastern and Central Basins of Lake Erie are in what is essentially a gas province. The traps of hydrocarbons are stratigraphic (lateral changes in permeability within widespread rock units), or were formed by ancient porous coral reefs. The bed rock sediments, into which the surface casing required in drilling operations must be cemented, are a minimum of 300 million years old, hard, and competent enough to control any subsurface pressures that might be encountered. The pressures encountered are less than those expected under normal hydrostatic conditions.

In contrast, active oil seeps have been known to exist in the Santa Barbara Channel area for many years. The rate of flow from these seeps has been estimated to be 50 barrels a day or one tenth of the maximum rate of flow that escaped from the blowout on January 28, 1969. The Santa Barbara area is considered to be an oil province. It is an unstable area. Vertical uplift and subsidence is still being recorded on land. The traps which produce the hydrocarbons are tightly folded anticlinal structures, and complex fault features formed only a few million years ago. Strata underlying the Santa Barbara Channel are unconsolidated and apparently not strong enough to contain the pressures developed in the deeper formations. The pressures encountered are slightly greater than hydrostatic. Thus, the hazard of subsurface fluids breaking through the underlying strata is always great.

This explains why those who know the geology of both areas have assured the Commission that it is highly improbable that a dramatic drilling accident similar to the Santa Barbara incident would occur in Lake Erie.

DRILLING REGULATIONS

The essence of pollution prevention from drilling operations is the containment and control of drilling and reservoir fluids. The primary considerations which drilling regulations must take into account for each well are: the design and implementation of effective casing and cementing programmes, the adequacy of blowout prevention and related equipment, and the disposal of drilling and reservoir fluids. The regulations must be designed so as to ensure that operators during their drilling and development operations use the best materials and technology available.

The offshore drilling regulations of Ontario and Pennsylvania and those proposed for New York can provide effective protection of the waters of Lake Erie if adequate supervision and enforcement are also provided. A high degree of coordination between interested agencies is necessary to provide adequate but not repetitious coverage. However, if drilling is extensive accidents may occur. Thus, it is necessary to have contingency plans prepared to cope with such incidents.

Adequate drilling regulations are only as strong as their enforcement and the willingness of the industry to act responsibly. Drilling and gas production activities in Lake Erie at present are limited to the Ontario portion of the lake. According to testimony received at the Commission's hearings, the Ontario Department of Energy and Resources Management, now the Department of Mines and Northern Affairs, does provide careful inspection and surveillance over the drilling and development operations in the Ontario portion of Lake Erie; and the industry has demonstrated a willingness to

cooperate with the Government and has an awareness of the environment in which it operates. The Ontario departmental inspectors are on board the drilling platforms most of the time and are always present during critical periods such as spud-in and completion operations.

In Ontario, the Minister of Mines and Northern Affairs has discretionary power to suspend a drilling permit in whole or in part at any time or impose any terms or conditions on a permit which he deems proper. Such action is subject to a subsequent hearing and review by the Ontario Energy Board. The Minister can thus move very quickly to halt any operation which might pose a threat to water quality. The best evidence of effective implementation of existing regulations is the successful record of trouble-free drilling for gas in Lake Erie; oil production has not been permitted to date. Furthermore, the Ontario regulations are being progressively strengthened.

At the hearings, an official of the Ontario Department of Mines and Northern Affairs described the existing safety requirements and procedures in Canada applicable to drilling and production operations in Lake Erie and an official of the State of Michigan described its present policy of not permitting underwater drilling. Although officials of the States of New York and Ohio and the Commonwealth of Pennsylvania cooperated with the Board during the investigation, no officials of these states presented testimony at the hearings to assist the Commission in assessing the safety requirements and procedures applicable in the portions of Lake Erie within their jurisdictions.

CONTAINMENT AND CLEAN UP

Although there have been no oil spills in Lake Erie from drilling (except for a minor incident in 1959 involving an estimated five barrels), the Commission is aware of the many oil spills reported along the shipping lanes in Lake Erie and from land-based sources. The frequent occurrence of accidental spills requires that effective means be available to contain and clean up oil spillages before the legitimate uses of Lake Erie waters are inhibited. Moreover, the collision or stranding of ships are potential sources of major pollution by oil or hazardous materials in Lake Erie as elsewhere.

The Board, on behalf of the Commission, reviewed the current methods of containment of oil on water; its removal by mechanical methods, by physical materials and by chemicals; and of protection and clean up of shore areas. According to reports on major oil spills elsewhere in the world, the adverse effects of materials used to sink or disperse oil can be more harmful than the effects of the oil itself. As indicated in the Board's report, the equipment and techniques for the containment and removal of large oil spills under adverse climatic conditions are primitive.

CONTINGENCY PLANNING

The Commission is of the opinion that those responsible for the confinement and clean up of spilled oil and hazardous materials must have at their disposal the best technical advice and the required resources of manpower, materials and equipment. The onscene commander needs sufficient executive authority to fulfil his responsibilities. Any contingency plan should provide for the discovery and reporting of pollution incidents and for the initiation of prompt action to restrict the spread of the pollutant. Experienced personnel should be available to direct the clean up and disposal of the collected pollutants.

The Board, at the direction of the Commission, examined the state of preparedness in both countries to respond to major oil pollution incidents which might occur on Lake Erie. Regional contingency plans have been developed by the United States for the Great Lakes and provide a response capability for spills that might occur in U.S. waters. However, there appears to be a concentration of responsibility on the federal establishment and little, if any, actual recognition of state and local capabilities or delegation of responsibility. Although the United States contingency plan for the Great Lakes region appears to be generally complete and detailed, its adequacy cannot be fully assessed in the absence of a satisfactory record of experience.

Canada's comprehensive contingency plan is still in the embryo stage. However, an interim federal plan was developed in the summer of 1970. Individual agencies such as the Ontario Water Resources Commission, the Ontario Department of Mines and Northern Affairs and the Federal Department of Transport have internal response mechanisms established. The Ontario Water Resources Commission has a detailed contingency plan for spills of oils and hazardous materials for Lake Erie. A major oil spill in the Canadian waters at the present time, however, would not be met with the full response capabilities available because of the lack of a detailed plan for coordination between the Canadian federal, provincial and local authorities.

Furthermore, the Commission notes that at the present time there is no formal plan for a concerted international response, only informal notification.

Chapter VIII

TRANSBOUNDARY MOVEMENT

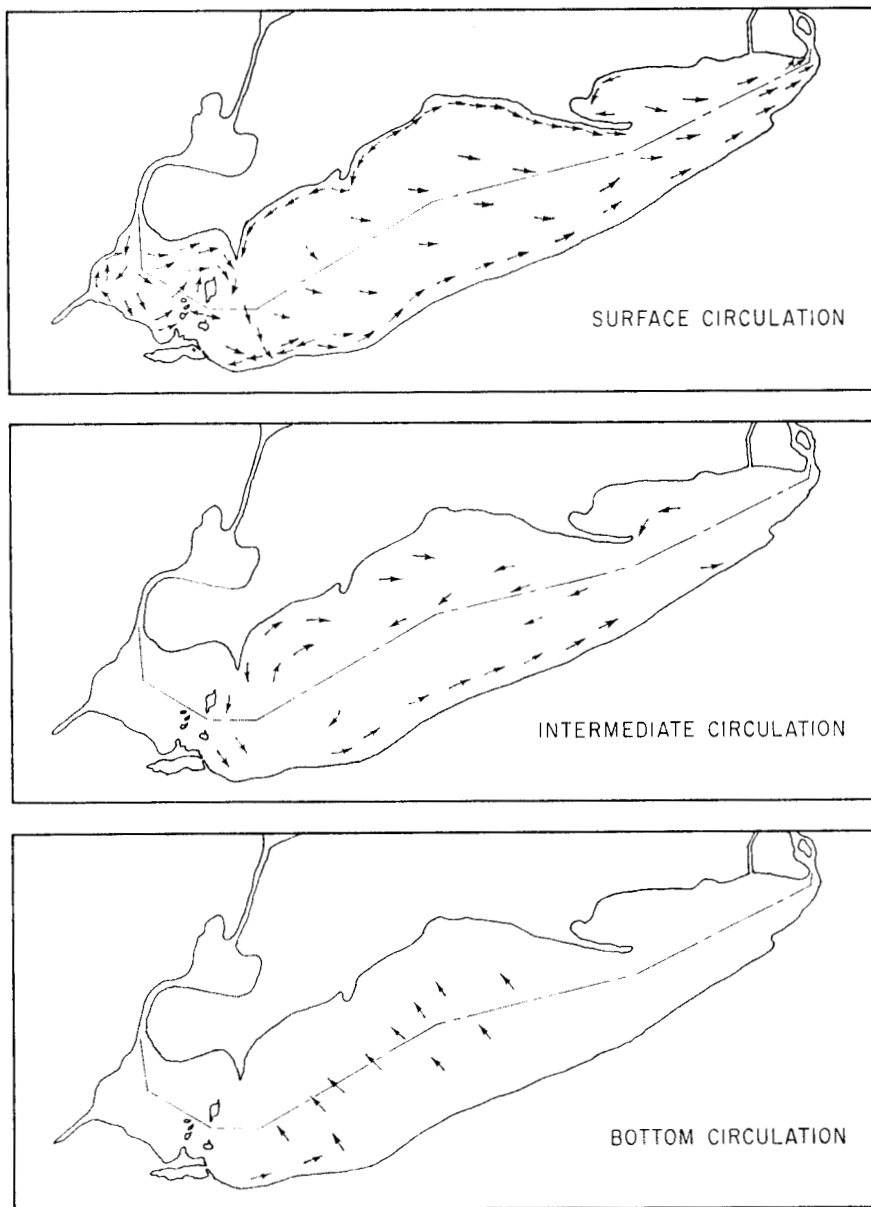
There is no doubt that contaminants entering Lake Erie and Lake Ontario from one country move across the boundary and affect the water quality in the other country. Extensive current metre surveys, the movements of drift objects and the uniform distribution of chemicals in the waters of both lakes attest to that fact.

The movements of contaminants were ascertained by analyzing direct measurements of lake water currents at various depths. The dominant features of surface, intermediate and bottom circulation patterns for Lake Erie and Lake Ontario are shown on Figures 3 and 4. It is emphasized that these general patterns are net flows and may not represent the situation at any given point in time. Furthermore, significant deviations from the average flow can be expected at any time. The currents, particularly surface flows, are typically erratic and responsive to winds. Changes in the direction and speed of the wind can cause changes in the surface currents and induce substantial changes at intermediate depths.

Ninety percent of the inflow to Lake Erie is derived from the heavily polluted Detroit River. The southward thrust of the waters of the Detroit River extends to the Ohio shore. The Detroit River flows are then deflected northwestward along the west side of Bass Island. Contaminants from the Raisin and Maumee Rivers are concentrated by a gyre, a large circular motion of water, which develops between the Detroit River outflow and the western shore of Lake Erie. The dominant outflow from the Western Basin is through Pelee Passage on the Canadian side of the Lake. (*See Frontispiece*)

The flow pattern of the Central Basin of Lake Erie is a composite of three distinct regimes, surface, intermediate and bottom circulations. Wind generated surface flows in the open Lake are counter-balanced by the intermediate and bottom currents. The predominant surface flow is southward from Pelee Passage toward the Ohio shoreline. Easterly surface flows dominate throughout the rest of the Central Basin.

In the intermediate regime of the Central Basin the open lake flow is diffuse and aligned in a westerly direction parallel to the axis of Lake Erie



DOMINANT CIRCULATION PATTERNS
LAKE ERIE

Figure 3

but with a continuing easterly flow near the United States shoreline. Bottom flows near the south shore move in an easterly direction. There is strong evidence that materials originating in the United States are transported to the Canadian side of the Lake by bottom currents. This is confirmed by upwelling or upward movement of bottom waters along the northern shore of the Central Basin.

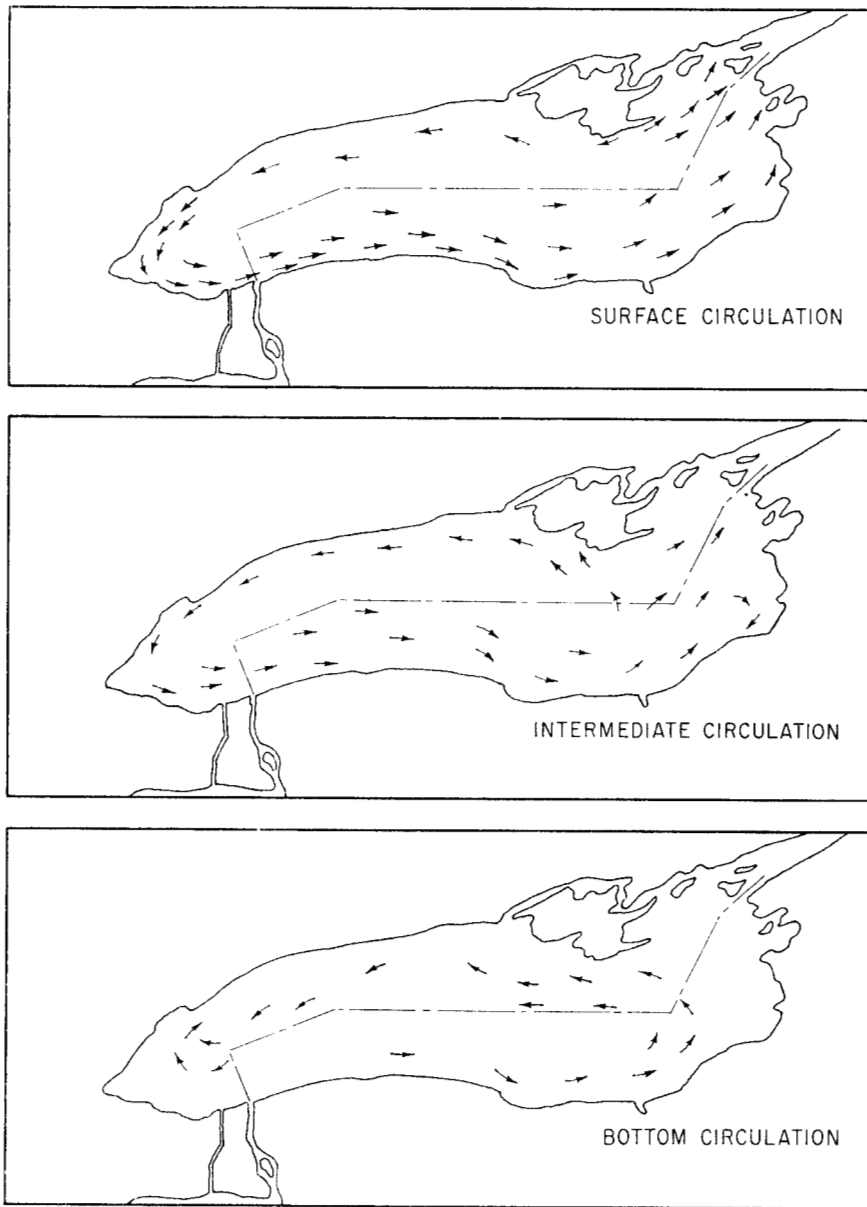
Three distinct flow regimes are also present in the Eastern Basin. Surface flows generally move in an easterly direction toward the Niagara River outlet. Returns of drift objects attest to the fact that most of the discharge from Lake Erie to the Niagara River is drawn from the United States shoreline. Contaminants not caught in the Niagara River outflow are circulated throughout the whole of the Eastern Basin. At intermediate depths a counterclockwise gyre is evident. It causes an exchange of waters across the international boundary from the south shore to the Long Point Bay area on the north shore. The bottom waters, although relatively quiescent, are not devoid of movement. A wind blowing from the same direction over a period of two or three days displaces the bottom waters at a slow rate in the opposite direction to that of the wind.

Transboundary movements are clearly evident in the Niagara River. Contaminants from the densely populated and industrialized area along the United States shoreline are added to the pollutants carried through Lake Erie. There is no doubt that the heavily polluted waters of the Niagara River are thoroughly mixed by the turbulent 37 mile journey from Lake Erie to Lake Ontario.

About 80 percent of the total inflow into Lake Ontario is from the Niagara River. It accounts for 56 percent of the phosphorus and 76 percent of the chloride inputs into Lake Ontario. The discharge from the Niagara River is usually chemically distinguishable from the water in the main body of the Lake for a distance of 30 miles to the east.

The circulation characteristics of Lake Ontario are divided into three regimes, surface currents in the upper 10 metres, intermediate currents and bottom currents in the 10 to 20 metre layer above the bed of the Lake. The surface currents are strongly dependent on wind conditions, especially during summer stratification. The bottom currents, modified by friction and topography, are a result of a mass imbalance or density variations in the Lake.

The net surface flow of Lake Ontario circulates in a counterclockwise direction parallel to the northern and southern shores. During westerly wind conditions contaminants originating in the Toronto-Hamilton area move toward the Niagara River and thence along the United States shoreline. However, during easterly winds the major component of the Niagara River outflow moves directly across the lake to the Canadian shoreline.



DOMINANT CIRCULATION PATTERNS
LAKE ONTARIO

Figure 4

The mean summer and fall circulation of the intermediate regime of Lake Ontario is characterized by a counterclockwise flow. This causes some recirculation of water back to the western end of the Lake. The concentration of chemical constituents increases as the flow passes large urban areas and the outlet of the Niagara River. Only part of this flow passes out through the St. Lawrence River, the remainder being circulated back to the north shore and the west end of the Lake. During the winter and early spring when the water is unstratified and nearly homogeneous the circulation is characterized by a surface flow to the east, and near the bottom a return flow toward the west. This causes upwelling in the western end of the Lake. Observations indicate a counterclockwise flow in the bottom regime of Lake Ontario with upwelling in the Toronto area.

Transboundary movements can be illustrated by reference to stable contaminants such as chlorides. Let us for the moment assume that there is no transboundary movement of Lake Huron waters as they flow down the St. Clair and Detroit Rivers and that there is no transboundary movement in Lake Erie. Based on the Canadian contribution to the St. Clair River, the Detroit River and Lake Erie, the concentration of chlorides in the Canadian waters of Lake Erie should be approximately 10 mg/l. Likewise, the concentration of chlorides in the U.S. waters of Lake Erie, based on waste discharges to the U.S. waters, should be more than 30 mg/l. The analysis of thousands of water samples proved that this is not the case. The chloride concentration, especially in the Central and Eastern Basins of Lake Erie, is remarkably uniform, about 25 mg/l, across the whole Lake. This indicates complete mixing and diffusion of such stable substances as chlorides. Dye diffusion experiments also confirm that there is extensive redistribution of materials in both Lake Erie and Lake Ontario.

Although the redistribution of these stable contaminants is not of concern at this time, it should be emphasized that many changes take place to some materials once they are in Lake Erie and Lake Ontario. As long as the materials remain in the waters and sediments of the lake further chemical reactions and biological changes are likely to occur. Mercury provides an example. Although the concentrations of some pollutants such as mercury or compounds of mercury were less than the detectable levels in the receiving waters, these compounds entered the aquatic food chain and eventually accumulated in the tissue of certain fish making them unfit for human consumption. Materials which are now recognized to be damaging include nutrients, toxic compounds, oxygen-consuming substances, bacterial pollution and other micro-organisms.

As far as transboundary movement in the lakes is concerned, most pathogenic bacteria can be discounted because of their limited viability or capability to remain alive long enough to cross the Lakes. Discharges of oxygen-consuming substances are primarily of local concern since the lake

supply of oxygen satisfies their demand during the time involved in trans-boundary movement.

All of Lake Erie is being adversely affected by pollution in the form of nutrients. The resultant algal production in the north shore waters, although serious, is not as intense as along the south shore. The loss of dissolved oxygen in the bottom waters on both sides of the boundary in the Central Basin is a consequence of high algal production. The late summer blooms of blue-green algae in the north-western part of the Central Basin results from upwelling of nutrient laden bottom waters.

Nutrients are a total lake problem, meaning that inputs from both sides of the boundary are eventually widely diffused, causing damage to water users in both countries. Although the degree of damage varies from mild to serious in various parts of Lake Erie, the condition in the Lake is caused by nutrient inputs from both the United States and Canada. Each country's share of the cause can be viewed as being roughly proportional to its share of the nutrient inputs. Improvements can be expected only when both countries reduce their nutrient inputs.

The transboundary movement of stable contaminants in Lake Ontario is similar to the situation in Lake Erie. Although less dramatic, the nutrient inputs from both sides of the boundary in Lake Ontario are eventually widely diffused and cause damage to water users in both countries.

It is difficult to establish positively that the concentration of a particular pollutant on one side of the boundary in the Lakes is due to a specific source on the other side. However, on the basis of the foregoing there is no doubt that contaminants originating in one country do move across the boundary and degrade the quality of the waters in the other country. It follows that these boundary waters are being seriously polluted on both sides of the boundary to the detriment of both countries.

Chapter IX

SOURCES OF POLLUTION

Treated, partially treated and untreated wastes are discharged continuously to Lake Erie, Lake Ontario and the St. Lawrence River from their tributaries and from direct sources on their shores. The major tributaries carry significant waste loads from upstream municipalities, industries, agricultural activities and land runoff. Other sources include dredging, commercial vessels, pleasure craft, lake sediments and the atmosphere itself. The effects of these pollutants are discussed in Chapter X.

MUNICIPALITIES

The constituents of municipal wastes which contribute to local or lake-wide pollution include dissolved and suspended solids, oxygen-consuming organic matter, oils, toxic materials, pathogenic bacteria and nutrients. In addition, municipal discharges may also include a variety of wastes from industries connected to municipal sewerage systems.

The major urban areas are shown on Figure 5. It graphically illustrates the magnitudes of the principal concentrations of population and hence, the significant sources of pollution. In order to ensure that all wastes from these municipalities receive adequate treatment at all times there must be ample facilities to safeguard the boundary waters from pollution attributable to municipal discharges.

Municipalities discharging wastes directly to the Lakes contribute about 10 percent of the total phosphorus loading to Lake Erie and 22 percent to Lake Ontario. Approximately 55 percent of the total phosphorus contribution to Lake Erie is from municipalities discharging wastes into the tributaries. The comparable figure for Lake Ontario is 32 percent. The large metropolitan areas that discharge their wastes near the mouths of tributaries include Detroit, Windsor, Toledo, part of Cleveland, Buffalo and Niagara Falls, New York.

Storm runoff from urban areas carries high concentrations of organic matter, bacteria and suspended solids. A number of large municipalities such

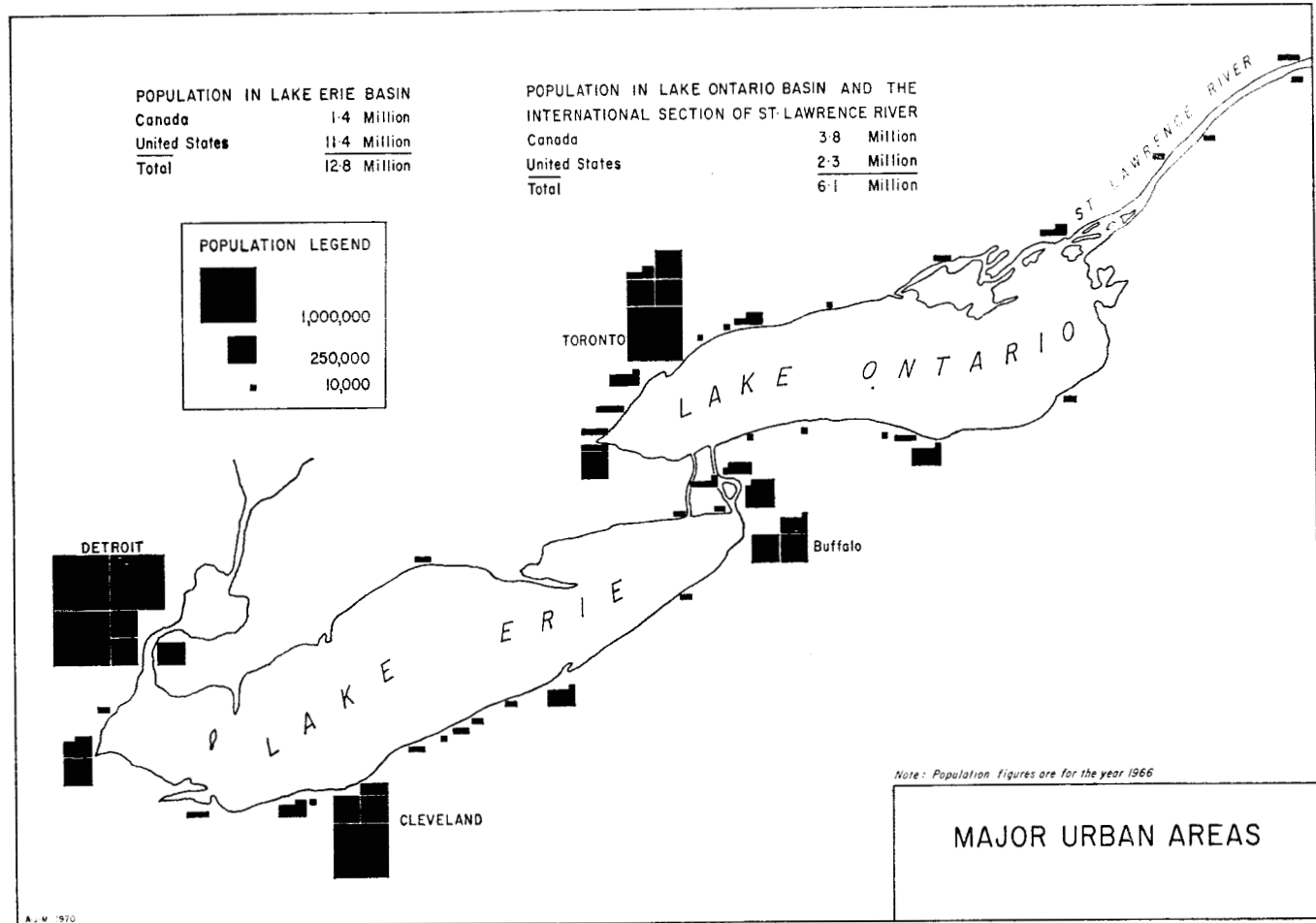


Figure 5

as Toledo, Cleveland, Erie, Rochester, Hamilton and Toronto have combined storm-sanitary sewer systems which discharge into municipal treatment plants. The capacities of these municipal treatment plants are not large enough to cope with the increased flows during periods of heavy rainfall. Consequently, a combination of domestic and industrial wastes as well as storm runoff from the urban areas is bypassed directly to the tributaries or shorewaters of the Lakes without any treatment. It is essential that all communities prevent storm waters from entering the Lakes or their tributaries in an untreated condition.

INDUSTRIES

The major industrial waste producers are located in or near large municipalities and augment the municipal waste load from these areas. The tributaries and the Lakes are used to convey large quantities of oil, suspended and dissolved solids, oxygen-consuming materials, acids, alkalis, iron, phenols, heavy metals and toxic substances away from the steel making, automotive, aluminium fabricating, petroleum, chemical, pulp and paper, rubber and food processing industries.

The Boards' report listed the companies discharging wastes directly into the Lakes and summarized their wastes, treatment and loading rates. However, the description of wastes discharged by the tributaries was limited to six parameters. These latter wastes were not attributed to specific municipal and industrial effluents discharged to the tributaries. Identification of all sources of pollutants entering the Lakes would require monitoring of all municipal and industrial wastes discharged into the tributaries as well as direct discharges.

COMMERCIAL VESSELS

Waste discharges from commercial and pleasure watercraft are mobile sources of water pollution and hence significant. They include sewage containing human excreta, garbage, litter, oils, bilge and ballast water. More than 600 foreign vessels move cargo through the Great Lakes System each year. The domestic fleet is composed of nearly 600 Canadian and United States vessels. Approximately 7,000 passages are made through the St. Lawrence Seaway and across Lake Ontario each year. Only a small percentage of the commercial vessels have holding tanks or treatment facilities for sewage. Only a few of the ports on the Lower Great Lakes have facilities to collect and treat vessel wastes. The domestic waste load from commercial vessels in Lake Erie is equivalent to the contribution of 1,200 persons.

In the event of a mishap, such as the sinking of the ship "Eastcliffe Hall" in the International Section of the St. Lawrence River, some cargoes accident-

ally released to the waters of the Great Lakes could cause hazardous conditions. Some cargoes now carried by commercial vessels and handled in Great Lakes ports would pose environmental problems if accidentally spilled. They include petroleum products, organic and inorganic chemicals, sulphuric acid, glycol, fertilizers and dyestuffs.

PLEASURE CRAFT

It is estimated that more than 250,000 pleasure craft now use the Lower Great Lakes. Relatively few have holding tanks. The custom of using pleasure boats as "weekend apartments" without moving them from their moorings results in heavy waste loadings to the confined waters of harbours. The annual waste contribution from pleasure craft to Lake Erie alone is equivalent to the raw sewage from a permanent population of 5,500. Though an increasing number of marinas are being equipped with pumpout facilities for pleasure craft, the number is still inadequate.

DREDGING

Routine maintenance dredging is performed at 15 major and several smaller harbours in the U.S. waters of Lake Erie, the lower Detroit River and the Niagara River and at three major U.S. harbours in Lake Ontario. Similar work is performed at four small Canadian harbours in Lake Erie and eight locations in the Canadian waters of Lake Ontario. The United States Corps of Engineers estimates future annual U.S. dredging to be 6,800,000 cubic yards for Lake Erie and 480,000 for Lake Ontario. In 1968 Canadian dredging amounted to 297,000 cubic yards in Lake Erie and 577,000 in Lake Ontario.

It has been the general practice at most harbours to dispose of dredged materials in the open waters of the lakes at locations that do not interfere with navigation. The bottom sediments in the major harbours consist of a combination of silt, municipal wastes and industrial wastes. The dredged sediments consist of high concentrations of compounds of iron and other materials, oil and grease, nutrients and oxygen-consuming wastes. The transfer of these dredged materials and their redistribution in the open lake environment constitute a source of pollution. For example, during 1966 approximately 140 million pounds of volatile solids, 35 million pounds of oil and grease, 4 million pounds of phosphorus, 4 million pounds of nitrogen and 120 million pounds of iron were dredged from Cleveland Harbour and transferred to Lake Erie.

The disposal of dredged materials in these boundary waters is a problem that requires consideration to avoid pollution. The Commission has noted that a recent joint study by United States agencies found that confined

disposal areas on the shore and confined disposal areas in the lake near the shore provide satisfactory protection for the water quality of the lake. The Commission has also noted that of the 577,000 cubic yards dredged on the Canadian side of Lake Ontario, 450,000 were used for land fill.

SEDIMENTS

The lake bottom is a repository for materials, including pollutants, which settle out of the overlying waters. Large quantities of sediment enter the lakes from rural and urban runoff as well as stream bank and shore erosion.

The chemical reactions of the sediment-water interface during the summer in the oxygen-depleted hypolimnion causes the release of significant quantities of phosphorus, nitrogen, carbon dioxide, iron, manganese and sulphides. Phosphorus compounds, unlike the other typical constituents of fertilizers, are not easily leached out of the soil, but rather tend to cling to soil particles. Thus, when soil erosion occurs these materials are eventually transported into the lakes and provide an additional supply of nutrients. Many types of pesticides, notably DDT and dieldrin, adhere to soil particles in a similar fashion. These accumulate in stream and lake sediments and are taken up by the bottom-dwelling worms that ingest in the mud, and subsequently reach other life forms in the food chain of aquatic life. Subtle biological activities can also release metallic pollutants to the aquatic environment. For example, metallic mercury is transformed by micro-organisms to mercuric salts and organo-mercurials which enter the aquatic food chain.

QUANTITIES DISCHARGED

The Commission has summarized in Table 2 the detailed data in the Board's report, using six parameters, to indicate the relative contribution of pollutants to the Lower Great Lakes System. Complete information on the contributions of pollutants such as oils and greases, iron, phenols, toxic wastes and pesticides is not available. Nor does Table 2 include data on the wastes periodically by-passed by municipal treatment plants.

The Detroit River is by far the greatest source of contaminants to Lake Erie. The highly industrialized Detroit-Windsor area, as shown on Figure 5, is responsible for most of this waste input. Second only to the Detroit River as a source is the State of Ohio. Major waste loads are carried to Lake Erie by the Maumee, Cuyahoga, Sandusky and Grand Rivers of Ohio, Cattaraugus Creek and Buffalo River of New York. The Grand River in Ontario also carries heavy waste loads to Lake Erie.

TABLE 2. WASTES DISCHARGED TO LAKE ERIE, LAKE ONTARIO AND ST. LAWRENCE RIVER
Millions of Pounds Per Year

Source	Total Solids	Suspended Solids	BOD ₅	Total Nitrogen	Total Phosphorus	Chlorides
TO LAKE ERIE						
Detroit River...	61,200	3,200	182	252	35	6,600
Michigan.....	341	13	2	2	1	88
Ohio.....	13,806	5,299	123	74	19	2,027
Pennsylvania....	195	31	25	1	1	4
New York.....	1,738	556	45	16	1	153
Ontario.....	2,150	173	22	10	3	104
TOTALS.....	79,430	9,272	399	355	60	8,976
TO LAKE ONTARIO						
Niagara River..	85,600	10,060	•	191	15	10,400
New York.....	11,106	1,692	173	44	5	2,456
Ontario.....	8,319	985	236	88	7	870
TOTALS.....	105,025	12,737	*	323	27	13,726
TO INTERNATIONAL SECTION OF THE ST. LAWRENCE RIVER						
New York.....	1,161	281	42	7	1	42
Ontario.....	689	57	105	12	1	100
TOTALS.....	1,850	338	147	19	2	142

*Not determined.

No large population centres exist along the Canadian shore. Consequently, Canadian inputs to Lake Erie are relatively small compared to the United States inputs.

The Niagara River contributes over half of the contaminants discharged into Lake Ontario. Pollutants in the Lake Erie outflows are augmented by local sources in the Niagara Basin. For example, between Lake Erie and Lake Ontario the phosphorus content in the Niagara River is increased by 71 percent. Due to the concentration of population and industry in the area extending from Buffalo to Niagara Falls, N.Y., most of the wastes introduced directly to the Niagara River originate in the United States. In most cases, treatment of municipal wastes is limited to sedimentation and chlorination.

The Rochester and Toronto regions discharge large quantities of wastes directly to Lake Ontario. The Oswego and Genesee Rivers of New York and Twelve Mile Creek of Ontario carry significant waste loads to Lake Ontario.

The International Section of the St. Lawrence River receives wastes from its tributaries and the sources along the shoreline. The principal sources of contaminants entering the international reach of the St. Lawrence River are from the Grass, Oswegatchie and Raquette Rivers of New York and the industries along the Canadian shoreline. Table 2 does not include pollutants carried by the outflows from Lake Ontario.

PHOSPHORUS INPUT

Of the nutrients involved in the accelerated eutrophication of the lakes phosphorus is the only one that is both growth-limiting in the lakes and can be controlled effectively by man with present day technology. Thus, it is of particular importance to identify with greater precision the sources of phosphorus.

TABLE 3. INPUT OF TOTAL PHOSPHORUS* IN 1967

Source	Millions of Pounds			
	TO LAKE ERIE		TO LAKE ONTARIO	
	U.S.A.	Canada	U.S.A.	Canada
Lake Huron.....	4.5	—	—	—
Lake Erie.....	—	—	9.0	—
Municipal.....	35.7	2.5	7.7	7.0
Industrial.....	1.8	2.2	0.3	0.6
Land Drainage.....	9.6	3.9	1.0	0.6
Unaccounted.....	—	—	1.1	—
TOTAL.....	60.2	—	27.3	—

*As explained in Chapter II, the term phosphorus in this Report refers to phosphorus as a constituent of various organic and inorganic complexes and compounds, not to elemental phosphorus as a chemical substance. The term phosphorus includes orthophosphates such as trisodium phosphate, crystalline phosphates such as sodiumtripolyphosphates, and polyphosphates such as sodiumhexametaphosphate. However, in this Report concentrations and loads are given in terms of the element phosphorus as part of any compound to assure uniformity of expression.

The major source of phosphorus is municipal sewage. In the United States portion of the basin 70 percent of the phosphorus in sewage originates from detergents, most of the remainder from human excreta. In Canada approximately 50 percent originates from each source. Other significant sources of phosphorus are agricultural runoff and some industrial wastes.

It is evident from Table 3 that the principal input of phosphorus is from the United States and that, in both countries, municipalities are the major source of total phosphorus. In 1967, the input of total phosphorus from United States municipal sources to Lake Erie was 35.7 million pounds, of which 25 million came from detergents. The input of total phosphorus from Canadian municipal sources to Lake Erie was 2.5 million pounds, of which 1.3 million came from detergents. Similarly, the input from United States municipal sources to Lake Ontario was 7.7 million pounds, of which 5.4 million came from detergents. The Canadian municipal input to Lake Ontario was 7.0 million pounds, of which 3.5 million came from detergents. It is apparent from the foregoing that detergents are by far the greatest single source of total phosphorus input into the Lakes.

Chapter X

EFFECTS OF POLLUTANTS

The wastes willfully or unwittingly discharged into Lake Erie, Lake Ontario and the International Section of the St. Lawrence River produce not only local but also lakewide pollution that has both immediate and long-term effects. Present knowledge and understanding of the intricate chemical reactions, biological activities, and the dispersal and disposition of unusual and relatively unknown pollutants is limited. Thus, the Commission cannot report on all the possible effects brought about by the activities of man.

EUTROPHICATION OF THE LAKES

The effects of over-enrichment on the aquatic environment were analyzed by evaluating the trophic state of Lake Erie and Lake Ontario. A number of physical, chemical and biological parameters were assessed to provide an over-all evaluation of the state of eutrophication. The various physical criteria, the nutrient loadings and concentrations, the abundance and species of phytoplankton and the benthic communities do not individually provide an accurate over all assessment. However, collectively they provide a reliable evaluation of the trophic state of the Lakes. For comparative purposes Lake Erie was separated into three areas, the Western, Central and Eastern Basins.

From the physical standpoint, the shallower a lake is the more it is predisposed toward eutrophy. In this regard, the Western Basin of Lake Erie is prone to eutrophic conditions because its mean depth is only 23 feet; the Central Basin with a mean depth of 60 feet exhibits primarily mesotrophic-eutrophic characteristics; the Eastern Basin with a mean depth of 80 feet is primarily oligotrophic-mesotrophic. Lake Ontario with a mean depth of 280 feet would be primarily oligotrophic from a physical standpoint.

The waters of the Western Basin of Lake Erie exhibit poor transparency characteristics of eutrophic lakes while the rest of Lake Erie and Lake Ontario can be classified as mesotrophic in this regard.

Data on nutrient levels, such as phosphorus and nitrogen, are also used to classify the trophic conditions of a lake. The mean summer concentration

of phosphorus was $60 \mu \text{ g/l}$ in the Western Basin of Lake Erie, 20 in the Central and Eastern Basins and $14 \mu \text{ g/l}$ in Lake Ontario. The observed total nitrogen concentrations were $740 \mu \text{ g/l}$ in the Western Basin, 470 in the Central and Eastern Basins and from 400 to $600 \mu \text{ g/l}$ in Lake Ontario. The above data pertain to late spring, summer and fall months when these nutrients are depleted by algal growth. Based on these data, the Western Basin is classified as being clearly eutrophic and the rest of Lake Erie and Lake Ontario as being mesotrophic from the standpoint of nutrient levels.

The Lakes were also assessed on the basis of total loading of phosphorus and nitrogen. The annual loadings were first expressed as grams of total phosphorus or total nitrogen per square metre of lake surface, and then evaluated as a function of the mean depth, thus bringing all comparisons to a standard volume of lake water.

The permissible loading of total phosphorus according to the criteria endorsed by the Board is $0.13 \text{ g/m}^2/\text{yr}$. (grams per square metre per year) for Lake Erie and 0.37 for Lake Ontario. Beyond this, the loadings are critical and become dangerous at $0.28 \text{ g/m}^2/\text{yr}$. for Lake Erie and 0.75 for Lake Ontario. The actual total phosphorus loading converted to a unit of surface area for Lake Erie was $1.1 \text{ g/m}^2/\text{yr}$. and for Lake Ontario $0.7 \text{ g/m}^2/\text{yr}$. These nutrient loadings produce advanced eutrophic conditions in Lake Erie and serious mesotrophic conditions in Lake Ontario.

Based on the variations in the concentration of dissolved oxygen in the hypolimnion, there are indications that the Central Basin of Lake Erie has mesotrophic characteristics with eutrophic tendencies and that the Eastern Basin of Lake Erie is oligotrophic-mesotrophic and Lake Ontario oligotrophic. The Western Basin of Lake Erie is normally unstratified.

The total number and the distribution patterns of phytoplankton, zooplankton, bottom fauna and fish are also used to assess the state of eutrophication. Phytoplankton consist of micro-plants such as unicellular algae which live, float and drift in water. Zooplankton consist of corresponding animal micro-organisms. Bottom fauna consist of benthic invertebrates which burrow in, cling to or crawl over the bottom sediments.

Algae are primitive photosynthetic plants which occur in fresh water as microscopic forms suspended in water or as filaments attached to submerged rocks and other objects. Certain species of green algae, yellow-brown algae and diatoms are common in oligotrophic lakes. On the other hand, blue-greens and other species of diatoms appear most often in the nutrient enriched waters of eutrophic lakes.

Results from phytoplankton studies indicate eutrophic conditions in the Western Basin with algal populations decreasing from the Western to the Eastern Basins. High levels of blue-green algae are now prevalent in the

Western Basin during the summer and early fall periods, reflecting the impact of nutrients from the Detroit, Raisin and Maumee Rivers.

Phytoplankton levels throughout Lake Ontario are moderate to low. Generally, inshore populations declined from the western to the eastern end of the lake. With minor exceptions, a classical bimodal pattern (two summer peaks) of phytoplankton development is evident throughout Lake Ontario. The breakdown of this pattern to an extended peak in Lake Erie indicates an increasingly eutrophic condition. Phytoplankton concentrations in the main body of Lake Ontario suggest a condition between oligotrophy and mesotrophy.

Studies of the zooplankton indicate eutrophic conditions in the Western Basin, mesotrophic in the Central and Eastern Basins and mesotrophic to oligotrophic conditions in Lake Ontario. Similar studies of bottom fauna indicate a gradation of eutrophic characteristics in the Western Basin to mesotrophic with oligotrophic tendencies in the Eastern Basin. The bottom fauna of Lake Ontario is described as mesotrophic with oligotrophic characteristics.

On the basis of a collective evaluation of the foregoing categories, it is obvious that the Western Basin of Lake Erie is eutrophic; the Central Basin moderately eutrophic and the Eastern Basin mesotrophic with some oligotrophic characteristics. Lake Ontario is presently in a stage between oligotrophy and mesotrophy.

OXYGEN DEPLETION

Oxygen depletion in the bottom waters of Lake Erie's Central Basin has been reported since 1959. In September 1959 the dissolved oxygen value for two-thirds of the bottom waters in the Central Basin were below 2 mg/l (milligrams per litre) and below 0.5 mg/l in the southwest corner of the Basin. In August 1960 bottom waters with values of 0 to 2 mg/l dissolved oxygen extended over an area approximating that of the 15 metre bottom contour. In September of that year the bottom waters of the southeast half of the Central Basin had dissolved oxygen values of less than 10 percent saturation or 1 mg/l.

From May to October 1967 eight cruises covered all of Lake Erie. In early June the dissolved oxygen values at various depths and locations, ranged from 7 to 15 mg/l or 75 to 160 percent saturation. By early August the lake waters were in the following condition: a saturated epilimnion; a partially depleted hypolimnion in the Eastern Basin; and a depleted hypolimnion in the Central Basin. By late August further depletion had occurred. Oxygen values in the Eastern bottom waters were near 75 percent saturation while oxygen values in the hypolimnion of the Central Basin were down to 10 percent saturation.

Thermal stratification and oxygen depletion in the shallow Western Basin of Lake Erie is usually prevented by the mixing effect of the wind. Pronounced depletion of oxygen occurs during quiet weather due to biological utilization of oxygen near the sediment. Some fish-food organisms such as the mayfly nymph, *Hexagenia*, have become extinct in the Western Basin since 1950 due to oxygen depletion in quiet weather.

Taste and odour problems occur in the Cleveland water supply in the summer during periods of southerly winds and upwelling of the oxygen depleted hypolimnion.

Lake Ontario because of its volume has a large reserve of oxygen in the deep waters and is able to maintain adequate oxygen levels. In 1967 the minimum oxygen level in the bottom waters of the shallow northeast corner of the Lake was at 60 percent saturation. The low median value of the bottom waters of the whole lake was at 82 percent in mid September. These minimum values, although indicating some deficiency, are still considered adequate for the support of desirable fish species.

The levels of dissolved oxygen throughout the International Section of the St. Lawrence River remain at or near saturation. Turbulence or mixing appear to replenish any oxygen deficit through air-water exchanges.

BIOLOGICAL CHANGES

Pollution and enrichment have affected the biological communities in the Lower Great Lakes. The most obvious change is the rapid growth of *Cladophora*. Changes in the abundance and distribution of benthic organisms also reflect the changes in the aquatic environment.

Cladophora is a branched filamentous green alga which has special hold-fast organs. It grows in enriched waters, attached to submerged rocks or other objects in waters usually less than 15 feet in depth and where there is sufficient light penetration. The inshore waters of Lake Erie and Lake Ontario are in general rich enough in nutrients to support *Cladophora* growths. For this reason the distribution and quantities of algae produced depends primarily on the physical conditions of the shoreline.

Nuisance growths of *Cladophora* are a problem in the island area of the Western Basin of Lake Erie. Recently the Board detected a luxurious *Cladophora* growth covering four square miles. *Cladophora* nuisance problems have increased on beaches in Ohio, Pennsylvania and New York. An estimated 350 square miles of the United States inshore waters on Lake Erie are covered with *Cladophora*. Accumulation of *Cladophora* growths have increased along the northern shore of Lake Erie, particularly between Port Dover and Fort Erie where the shoreline is characterized by sandy bays, rocky points and shoals.

In the summer there is a continuous band of *Cladophora* along the shoreline between Hamilton and Toronto. About one-third of the inshore area between Toronto and Presqu'ile Point near Kingston is badly affected. In the summer much of the United States shoreline, particularly east of the Niagara River and east of Rochester have large amounts of *Cladophora* washed up on the beaches. *Cladophora* is also becoming more extensive in the eastern portion of Lake Ontario. Major problems with *Cladophora* are not expected to develop in the St. Lawrence River because growth beds are limited by a steep gradient. However, other aquatic growths do cause problems.

At Cleveland the average algal abundance increased from 100-200 cells per ml during the period 1927 to 1930, to 1200 cells per ml during the period 1944 to 1948 and ranged from 1300 to 2400 cells per ml during the period 1960 to 1964. The generic composition of the phytoplankton also changed during this time to forms more typical of eutrophic waters. At Toronto the phytoplankton level doubled between 1923 and 1954. Ten years later the phytoplankton level had doubled again.

The change in benthic fauna has been well documented for Lake Erie. The Western Basin now contains only those organisms very tolerant to pollution while organisms that require cleaner water are present in the Eastern Basin. During the interval 1930 to 1961 the number of pollution-tolerant sludgeworms increased nine fold. Also, in the Western Basin during that period the area of light pollution (100-999 worms per square metre) increased three fold; that for moderate pollution (1000-5000 worms/m²) increased eleven fold; and that for heavy pollution (more than 5000 worms/m²) increased ten fold. Furthermore, the pollution-tolerant midge larvae population increased four fold. In contrast, the burrowing mayflies which require a moderate to high concentration of oxygen decreased to 1 percent of the earlier levels. Thus, the mayflies which once were the dominant invertebrate in the benthos of the Western Basin are essentially non-existent. The change in benthic fauna is primarily due to the fact that most sources of pollution to Lake Erie are in the Western Basin.

In Lake Ontario the offshore benthos is more like the Upper Great Lakes than Lake Erie. However, organisms which are dominant in enriched waters were evident at inshore locations such as Toronto and at the mouths of the Niagara, Genesee and Oswego Rivers.

FISH

Fish are a useful barometer of the actual degree of water pollution present. Water in satisfactory condition will support a variety of fish life. Fish

are the terminal part of the food chain in a complex aquatic environment. Unless the lakes continue to supply the fish with the food, shelter, spawning sites, oxygen and suitable temperatures, they cannot thrive.

The increase of phytoplankton production in Lake Erie has been accompanied by a serious decrease in dissolved oxygen, particularly in the deep, cool waters of the Central Basin. This restricts the remaining cold water species of fish to a thin layer between the oxygen-deficient hypolimnion and the warm epilimnion. Mayfly nymphs, an important item in the diet of fish, were abundant at one time. Now they are scarce and have been succeeded by *oligochaeta* and other forms tolerant to low oxygen levels.

The fish populations in the Lower Great Lakes have undergone dramatic changes in the last two decades. The once famous fishery for blue pike, whitefish and cisco is gone. The blue walleye unique to Lakes Erie and Ontario, is apparently extinct. Sauger populations have declined, as have the yellow walleye and lake trout. Accompanying changes in the physical environment, factors such as lamprey predation and inadequate fishery management practices have set off chain reactions among fish populations. The result has been the disappearance or near disappearance of commercially valuable species such as whitefish and ciscoes and an increase in less valuable species such as the smelt, yellow perch and gizzard shad. White perch, a recent invader, is now a dominant species in many parts of Lake Ontario. Pollution-tolerant species have become dominant in the commercial production of Lakes Erie and Ontario, with the exception of the Bay of Quinte region. This situation could be at least partially reversed by effective pollution abatement.

Recent studies indicated that the pesticide levels in the organs of fish in Lake Erie and Lake Ontario were generally low. However, in Lake Michigan, higher DDT levels in fish have affected reproduction and are threatening the rehabilitation of the fishery resources of that lake. The persistency of such organic chemicals is a matter of serious concern. This will be discussed later.

Although the concentration of mercury in water samples taken from the St. Clair-Detroit River system was less than the detectable level, high concentrations were found in various species of fish. The mercury content of some fish taken from Lake St. Clair was as high as 7 ppm. Recent investigations have also revealed mercury contamination of some species of fish in Lake Erie, Lake Ontario and the St. Lawrence River. Thus, restrictions have been imposed on fish taken from Lake Huron and those waters of the Great Lakes System downstream from Lake Huron. The economic cost and social consequence of the current mercury pollution situation are difficult to assess. It has materially affected commercial fishermen, processors and distributors, as well as the tourist and sport fishing industry.

BACTERIAL CONTAMINATION

Most bacterial pollution appears to be localized. Collected data indicate that the Canadian shoreline for 10 miles east of the Detroit River is the only area affected by transboundary bacterial pollution.

In Lake Erie the Canadian shoreline waters are much more acceptable than the waters along the United States shoreline. Approximately one-third of the United States shoreline is either continuously or intermittently fouled with bacterial contamination. The bathing beaches in the Detroit River below the mouth of the Rouge River and along Lake Erie near Toledo, Cleveland, Erie and Buffalo are a direct hazard to health. Coliform counts have run as high as a million organisms per 100 ml. The satisfactory level is considered to be a thousand per 100 ml. Notable among the acceptable beaches are East Harbour State Park, Cedar Point, Headland State Park, Presque Isle and Evangola State Park. The bacterial quality along the Canadian shoreline is acceptable except for the shoreline extending 10 miles east of the Detroit River and near Port Maitland.

The waters of Lake Erie two or more miles offshore can be classified as bacteriologically excellent. Most of the collected samples had a median coliform density of less than 1 coliform per 100 ml, and at the most 10 coliforms per 100 ml. Deep water samples had the lowest densities. Data collected in the winter were comparable to those obtained during the summer. The highest coliform counts were observed in the Western Basin at all depths.

The highest coliform, fecal coliform and fecal streptococcus densities in Lake Ontario were recorded near the mouth of the Niagara River. Fecal coliform counts of 250 and 350 per 100 ml as compared with the Ontario and Michigan standards of 100 per 100 ml, indicate that sewage from the Niagara River is responsible for much of the degradation of water quality at this location.

Along the shoreline of Lake Ontario the bacterial densities show a close correlation with heavily populated areas. The median coliform concentration along the shoreline is less than 5 per 100 ml, except within a 10 mile radius at the mouth of the Niagara River, the Toronto and Rochester areas where bathing beaches have been closed, and areas at the mouths of the principal tributaries.

The bacterial quality of the offshore waters in Lake Ontario is excellent. The majority of monitoring stations recorded coliform densities of less than 1 coliform per 100 ml. Only six offshore stations, all located in the Toronto and Niagara River areas, recorded median coliform densities greater than six coliforms per 100 ml.

Bacterial contamination in the International Section of the St. Lawrence River is local in nature. The cross-sectional variation of coliform densities

confirm that there is no transboundary pollution. The compiled data indicate a progressive downstream increase in coliform densities from less than 5 per 100 ml to greater than one thousand.

ORGANIC CONTAMINANTS

Observations to date show that in most cases the waters of Lake Erie, Lake Ontario and the St. Lawrence River have CCE (carbon chloroform extract) values close to those generally found in clean surface and ground waters (25-50 μ g/l). Recent levels near Toronto are higher than desirable but still within current Ontario standards. However, concentrations of 250-660 μ g/l CCE have been found in Lake Erie off Cleveland where the Cuyahoga River discharges into the Lake.

Pesticides have been observed in Lake Erie since 1958 and in Lake Ontario and the St. Lawrence River since 1962. Positive identification of DDT and its derivative DDE have been made in the sediments of Lake Erie at three locations. The pesticide residues in the fish caught in Lake Erie and Lake Ontario were generally low, less than 2 mg/kg (2 milligrams per kilogram). As previously noted, DDT levels in fish in the Lower Great Lakes are not as high as in Lake Michigan fish. The persistency of these chemicals is a matter of serious concern not only for the fishery resources but also for human health. This was demonstrated by the seizure of 34,000 pounds of Lake Michigan Coho salmon in 1969 by the United States Food and Drug Administration. The DDT residue in this salmon ranged from 13 to 19 parts per million, about twice the allowable limit for red meat.

There has been a steady reduction of phenol levels in Lake Erie over the past 19 years. In 1948 inshore stations had concentrations as high as 500 μ g/l at the head of the Niagara River; and off Buffalo the average was 10.2 μ g/l. In some areas after significant reduction of phenols in industrial wastes had been achieved in 1955, the maximum phenol levels dropped from 500 to 10 μ g/l. In 1967, phenol levels throughout, all of Lake Erie had a median value of 2 μ g/l with a maximum of 17.

The phenol concentrations in Lake Ontario in 1967 ranged from 0 to 15 μ g/l, with a median value of 2 μ g/l. The median phenol levels for the International Section of the St. Lawrence River ranged from 1.2 to 2.4 μ g/l except for a sampling point below Cornwall which had a median value of 4.2 μ g/l for 1967.

ACCUMULATION OF MATERIALS

Since 1910 the concentration of dissolved solids in Lake Erie and Lake Ontario has been accelerating rapidly. They have a higher rate of increase

and a greater accumulation of solids than the Upper Lakes. Over the past 55 years the chloride ion concentrations in Lakes Erie and Ontario have increased three fold while sulphate, sodium and potassium ions have doubled. The chloride level in Lake Erie is two and a half times greater than Lake Huron.

The total concentrations of dissolved solids in Lake Erie and Lake Ontario have increased from approximately 145 mg/l in 1910 to 185 mg/l. The build-up of total dissolved solids is not in itself, at this time, a serious problem but it indicates large accumulations of materials.

Turbidity impairs the aesthetic quality of the near shore waters. The subsequent deposition of materials causing turbidity endangers spawning beds.

The over all balance of materials provides a measure of the origin and fate of pollutants entering the lakes. This involves a comparison of all inputs into the lakes and quantities observed in their outflow. Four constituents—chlorides, total dissolved solids, total nitrogen and total phosphorus—were used in this particular analysis.

The inputs of chlorides and total dissolved solids to Lake Erie and to Lake Ontario were in reasonable balance with the outputs. The imbalance of nitrogen and phosphorus indicated a retention or conversion of these constituents in the Lakes. In Lake Erie, 84 percent of the phosphorus and 56 percent of the nitrogen was retained, while in Lake Ontario 77 percent of the phosphorus and 35 percent of the nitrogen was retained. The difference in the phosphorus and nitrogen retention is due to the fact that only under special circumstances is stored phosphorus returned from the sediments to the water in significant quantities.

A substantial portion of phosphorus is removed from the lake water each year by growing plants and subsequently is deposited on the lake bottom where it tends to be retained. Thus, there are strong theoretical reasons for believing that the lakes will react quickly to a decreased phosphorus loading. It has been estimated that if all phosphorus inputs were eliminated there would be a 90 percent reduction in the phosphorus concentration in the waters of Lake Erie in less than five years.

OILS

Oils and greases probably cause more noticeable damage to the current uses of most tributaries of the Lower Great Lakes than any other single pollutant. Very little is known of the subtle effects on the aquatic ecology of oil accumulations in the water column and in the sediments of the lakes. There have been many cases, particularly in the Niagara River, where there is no apparent relationship between the location of oil concentrations and the presence of known discharges or observed films on the waters upstream.

When oils do enter or accumulate in marinas in quantity, there is the significant cost of cleaning the hulls of boats. Oil coated beaches and shorelines are unusable and aesthetically disagreeable. In addition, oil accumulations can damage water filtration facilities and destroy waterfowl.

RADIOACTIVITY

The radioactivity levels observed in Lake Erie and Lake Ontario are well below the permissible concentrations recommended by the International Commission for Radiological Protection, which have a tenfold factor of safety and are well within the allowable limits of the U.S.P.H.S. drinking water standards. The ICRP standards are: alpha emitters 1 pCi/l; beta emitters 10 pCi/l. The unit quantity of radium emanation in equilibrium with one gram of radium is a curie. A microcurie is a millionth of a curie and a picocurie (pCi) is a millionth of a microcurie.

Ontario Hydro's Douglas Point nuclear reactor on Lake Huron has been continuously monitored since it began operation in 1963. Samples of water, fish and beach sands have been analysed for gross alpha and beta activities from strontium-90 and caesium-137. Only low levels of radioactivity were recorded and these were attributable to uncontrollable background sources.

The radioactivity levels in Lake Erie are due to fall-out and naturally occurring radionuclides or both because it does not at this time receive significant radioactive wastes from nuclear installations.

In the late 1950's, after atmospheric testing of nuclear weapons, the measured radioactivity level for Lake Ontario was 35 pCi/l. In the early 1960's, after a moratorium on atmospheric testing, the total beta activity dropped to 10 pCi/l. Subsequent testing in 1962 produced an increase in radioactivity to 26 pCi/l. Recent Lake Ontario measurements indicate a gross beta activity of less than 10 pCi/l. The average values for the Toronto water supply were less than half of the national average for strontium-90 and one seventh of the national average for caesium-137.

There has been no accidental spill of radionuclides to date. Nevertheless, a lake surveillance programme should be implemented for observance of total levels of radioactivity. The need for contingency plans must be recognized in advance of a serious accident or undesirable radioactive levels in the Great Lakes.

WATER SUPPLY

Most intakes for public water supplies are located well out from the shoreline and away from sources of bacterial pollution. Conventional treatment of raw water (coagulation, filtration and chlorination) can cope with most circumstances. However, the processes cannot cope with sudden detri-

mental changes without impairing the quality of treated water or drastically reducing the quantity of water produced. The cost of providing the necessary treatment facilities and materials increases as the quality of raw water deteriorates. The factors of major concern are bacteria, turbidity, ammonia, phosphorus, iron and manganese, as well as taste and odour producing substances. Even minute amounts of phenol compounds require careful treatment to avoid offensive tastes.

Heavy algal concentrations cause turbidity and obnoxious odours. Micro-screening or treatment with active carbon and algicides are required in the Western Basin of Lake Erie and to a lesser extent in the Central and Eastern Basins and in Lake Ontario. Algae are also responsible for clogging water intakes and for increasing the frequency of backwashing operations. They also interfere with the coagulation and sedimentation processes.

The demand for process, boiler-feed and cooling waters is expected to increase at an accelerated rate. Thus, the characteristics of raw water used for these purposes is of great importance. Such water supplies should be non-corrosive, non-scale forming, low in suspended solids and free from oil and other organic compounds. The process water used by the canning industry must meet criteria similar to those for domestic supplies.

Watercraft, because of their mobility, pose a contamination threat to water supplies. Sewage or other wastes discharged in close proximity to water intakes have an impact out of proportion to the volume because the waste immediately enters the facilities in an undiluted form.

The water presently withdrawn from the Lakes for municipal and industrial purposes generally meets their quality criteria. However, improved waste treatment is essential to ensure water of satisfactory quality and to avoid additional expenditure on water treatment.

RECREATION

Recreation and aesthetic values are seriously affected by accumulations of the filamentous green alga *Cladophora*. In July, long algal filaments break off during stormy weather and are blown into shore. Additional quantities of a lesser magnitude are periodically deposited throughout the remainder of the summer. The unsightly decomposing algae produce obnoxious odours. In some areas sturdy mats of *Cladophora*, 2 or 3 feet thick extend 25 to 50 feet from shore. Such was the situation between the Niagara River and Rochester in 1965 and 1966. Bathers refused to swim in the fouled waters near Rochester.

Some beaches, such as at Presqu'île on Lake Ontario act as a collecting basin for algae washed in from other areas. Beaches become deserted because of the encroachment of emerged and submerged vegetation. *Cladophora* growths have also restricted the navigation of pleasure craft in shallow con-

finned areas and reduced the open water area suitable for sport fishing. The Thousand Islands region of the St. Lawrence River has now been greatly affected by profuse growths of aquatic vegetation which has obstructed the movement of pleasure craft and destroyed sport fishing areas.

Bacterial contamination has made many beaches unsafe for swimming. This undesirable effect on recreation was discussed in the section dealing with bacterial contamination.

Wastes discharged from commercial and pleasure watercraft can endanger the health of those using the receiving waters for swimming, water skiing and other water contact sports. Bathing beaches and marinas can be seriously contaminated. Garbage and litter are not only aesthetically displeasing but also they can be extremely hazardous. Critical conditions occur where vessels congregate in harbours, at marinas and along the shoreline.

WILDLIFE

Observations of the effects of pollutants on wildlife provide early warning of the presence of contaminants which may become health problems. Such was the case in detecting mercury in the St. Clair River. The materials which are toxic for humans pose similar problems to mammals and to some extent to birds.

Wildlife, like humans, are at the top of the aquatic food chain. When birds eat fish with a high mercury content, the mercury either kills them or interferes with their reproduction. It is possible that other heavy metals such as arsenic, chromium or lead similarly endanger and destroy wildlife.

Organic contaminants also have detrimental effects on wildlife. DDT, an organo-chlorine compound not soluble in water, upsets the calcium metabolism in birds. This in turn causes production of eggs with abnormally thin shells which break before hatching. The measured DDT concentration in birds has been as high as 163 ppm (parts per million); and in their eggs as high as 227 ppm. In addition to killing wildlife, organic contaminants decrease their reproduction by as much as 50 percent.

Organic contaminants concentrate in the fatty tissue of mammals and birds as well as in humans. For example, at Green Bay, Wisconsin the DDT concentration in the bottom muds was 14 micrograms/l; in the invertebrate organisms, 50 times that amount; in the fish, 500; and in the Herring Gulls that ate the fish the DDT concentration was 15,000 times the amount in the muds.

Oil destroys the insulating air pockets in the plumage of waterfowl. Since birds have a high body temperature, a spot of oil one inch in diameter may make it impossible for the bird to maintain its normal temperature. This in

turn makes the bird susceptible to infection and death may occur from diseases such as pneumonia. For example, on December 10, 1968, 280 birds killed by oil were found on 10 miles of beach at Presqu'ile Park on Lake Ontario. It should be recognized that only massive bird kills are detected. Dead wildfowl are difficult to locate partly because they blend with the vegetation, are subject to scavenging and decompose within a few days.

After the "Torrey Canyon" incident 5,700 birds were taken to cleansing centres established by the British Government to have oil removed from their feathers. After cleansing, only 150 were considered fit for release. Of this number 37 died within a month. Thus, once birds come in contact with oil or ingest small amounts of oil there is essentially no survival. Oils similarly endanger and destroy fur-bearing animals.

Oils can be carried great distances on the water surface or in an emulsified state. Furthermore, oils may not stay emulsified. Cool weather causes the globules to congeal into slicks. Some of the oil that escaped from the "Arrow" when it sank in Chedabucto Bay was blown out onto the stormy Atlantic. Spectro-analysis confirmed that this same oil coated and killed the 4,800 birds that were later washed onto the shores of Sable Island. Furthermore, the shores of Sable Island were coated with the same oil. The distance between Chedabucto Bay and Sable Island is about 125 miles. Thus, it is reasonable to conclude that the oils discharged by industries and municipalities to the eastern end of Lake Erie and the Upper Niagara not only destroy wildlife on the Niagara River but may also kill waterfowl in Lake Ontario 100 or more miles away.

Chapter XI

JURISDICTIONAL AND LEGAL PROBLEMS

The waters of the Lower Great Lakes and the International Section of the St. Lawrence River lie within both the United States and Canada, and also within the States of Michigan, Ohio, New York, the Commonwealth of Pennsylvania and the Province of Ontario. All seven of these jurisdictions have laws relating to the prevention or control of pollution of that portion of the waters situated in their territory, and governmental agencies responsible for administering those laws. As might be expected in such circumstances, the policies and goals and the vigour with which they are pursued in the several jurisdictions are not uniform; and there is considerable variation in the actual laws, their administration and enforcement.

At the jurisdictional level, responsibility for navigation and shipping has to a large extent resided with the federal governments in both countries. Lake fisheries have been a federal matter in Canada but a state matter in the United States. Historically, jurisdiction over most aspects of pollution from municipal, industrial and agricultural sources and from drilling operations, has been vested in the provinces and states, as well as local governments. Enforcement in most cases has been a provincial and state responsibility.

Recently, however, the federal governments have become more deeply involved. In the United States, for example, the federal government has been given extensive authority over water pollution under the Federal Water Pollution Control Act which, among other things, provides that water quality standards of the states be submitted to the Department of the Interior, now the Environmental Protection Agency, for approval. In the event of a dispute, the federal government may, under certain conditions, impose federally determined standards.

The Canada Water Act which became law this year provides a framework for federal-provincial planning and cooperation. Among other things, it provides for the creation of joint water quality management agencies for waters designated by the federal and provincial governments. These agencies would be empowered by regulation to set water quality standards and to

implement programmes to achieve those standards. With regard to international waters and boundary waters, it is provided that if provincial cooperation cannot be achieved, the federal government itself may designate the waters, establish the agencies and the standards and carry out implementation of the programmes.

While in some cases the differences among jurisdictions are more apparent than real, in others the differences are such that the laws as applied in the various jurisdictions are incompatible. Obviously such inconsistency presents serious obstacles to the effective implementation of any concerted programme of pollution control and abatement throughout the Lower Great Lakes.

As an example of the foregoing, the movement of commercial vessels and pleasure craft across the international and state boundaries in these waters is unrestricted, yet the legal requirements in the several jurisdictions for the control of waste discharges from the watercraft are not compatible. In a special report on boat and vessel pollution, the Boards informed the Commission in 1969 that no single law or regulation in Canada or the United States dealt with all aspects of pollution of navigable waters from watercraft. The Board also stated that many of the laws in effect were of a token nature and not readily enforceable, because of their impracticability or lack of personnel to perform the task, or both. The Commission has since been informed that Ontario, Michigan and New York now have satisfactory and compatible regulations in force governing the discharge of wastes from pleasure craft. Because of the mobility of watercraft, it is essential that all of the governments concerned have compatible regulations governing the discharge of all forms of waste from the commercial and recreational watercraft using these waters.

In order to achieve effective pollution control and acceptable water quality in these boundary waters, the policies and laws of the several jurisdictions concerned must have a common goal and the programmes to achieve that goal need to be coordinated with the programmes of the other jurisdictions involved in the lakes. Otherwise, efforts put forth in one jurisdiction may be frustrated either by inaction or by inconsistent action in another jurisdiction. Water quality surveillance and monitoring to assess the effectiveness of control measures undertaken or the need for additional measures also need to be coordinated with similar activities in the other jurisdictions if meaningful results are to be obtained. A high degree of cooperation and a free exchange of relevant data and information among all jurisdictions concerned are essential elements of an effective programme to achieve and maintain a satisfactory water quality in these boundary waters.

Chapter XII

REMEDIAL MEASURES

The water pollution problems described in this Report, and their adverse effects on the environment and on the 18 million people who live on or near the shorelines, will become more critical unless there is vigorous and concerted implementation of imperative remedial measures. These remedial measures include agreement upon common water quality objectives, better treatment of municipal and industrial wastes, a phosphorus control programme, an international contingency plan to deal with emergencies, and programmes for further studies. Continuing surveillance, monitoring and implementation are discussed in Chapter XIII.

WATER QUALITY OBJECTIVES

Guidelines or objectives are essential if the water quality of the Lower Great Lakes is to be preserved and where necessary restored. The discharges of wastes must be limited so that the quality of the receiving waters approaches the ideal of lakewide cleanliness.

THE PURPOSE AND NATURE OF OBJECTIVES

In this Report *water quality criteria* are the scientific requirements for the preservation of the aquatic environment and designated water uses. They imply adequate water quality conditions. *Water quality objectives* are desirable levels of quality to be attained in the receiving waters. They take into account the criteria for a whole spectrum of water uses: supplies for municipal, industrial and agricultural purposes, recreation, aesthetic enjoyment and the propagation of aquatic life and wild life. *Water quality standards* are the prescribed levels of water quality established by governmental authorities in programmes designed to achieve water quality objectives.

It is in the best interest of the inhabitants of both countries to attain satisfactory water quality that will enhance the aquatic environment and will permit a maximum beneficial use of the water resources of the Lower Great Lakes. As contaminants originating in one jurisdiction move without restric-

tion across state and international boundaries they degrade the quality of the waters in another jurisdiction, and so inhibit present or future legitimate uses of these common boundary waters. Under the Boundary Waters Treaty, these uses should be respected by each country.

In view of the many types of contaminants, their variable persistence, the intermixing of the waters along the boundary, and the obligation of both countries not to pollute on either side of the boundary to the injury of health or property on the other, the Commission has repeatedly recommended the adoption of the same water quality objectives for all jurisdictions which share each international river basin with which it has dealt, including the Connecting Channels of the Great Lakes. One set of objectives should now apply to all jurisdictions that share the waters of the Lower Great Lakes.

The Water Quality Objectives for Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, hereinafter referred to as the Objectives, have been developed to protect these waters for all legitimate uses including the most restrictive. Furthermore, these Objectives should also apply to the Connecting Channels of the Great Lakes, (the St. Marys, St. Clair, Detroit and Niagara Rivers) particularly the Detroit and Niagara Rivers, because they are the principal sources of wastes and they have a profound effect on the water quality of the Lower Great Lakes.

These Objectives should apply to all the receiving waters enumerated above, at all places and at all times. They are particularly applicable to inshore waters. Since the shorelines and the tributaries are the most significant sources of contaminants, the water quality of the deeper waters of the Lakes will be preserved and eventually enhanced if the quality of the inshore waters are in compliance.

The Objectives are intended to be the minimum basis for formulating provincial and state water quality standards and meaningful programmes to achieve the desirable levels of water quality. The Commission does not condone degradation of waters which now have a quality superior to that envisaged by the Objectives. Each municipality, industry and jurisdiction is urged to undertake the most effective treatment feasible consistent with the maintenance of that superior quality.

The Commission recognizes that the primary responsibility for the abatement of water pollution rests with the provinces and the states. However, each Federal Government has certain related responsibilities and in addition the obligation to the other, under Article IV of the Boundary Waters Treaty, which provides that the "boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other." This commitment is expressive of the common law of both countries. In moral law it is expressive of the Biblical concept, "Do

unto others as you would have them do unto you." Attainment of the Objectives will require the cooperation of all levels of government in both countries.

Compliance with the Objectives involves the monitoring of waste discharges by provincial and state water pollution control agencies and may involve effluent controls or other measures in some cases. In this connection, the important criterion is not the degree of treatment provided but the amount of wastes left in the effluent. Furthermore, from the standpoint of a pollution control programme it is the total amount of contaminants discharged by all sources within the jurisdiction. The growth of population and industry has a dual effect of generating more wastes and creating more demands on a limited water resource.

The Objectives are not immutable. The Specific Objectives and the numbers associated with them are limited to those parameters on which there is ample data and knowledge. New or modified Specific Objectives will be warranted when the subtle actions and interactions of water quality degradation and improvement become more fully understood. It is intended that the Objectives be reviewed periodically in the light of quality requirements, technological changes in both industry and waste treatment processes, and policy.

GENERAL OBJECTIVES

The General Objectives are the five "freedoms" or goals of an effective pollution control programme.

The receiving waters of Lake Erie, Lake Ontario, the International Section of the St. Lawrence River and the Connecting Channels of the Great Lakes at all places and at all times should be:

- (a) Free from substances attributable to municipal, industrial or other discharges that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life or waterfowl.
- (b) Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges in amounts sufficient to be unsightly or deleterious.
- (c) Free from materials attributable to municipal, industrial or other discharges producing colour, odour or other conditions in such a degree as to create a nuisance.
- (d) Free from substances attributable to municipal, industrial or other discharges in concentrations that are toxic or harmful to human, animal or aquatic life.

- (e) Free from nutrients derived from municipal, industrial and agricultural sources in concentrations that create nuisance growths of aquatic weeds and algae.

Furthermore, no substance should be introduced into these waters unless reasonable efforts have been made to ensure that it will not lead to the violation of any of the foregoing objectives.

SPECIFIC OBJECTIVES

The Specific Objectives are the desirable levels of water quality considered necessary at this time to achieve the General Objectives. Each Specific Objective has been developed in recognition of the appropriate restriction necessary to permit all legitimate uses of these waters. They constitute the parameters against which the effectiveness of provincial and state water programmes can be measured.

The Specific Objectives are for the receiving waters except in the restricted mixing zones at outfalls. (The periphery of the restricted mixing zones should be prescribed by water pollution control agencies).

- (a) *Microbiology (Coliform Group)*—The geometric mean of not less than five samples taken over not more than a 30-day period shall not exceed 1,000/100 ml total coliforms, nor 200/100 ml fecal coliforms in local waters.
Waters used for body contact recreation activities should be free from bacteria, fungi, or viruses that may produce enteric disorders, or eye, ear, nose, throat and skin infections.
- (b) *Dissolved Oxygen*—In the Connecting Channels and in the upper waters of the Lakes not less than 6.0 mg/l at any time; in the hypolimnetic waters not less than the concentrations necessary for the support of fishlife, particularly cold water species.
- (c) *Total Dissolved Solids*—Less than 200 mg/l in Lake Erie, Lake Ontario and the International Section of the St. Lawrence River; in the St. Marys River, pending the results of a study of the Upper Great Lakes, a level of total dissolved solids not exceeding that of 1970; and in the other Connecting Channels a level consistent with maintaining the levels of total dissolved solids in Lake Erie and Lake Ontario less than 200 mg/l.
- (d) *Temperature*—No change which would adversely affect any local or general use of these waters.
- (e) *Taste and Odour*—No objectionable taste or odour. Phenols desirably absent but not to exceed a monthly average of 1.0 μ g/l. Other taste and odour producing substances absent.

- (f) *pH*—No change from the range of levels, 6.7 to 8.5, which now exist.
- (g) *Iron*—Less than 0.3 mg/l.
- (h) *Phosphorus*—Concentration limited to the extent necessary to prevent nuisance growths of algae, weeds and slimes which are or may become injurious to any beneficial water use. (Meeting this objective will require that the phosphorus loading to Lake Erie be limited to 0.39 g/m²/yr. and the phosphorus loading to Lake Ontario be limited to 0.17 g/m²/yr.)
- (i) *Radioactivity*—Elimination of radioactive materials to the extent necessary to prevent harmful effects on health. Pending the adoption of more stringent limits, in no event is gross beta activity to exceed 1,000 pCi/l, Radium-226 not to exceed 3 pCi/l and Strontium-90 not to exceed 10 pCi/l.

ADDITIONAL SPECIFIC OBJECTIVES

When required, appropriate Specific Objectives will be established for water quality parameters including, but not restricted to, toxic wastes, oils and heavy metals.

DISCUSSION OF SPECIFIC OBJECTIVES

Where ingestion of water is probable, recreational waters are considered "impaired" when the specified Objectives are exceeded. In 1950 this Commission recommended the adoption of an objective for bacteria in the Connecting Channels under which the coliform median value, MPN (most probable number) was not to exceed 2,400/100 ml. The Commission considers that this objective should be made more stringent and should include an objective for fecal coliforms.

The Objective for dissolved oxygen was established to maintain the levels necessary for fish life, particularly cold water species and the associated biota.

The total dissolved solids concentration is a collective indicator of water quality and reflects increases in major mineral contaminants. The present concentration of dissolved solids in the lakes indicates the need for immediate action to reduce the discharge of dissolved materials. Thus, the Commission envisions an Objective for dissolved solids more stringent than a level which merely impairs domestic and industrial water supplies.

Waste heat discharges should not be permitted if the resulting water temperature stimulates production of nuisance organisms or vegetation that may effect the propagation of aquatic and wildlife. It is not considered desirable at this time to establish absolute limits, owing to the fact that

information on the effects of temperature changes in the Lakes is not complete or adequately correlated.

It is desirable that odour and taste producing materials be essentially absent in public water supplies. The effectiveness of conventional water treatment in removing odour is highly variable depending on the nature of the material causing the odour. Tainting of fish flesh may result from materials not adequately removed by waste treatment processes. While an average monthly concentration of $1 \mu \text{ g/l}$ of phenols may be used as a numerical guideline, it is desirable that phenols be absent.

The present pH levels of the Lakes are considered to be within the desirable range. They fall within the 1950 Objectives established for the Connecting Channels, *i.e.* a pH not less than 6.7 nor more than 8.5.

The Objective for iron conforms to the United States Public Health Service and the Canadian Department of National Health and Welfare drinking water standards for protection of public water supplies. This value is the same as the 1950 Objective for the Connecting Channels.

The Objective for phosphorus is based on Chapter VI where it is explained that phosphorus will, under certain conditions, stimulate nuisance growths of algae, weeds and slimes. Although a maximum acceptable concentration in the Lakes cannot be specified at all times, it has been found that algal blooms can be expected to follow in years when the concentration of inorganic phosphorus and inorganic nitrogen exceed 10 and $300 \mu \text{ g/l}$, respectively, at the time of the spring turnover.

The numerical values in the radioactivity objectives conform with United States Public Health Service and Canadian drinking water standards which are based on those recommended by the International Commission on Radiological Protection, as set out in ICRP Publication 9, 1965.

MUNICIPAL AND INDUSTRIAL WASTE TREATMENT

Waste treatment includes the removal of solids, deoxygenating wastes, nutrients, bacterial contaminants, toxic materials, oils and greases in the waste water from residences, from public and commercial buildings and from industries.

Many of the existing municipal waste treatment plants do not adequately cope with the demands placed upon them. The column in Table 4 under the heading "Existing Backlog", sets out the capital costs of the remedial facilities necessary to meet the current requirements in each jurisdiction. These costs reflect the extent of pollution attributable to each state and province. The pollution described in this Report will be significantly alleviated when remedial facilities are constructed to take care of future municipal growth.

TABLE 4. ESTIMATED CAPITAL COSTS FOR WASTE TREATMENT AND PHOSPHORUS REMOVAL INCREMENT

Millions of 1968 Dollars

State or Province	Municipal Waste Treatment		Industrial Waste Treatment Backlog	Phosphorus Removal Industrial and Municipal	Total
	Existing Backlog	Future* Growth			
LAKE ERIE INCLUDING DETROIT AND ST. CLAIR RIVERS					
Michigan.....	48	40	100	62	250
Ohio.....	55	76	140	105	376
Indiana.....	2	3	5	4	14
Pennsylvania.....	2	3	5	4	14
New York.....	6	8	35	12	61
Ontario.....	9	29	7	10	55
TOTALS.....	122	159	292	197	770
LAKE ONTARIO INCLUDING NIAGARA AND ST. LAWRENCE RIVERS					
New York.....	222	165	193	78	658
Ontario.....	27	80	19	30	156
TOTALS.....	249	245	212	108	814

*Based on a projected municipal growth to 1986.

The capital costs of these facilities are expressed in Table 4 in 1968 dollars. Their numerical value will increase at a rate similar to that of the construction cost index.

Remedial measures are required for the removal and control of phosphorus. They include immediate reduction and eventual replacement of phosphorus in detergents. They also include capital expenditures for programmes to reduce phosphorus in municipal and industrial waste effluents. These remedial measures are complementary, not alternatives, since detergents and human wastes are the principal sources of phosphorus to the Lakes. The incremental capital cost for phosphorus removal is shown in Table 4.

The Commission is convinced that the reduction of phosphorus input into Lake Erie, Lake Ontario and the International Section of the St. Lawrence River will significantly delay further eutrophication and will allow the recovery of the Lakes to begin through natural processes. All feasible approaches to the phosphorus removal problem must be implemented. The Boards' report stressed that Lake Erie as a whole might well return to a mesotrophic state if the phosphorus loading were reduced to 0.39 g/m²/yr.,

and that Lake Ontario might well return to an oligotrophic state if the phosphorus loading were reduced to $0.17 \text{ g/m}^2/\text{yr}$. This can be achieved if all phosphorus is eliminated from detergents plus a 95 percent removal of the predicted 1986 load of phosphorus at municipal and industrial waste treatment plants. Such remedial measures would limit the annual input of phosphorus to 22 million pounds for Lake Erie and to 7 million pounds for Lake Ontario. It must be emphasized that Lake Erie prior to World War II was probably a mesotrophic lake and that even more stringent phosphorus control measures would not result in it becoming oligotrophic.

The reasons for reducing phosphorus in detergents are several. The first concerns timing. If a replacement for detergent phosphorus could be developed rapidly, a significant reduction of phosphorus inputs would be achieved prior to completion of phosphorus removal facilities at sewage treatment plants. Secondly, the effect would be to reduce phosphorus input from small communities, cottages and individual homes where the installation of phosphorus removal facilities would be very costly. Thirdly, it is estimated that treatment costs for phosphorus removal at sewage treatment plants would be reduced considerably by removing phosphorus from detergents.

Water pollution control should be provided like any other public utility, the purpose of which is to serve the public with the best and most efficient services. Thus, greater attention should be given to providing standby equipment capable of preventing water pollution during periods of breakdown or inadequate performance. The need also exists for municipalities to provide facilities that will allow treatment of wet weather flows in combined sewers. Where storm and sanitary sewers are separate there is also a need to treat the effluents from the storm sewers.

Industrial waste recovery and waste treatment facilities are inadequate in many cases. The costs of industrial waste control to correct the existing backlog of needed works are set out in Table 4. Accelerated industrial remedial programmes are required to control oxygen-consuming materials, organic substances, acids, alkalis, iron, phenols, oils and toxic materials.

CONTROL OF POLLUTION FROM LAND DRAINAGE

Those responsible for livestock and land management should take steps to control both animal waste disposal and soil erosion as well as riverbank erosion. Agricultural agencies should develop further measures to improve the practices of soil fertilization, land tilling and conservation in order to reduce the amount of phosphorus and sediments entering the Lakes from the drainage basin.

A distribution inventory and improved techniques for the application of toxic pesticides to field crops should be developed at the earliest opportunity. Substitutes should be found for these persistent organic contaminants.

CONTINGENCY PLANS

Contingency plans are essentially coordinated procedural arrangements for the notification, containment and clean-up of pollutants arising from unauthorized or accidental discharges of oils, toxic and hazardous materials which can originate from the transfer, storing and handling of these materials, from vessels, from under-water drilling and production operations and from stationary sources. Preventative measures are necessary to minimize the adverse effects of such spills.

A proper surveillance and reporting system is necessary to organize effectively countermeasures and to minimize damages from sudden pollution incidents. Existing legislation at all levels of government should also be reviewed to ensure that in the event of pollution from either a recurring or non-recurring source, authority exists for the appropriate government agency undertaking adequate measures to abate the pollution in the event that the parties concerned fail to do so.

Spills that cross the international boundary or major spills may require the combined resources of manpower, materials, equipment and technology available in both countries. Thus, it is essential that the two Governments develop in advance an international contingency plan to deal with such incidents in the Great Lakes. Such a plan would recognize and utilize local, regional, state, provincial and national capabilities. It would also recognize and make provisions for the administrative and other problems associated with their integrated action. For example, attention should be given to the development of a plan to cope with radioactive wastes accidentally discharged directly to the Lakes or their tributaries from nuclear reactors, waste processing plants and industrial operations.

FURTHER STUDIES

Although available technology can remedy many of the pollution problems, solutions to many other problems cannot be prescribed at this time because the knowledge and understanding of the physical phenomena, chemical interactions and biological activities are woefully inadequate. Federal, provincial and state governments should encourage and support research and development undertakings leading to more effective water quality policies for the future.

Among the scientific problems of the environment needing the most urgent attention are those concerned with: the nutrient requirements for

algal growth and more refined determinations of whether and how micro-nutrients may limit growth; environmentally harmless substitutes for phosphorus in detergents; sediment-water interchanges of polluting substances; movement of pesticides and heavy metals through the food chain and their effects on various life forms; more refined estimates of lake chemical budgets, including an assessment of the extent of man-made and natural sources; the impact of pollutants on particular fish populations; better understanding of the circulation of lake waters and of the diffusion of pollutants; development of reliable remote reading or automatic recording instruments for monitoring chemical, biological and physical parameters in the lakes; effects of increased thermal inputs on the heat balance and the ecological balance of nearshore areas; and viral epidemiology.

There is a need to find alternative means for reducing the pollution overflows from combined storm and sanitary sewage systems. Further studies are needed not only to develop water quality prediction models but also to incorporate into such models and other studies the sociological and economic aspects of pollution and its control. They would enable authorities to anticipate water pollution control needs and permit rational planning for pollution control.

Studies are also necessary to find solutions to legislative, legal and enforcement problems related to water pollution. Indeed, the solution of some of these complex social problems may well be as difficult and as time-consuming as the solution of some of the scientific and technical problems.

Chapter XIII

SURVEILLANCE, MONITORING AND IMPLEMENTATION

The purpose of this chapter is to explore the arrangements required to achieve the remedial measures discussed in Chapter XII.

The investigations and studies carried out by the Commission's Boards and the testimony presented at the subsequent public hearings have disclosed much information about the sources and consequences of pollution of the waters of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, as of the time the inquiry was in progress. They have also provided a firm basis for determining the remedial measures which must be undertaken in the several jurisdictions involved, not only to correct the present situation but also to ensure that the quality of the waters does not again deteriorate to unsatisfactory levels through neglect, inaction or inappropriate action in any of the jurisdictions. Any programmes to achieve and maintain a satisfactory water quality throughout these boundary waters, to be effective, will require the commitment and cooperation of all the jurisdictions, the coordination of actions having an effect on implementation of the agreed programmes and the free exchange of relevant data and information among the several jurisdictions.

Continuous surveillance of these waters must be provided to detect any changes in quality, to assess the effectiveness of remedial measures undertaken and to determine the need for further control measures to attain the agreed objectives. Most of the jurisdictions concerned now have their own local programmes for collecting and analysing water samples but some programmes will need to be coordinated and modified to ensure complete coverage of these boundary waters and to eliminate any unnecessary duplication of effort and expense. If the surveillance programmes are to be thus coordinated, it follows that the data and information obtained in each jurisdiction must be made available freely and expeditiously to all of the other jurisdictions concerned, so that each may assess the results obtained and take appropriate action.

Properly coordinated, these surveillance programmes will also permit continuous monitoring of compliance with agreements between Canada and

the United States regarding water quality objectives and standards and the programmes to achieve them. They will also permit a continuous review of the adequacy of the agreed objectives and programmes so that necessary changes may be recommended to the two Governments as appropriate and the international agreements amended accordingly.

Pursuant to the Boundary Waters Treaty of 1909, the International Joint Commission now has certain jurisdiction with respect to the conduct of investigations and to the levels and flows of the boundary waters of the Great Lakes System. In addition, as authorized by the Governments of Canada and the United States, the Commission since 1951 has maintained continuing supervision over pollution in the Connecting Channels, as a procedure to insure accomplishment of the Water Quality Objectives which the Governments approved for those waters.

In its surveillance of water quality and monitoring of remedial measures in the Connecting Channels, the Commission has been assisted by two international advisory boards it established for that purpose. Senior officials of federal, state and provincial agencies serve in their personal and professional capacities as members of one or both boards. Water quality surveillance and investigations by the agencies concerned are coordinated by these boards. Their frequent reports, supplemented on occasion by the Commission's public hearings, have enabled the Commission to draw the attention of Governments to cases of non-compliance with the agreed Objectives and to recommend appropriate action by the authorities having jurisdiction.

In view of the proven utility of the Boundary Waters Treaty and the flexibility it provides, as well as the unique role of the Commission over the years along the boundary, the Commission believes that it would be both logical and desirable for the two Governments to confer upon it the authority, responsibility and means for coordinating and ensuring the necessary surveillance of water quality and monitoring of compliance with any international agreements relating to pollution in the Lower Lakes and the St. Lawrence River.

Under such agreements, other specific functions should be assigned to the Commission, including such matters as a continuing review of contingency plans for dealing with spills, of regulations respecting pollution from watercraft, and of the handling of hazardous materials. The Commission should be empowered to review and make recommendations concerning legislation in each country relating to pollution of the Great Lakes System with a view, among other things, to harmonize and strengthen such legislation.

In summary, the Commission would be obligated to keep the two Governments informed of the results of its activities by means of regular and special reports, and to make such recommendations regarding objectives, standards, programmes, research, technical assessment of the environmental

impact of activities within the basin, regulations, legislation, agreements, enforcement and the like as it might consider appropriate. Similarly, it would make recommendations to the state and provincial governments for action in specific cases.

To assist it in carrying out these functions, the Commission would establish an international "board" or "boards" composed of highly qualified persons. The Commission would delegate to the board or boards certain of the authority and responsibilities given it by the two Governments. Members would be appointed by the Commission, after consultation with the Governments, with a view to ensuring not only technical excellence but also appropriate contact with state, provincial and national sectors, both governmental and non-governmental, whose support would be essential to the success of board operations.

The board would have responsibilities to coordinate surveillance and monitoring programmes of the agencies so that adequate and continuous coverage is obtained, arrange for such verification as may be necessary, analyze results obtained and report to the Commission with any recommendations for further action. A very important function of the board would be to ensure the rapid exchange of data and other relevant information among all the agencies concerned and to provide an early warning system for the agencies so they could react quickly in response to serious pollution incidents or significant scientific advances. Finally, the board would be the Commission's principal source of technical and scientific advice on matters affecting the quality of these waters. To this end the board probably would be authorized to establish committees to deal with specific geographical areas or specific aspects of water pollution.

The Commission would maintain close contact with the board and its operations and would conduct such supplemental investigations and public hearings as may be required. For this purpose its present subpoena powers might need to be strengthened and its authority to publish its findings and reports, without reference to governments, might be clarified. Unquestionably, an adequate staff of qualified professionals will be needed by the Commission on a permanent basis, in addition to the assistance it receives from its boards, to enable the Commission to discharge effectively the proposed responsibilities.

Chapter XIV

CONCLUSIONS

The Governments of Canada and the United States requested the International Joint Commission to inquire into and report on three questions.

1. In response to the question, "*Are the waters of Lake Erie, Lake Ontario, and the international section of the St. Lawrence River being polluted on either side of the boundary to an extent which is causing or is likely to cause injury to health or property on the other side of the boundary?*"

The Commission finds that the waters referred to in the question are being seriously polluted on both sides of the boundary to the detriment of both countries and to an extent which is causing injury to health and property on the other side of the boundary. On the basis of the trans-boundary movement described in Chapter VIII of this Report, the Commission concludes that contaminants originating in one country do move across the boundary and degrade the quality of the waters in the other country.

2. In response to the question, "*If the foregoing question is answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?*"

The Commission finds the polluted waters are lakewide in extent; that the two principal causes are wastes discharged by municipalities and industries into the above waters and their tributaries; and that pollution is taking place in all jurisdictions which share these boundary waters. The sources of pollution and their relative contributions are outlined in Chapter IX of this Report.

3. In response to the question, "*If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgement, be most practicable from the economic, sanitary and other points of view and what would be the probable cost thereof?*"

The Commission finds that the remedial measures include the adoption and adherence to this Commission's General and Specific Objectives as a matter of urgency; immediate reduction of the phosphorus content in detergents; the prompt implementation of a vigorous programme to provide the necessary municipal and industrial waste treatment facilities and

to reduce the phosphorus inputs into the above waters and their tributaries; and making provision for continuous surveillance and monitoring. The estimated cost in terms of 1968 dollars for the required municipal and industrial treatment facilities located in Canada would be \$211 million, and for those facilities located in the United States, \$1,373 million. These and other remedial measures are described in Chapter XII of this Report.

The Governments of Canada and the United States also requested the International Joint Commission to report on the following matters pertaining to potential oil pollution in Lake Erie.

4. In response to, "*The adequacy of existing safety requirements and procedures in Canada and in the United States applicable to drilling and production operations in Lake Erie to prevent oil from escaping into the Lake so as to produce serious transboundary oil pollution conditions.*"

The Commission concludes that the safety requirements and procedures applicable to drilling and production operations in Lake Erie of Pennsylvania, New York and particularly those of Ontario, if effectively supervised and properly enforced, are adequate to prevent oil escaping into the Lake so as to produce serious transboundary oil pollution conditions. Drilling is prohibited in the Michigan portion of Lake Erie. The exact status of Ohio regulations is not clear. In the Ontario portion of Lake Erie, the only area where there are at present drilling and gas production operations, the enforcement of the regulations and the required operational procedures have been adequate to date.

5. In response to, "*The adequacy of existing mechanical, chemical and other methods of confining, removing, dispersing and cleaning up any major oil spill that may occur in Lake Erie from any source, bearing in mind the damage that such methods may cause to marine life, domestic water supplies or to other beneficial uses of the Lake in both countries.*"

The Commission concludes that the current methods of confining, removing, dispersing and cleaning up a major oil spill that may occur from any source are primitive and inadequate. Current methods can deal effectively with large spills only under the most ideal weather conditions. There is no one method that is a panacea. Each oil pollution mishap presents a unique situation in terms of water temperature, winds, currents, type of oil and the ecology of the area. Very little is known on the residual effects on aquatic organisms of materials used to sink or disperse oil spills.

6. In response to, "*The adequacy of existing contingency plans and the action taken to implement them to confine and clean up transboundary pollution and to prevent or mitigate the destructive transboundary effects of any major oil spill from any source that may occur in Lake Erie.*"

The Commission concludes that the United States contingency plan for the Lake Erie region is generally adequate, although the roles of state and local agencies and of private organizations require clarification. On the other

hand, Canada does not yet have a detailed or coordinated contingency plan to marshal the capabilities of federal, provincial and local agencies or private organizations. Such local plans as exist are relatively uncoordinated. Furthermore, the Commission notes that there is no formal plan for international cooperation on oil spills.

In addition to the above responses, the International Joint Commission further concludes that:

7. There is need for international contingency plans to cope with major spills of hazardous or radioactive materials.
8. The introduction and accumulation of untreated and partially treated wastes from municipalities, industries and agricultural activities have been the causes of the pollution problems described in Chapter VI of this Report.
9. Lake Erie, particularly its Western Basin, is in an advanced state of eutrophication and accelerated eutrophication is occurring in Lake Ontario. The accelerated eutrophication of these waters is due to the presence of nutrients which have been and are being added to these waters. The resultant biological productivity is proportional to the annual rate of input of these nutrients. Of the nutrients involved, phosphorus is the only one that is both growth-limiting in the lakes and controllable effectively by man with present technology.
10. The major source of phosphorus is municipal sewage. In the United States 70 percent of the phosphorus in sewage originates from detergents, most of the remainder from human excreta. In Canada approximately 50 percent originates from each sewage source. Apart from municipal sewage, the other significant sources of phosphorus are agricultural runoff and some industrial wastes.
11. The input of phosphorus can be reduced by widespread improvement in the treatment in existing plants of municipal and industrial wastes containing phosphorus. An over-all programme to achieve this is essential if eutrophication is to be halted.
12. Because of the practical difficulties in implementing the municipal programme contemplated in the preceding conclusion within the reasonable future, it is essential that both countries reduce the phosphorus content of detergents to the maximum practicable extent at the earliest possible time.
13. The inputs to the waters of the basin of phosphorus, nitrogen and other nutrients from agricultural operations are difficult to control but methods must be found to diminish them.

14. The contribution of very large quantities of polluting materials from heavily industrialized areas such as those along the St. Clair River, the Detroit River, the Maumee River, the Cuyahoga River and the Buffalo-Niagara Falls, Rochester and Hamilton-Toronto regions has: causes eutrophication of the Lower Great Lakes; depleted the dissolved oxygen in the hypolimnion of the Lakes, particularly the Central Basin of Lake Erie; induced adverse biological changes; been partially responsible for the dramatic changes in fish population; caused bacterial contamination along the shorelines; increased the accumulated dissolved solids and wastes in the Lakes; increased water treatment problems; impaired the recreational and aesthetic values of the Lakes and of the International Section of the St. Lawrence River; and destroyed wildlife. These and other effects are described in Chapter X of this Report.
15. Although commercial vessels and pleasure craft are not major sources of pollution when compared with urban centres, they are mobile sources that can discharge pathogenic organisms and petroleum wastes at or near sensitive areas such as water intakes, bathing beaches and marinas.
16. Garbage, litter, bilge and ballast water discharged into the Lower Great Lakes System are not only aesthetically unattractive but also restrict recreational activities and interfere with the legitimate uses of these waters.
17. Unless the remedial measures outlined in Chapter XII of this Report, particularly waste treatment facilities and phosphorus control programmes, are undertaken as a matter of urgency the waters of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River will be further degraded.
18. The International Joint Commission should be assigned the tasks of coordinating continuous surveillance of water quality, of monitoring the implementation of pollution abatement programmes, of coordinating the exchange of information on all aspects of water pollution, and of reporting and publishing the results on the effectiveness of such governmental programmes.
19. The Upper Lakes and the Connecting Channels of the Great Lakes, particularly the Detroit and Niagara Rivers, have a profound effect on the water quality of the Lower Great Lakes. Thus, it is incumbent on both countries, as a matter of urgency, to take appropriate action to preserve and where necessary enhance the quality of all the boundary waters of the Great Lakes System and its tributaries.

Chapter XV

PROPOSED WATER QUALITY OBJECTIVES

WATER QUALITY OBJECTIVES FOR LAKE ERIE, LAKE ONTARIO, THE INTERNATIONAL SECTION OF THE ST. LAWRENCE RIVER AND THE CONNECTING CHANNELS OF THE GREAT LAKES

GENERAL OBJECTIVES

The receiving waters of Lake Erie, Lake Ontario, the International Section of the St. Lawrence River and the Connecting Channels of the Great Lakes at all places and at all times should be:

- (a) Free from substances attributable to municipal, industrial or other discharges that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life or water-fowl.
- (b) Free from floating debris, oil, scum and other floating materials attributable to municipal, industrial or other discharges in amounts sufficient to be unsightly or deleterious.
- (c) Free from materials attributable to municipal, industrial or other discharges producing colour, odour or other conditions in such a degree as to create a nuisance.
- (d) Free from substances attributable to municipal, industrial or other discharges in concentrations that are toxic or harmful to human, animal or aquatic life.
- (e) Free from nutrients derived from municipal, industrial and agricultural sources in concentrations that create nuisance growths of aquatic weeds and algae.

Furthermore, no substance should be introduced into these waters unless reasonable efforts have been made to ensure that it will not lead to the violation of any of the foregoing Objectives.

SPECIFIC OBJECTIVES

The Specific Objectives are for the receiving waters except in the restricted mixing zones at outfalls. (The periphery of the restricted mixing zones should be prescribed by water pollution control agencies.)

- (a) *Microbiology (Coliform Group)*—The geometric mean of not less than five samples taken over not more than a 30-day period shall not exceed 1,000/100 ml total coliforms, nor 200/100 ml fecal coliforms in local waters.
Waters used for body contact recreation activities should be free from bacteria, fungi, or viruses that may produce enteric disorders, or eye, ear, nose, throat and skin infections.
- (b) *Dissolved Oxygen*—In the Connecting Channels and in the upper waters of the Lakes not less than 6.0 mg/l at any time; in the hypolimnetic waters not less than the concentrations necessary for the support of fishlife, particularly cold water species.
- (c) *Total Dissolved Solids*—Less than 200 mg/l in Lake Erie, Lake Ontario and the International Section of the St. Lawrence River; in the St. Marys River, pending the results of a study of the Upper Great Lakes, a level of total dissolved solids not exceeding that of 1970; and in the other Connecting Channels a level consistent with maintaining the levels of total dissolved solids in Lake Erie and Lake Ontario less than 200 mg/l.
- (d) *Temperature*—No change which would adversely affect any local or general use of these waters.
- (e) *Taste and Odour*—No objectionable taste or odour. Phenols desirably absent but not to exceed a monthly average of 1.0 μ g/l. Other taste and odour producing substances absent.
- (f) *pH*—No change from the range of levels, 6.7 to 8.5, which now exist.
- (g) *Iron*—Less than 0.3 mg/l.
- (h) *Phosphorus**—Concentrations limited to the extent necessary to prevent nuisance growths of algae, weeds and slimes which are or may become injurious to any beneficial water use. (Meeting this objective will require that the phosphorus loading to Lake Erie be limited to 0.39 g/m²/yr, and the phosphorus loading to Lake Ontario be limited to 0.17 g/m²/yr.)

*The term phosphorus in this Report refers to phosphorus as a constituent of various organic and inorganic complexes and compounds, not to elemental phosphorus as a chemical substance. The term phosphorus includes orthophosphates such as trisodiumphosphate, crystalline phosphates such as sodiumtripolyphosphate, and polyphosphates such as sodiumhexametaphosphate. However, in this Report concentrations and loads are given in terms of the element phosphorus as part of any compound to assure uniformity of expression.

- (i) *Radioactivity*—Elimination of radioactive materials to the extent necessary to prevent harmful effects on health. Pending the adoption of more stringent limits, in no event is gross beta activity to exceed 1,000 pCi/l, Radium-226 not to exceed 3 pCi/l and Strontium-90 not to exceed 10 pCi/l.

ADDITIONAL SPECIFIC OBJECTIVES

When required, appropriate Specific Objectives will be established for water quality parameters including, but not restricted to, toxic materials, oils and heavy metals.

Chapter XVI

RECOMMENDATIONS

In response to the Reference dated October 7, 1964 and to the letter dated March 21, 1969, from the Governments of Canada and the United States, and as the minimum basis for programmes to achieve and maintain waters in satisfactory condition as contemplated by Article IV of the Boundary Waters Treaty of 1909, the International Joint Commission recommends that:

1. The Water Quality Objectives for Lake Erie, Lake Ontario, the International Section of the St. Lawrence River and the Connecting Channels of the Great Lakes as set forth in Chapter XV of this Report be adopted by the Governments of Canada and the United States and be recognized as the minimal basis for the establishment of standards for these waters by the States of Michigan, Ohio and New York, the Commonwealth of Pennsylvania and the Province of Ontario in the administration of their pollution control programmes.
2. The Governments of Canada and the United States enter into agreement on programmes and measures to achieve the said Objectives and the schedules for their implementation.
3. The Governments of Canada and the United States enter into agreement on an integrated programme of phosphorus control to include:
 - (a) the immediate reduction to a minimum practicable level of the phosphorus content of detergents and the total quantities of phosphorus-based detergents discharged into the Great Lakes System with the aim of complete replacement of all phosphorus in detergents with environmentally less harmful materials by December 31, 1972;
 - (b) further reduction, as a matter of urgency, of the remaining phosphorus in municipal and industrial waste effluents discharging to Lake Erie, Lake Ontario and their tributaries and to the International Section of the St. Lawrence River, with a

- view to achieving at least an 80 percent reduction by 1975 and thereafter additional reduction to the maximum extent possible by economically feasible processes;
- (c) the reduction of phosphorus discharged to these waters from agricultural activities.
4. The Governments of Canada and the United States agree to develop, as a matter of urgency, compatible and coordinated programmes, in concert with provincial and state agencies, to control effectively by 1972 the introduction of persistent organic contaminants such as herbicides and pesticides into these waters and that substitutes be found for such persistent substances.
 5. The Governments of Canada and the United States agree to develop compatible and coordinated programmes, in concert with provincial and state agencies, to control effectively the introduction of toxic materials from municipal and industrial wastes into these waters.
 6. The Governments of Canada and the United States agree to require a thorough investigation of the possible adverse health and ecological effects of substitutes proposed for use in lieu of organic contaminants, toxic materials and any other substances now considered hazardous in these respects such as mercury and phosphorus.
 7. Collection and treatment facilities for municipal and industrial wastes, be, as a matter of urgency, built, enlarged or improved to prevent pollution of these waters and be operated at all times at maximum capability; measures for handling storm water and combined sewage be so designed and operated as to avoid bypassing of untreated waste waters into these waters and their tributaries; all with a view of ensuring that all wastes receive adequate treatment at all times.
 8. Federal, provincial and state governments review, and if necessary amend, existing laws and regulations to control the disposal of solid waste materials in or on the shores of these waters so as to ensure maintenance of the Water Quality Objectives set forth herein and to prevent contaminants from entering these waters through seepage or runoff.
 9. Dredged materials containing objectionable quantities of pollutants be disposed of in a manner to ensure maintenance of the Water Quality Objectives set forth herein.
 10. The Government of Canada, as a matter of urgency, develop a detailed and fully coordinated contingency plan so that it can

quickly and effectively respond to major accidental spills of oils, hazardous or radio-active materials in the Canadian waters of the Great Lakes System; and the Government of the United States progressively improve its corresponding contingency plans so as to include all available response capabilities.

11. The Governments of Canada and the United States enter into agreement to develop coordinated international contingency plans so that both countries may quickly and effectively respond to major accidental spills of oils, hazardous or radioactive materials in the boundary waters of the Great Lakes System.
12. The two Governments, in concert with provincial and state agencies and with industry, accelerate and expand, as a matter of urgency, their applied research programmes on the containment and clean-up of oil spills so that those responsible for the execution of contingency plans may have available the best possible technical advice, equipment and support.
13. Until such time as each of the Governments is satisfied that the containment and clean-up methods and the contingency plans for oil spills applicable to the waters of Lake Erie within its jurisdiction are adequate;
 - (a) oil production and production of "wet gas" containing appreciable amounts of liquid hydrocarbons from wells in Lake Erie be prohibited,
 - (b) all wells in Lake Erie capable of oil production be adequately plugged,
 - (c) in the western basin of Lake Erie (west of a straight line drawn from the tip of Pelee Point in Ontario to Marblehead in Ohio) all drilling be prohibited,
 - (d) in the remainder of Lake Erie drilling not be permitted unless the regulating agency having jurisdiction has determined in the light of known geologic conditions that there would be no reasonable likelihood of discovering oil or "wet gas" containing appreciable amounts of liquid hydrocarbons.
14. The two Governments take steps to exclude from the Great Lakes ships and masters likely to present an unreasonable risk of pollution by oils, hazardous or radioactive materials; and also make provision to alert appropriate officials in both countries when hazardous materials are in transit in these waters.
15. The federal, provincial and state governments review and where necessary strengthen their existing laws and programmes relating to the reporting and control of spills and the disposal of oils, hazard-

- ous or radioactive materials, so as to prevent further pollution of these waters by oils, hazardous or radioactive materials.
16. The federal, provincial and state governments in concert consider and implement at the earliest possible date compatible regulations for the control of water pollution from all classes of commercial vessels and pleasure craft using the Great Lakes System.
 17. Appropriate governmental agencies be involved in site selection and consulted in the design of all thermal power plants, both public and private, so as to minimize adverse effects on the receiving waters of temperature changes and input of radioactive materials into these waters.
 18. The federal, provincial and state governments give high priority to research, including but not restricted to, those problems enumerated in Chapter XII of this Report with highest priority given to those problems related to human health such as viral diseases.
 19. The federal, provincial and state governments support fully this Commission's water quality surveillance and monitoring programmes for these waters, including the inputs from their tributaries.
 20. The Governments of Canada and the United States extend, at the earliest practicable date, the Reference dated October 7, 1964 to include the remaining boundary waters of the Great Lakes System and the waters tributary thereto.
 21. Until the Commission is in a position to recommend Water Quality Objectives for Lake Huron and Lake Superior, the States of Michigan, Wisconsin and Minnesota and the Province of Ontario recognize the Water Quality Objectives as set forth herein as the minimal basis for the establishment of standards in the administration of their pollution control programmes for Lake Huron and Lake Superior.
 22. The Governments of Canada and the United States specifically confer upon this Commission the authority, responsibility and means for coordination, surveillance, monitoring, implementation, reporting, making recommendations to governments, all as outlined in Chapter XIII of this Report, and such other duties related to preservation and improvement of the quality of the boundary waters of the Great Lakes—St. Lawrence System as may be agreed by the said Governments; the Commission to be authorized to establish, in consultation with the Governments, an international board or boards to assist it in carrying out these duties and to delegate to said board or boards such authority and responsibility as the Commission may deem appropriate.

Signed this 9th day of December, 1970, as the International Joint Commission's report to the Governments of Canada and the United States on the pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River.

A. D. P. HEENEY

CHRISTIAN A. HERTER, JR

EUGENE W. WEBER

CHARLES R. ROSS

A. D. SCOTT

BERNARD BEAUPRÉ

APPENDIX

TEXT OF REFERENCE TO THE INTERNATIONAL JOINT COMMISSION

On October 7, 1964, the Secretary of State for External Affairs, for the Government of Canada and the Secretary of State, for the Government of the United States, sent the following Reference to the International Joint Commission through identical letters addressed respectively to the Canadian and United States Sections of the Commission:

I have the honour to inform you that the Governments of the United States and Canada have been informed that the waters of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River are being polluted by sewage and industrial waste discharged into these waters. Having in mind the provision of Article IV of the Boundary Waters Treaty signed January 11, 1909, that boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other side, the two Governments have agreed upon a joint Reference of the matter to the International Joint Commission, pursuant to the provisions of Article IX of said Treaty. The Commission is requested to inquire into and to report to the two Governments upon the following questions:

- (1) Are the waters of Lake Erie, Lake Ontario, and the International Section of the St. Lawrence River being polluted on either side of the boundary to an extent which is causing or is likely to cause injury to health or property on the other side of the boundary?
- (2) If the foregoing question is answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?
- (3) If the Commission should find that pollution of the character just referred to is taking place, what remedial measures would, in its judgement, be most practicable from the economic, sanitary and other points of view and what would be the probable cost thereof?

In the conduct of its investigation and otherwise in the performance of its duties under this reference, the Commission may utilize the services of engineers and other specially qualified personnel of the technical agencies of Canada and the United States and will so far as possible make use of information and technical data heretofore acquired or which may become available during the course of the investigation.

The two Governments are also agreed on the desirability of extending this Reference to other boundary waters of the Great Lakes Basin at an appropriate time. The Commission is requested to advise the Governments when, in its opinion, such action is desirable.

The Commission should submit its report and recommendations to the two Governments as soon as practicable.

TEXT OF LETTER REGARDING POTENTIAL
OIL POLLUTION IN LAKE ERIE

On March 21, 1969, the Secretary of State for External Affairs, for the Government of Canada and the Secretary of State, for the Government of the United States, sent the following Reference to the International Joint Commission through identical letters addressed respectively to the Canadian and United States Sections of the Commission:

I refer to your letter of April 11, 1968 reporting the results of an exploratory meeting convened by the International Joint Commission approximately a year ago to obtain information about the programmes for drilling for oil and gas in Lake Erie which are in effect or are contemplated by the Province of Ontario and certain of the riparian States. In that letter you reported that the responsible State and Provincial officials considered that there was minimal risk of pollution of the lake's waters from drilling and production operations and that "with existing technology, any accidental escape of oil would be limited to a matter of minutes".

The recent serious oil spill off the coast of California may cast some doubt on the proposition that existing technology is adequate to confine the destructive consequences of a runaway oil well or that the risks of serious pollution can be described as minimal. The Californian experience suggests the necessity of a careful review of safety precautions and procedures applicable in Lake Erie, particularly in view of the shallow and confined nature of this body of water.

Accordingly the Commission is requested as a matter of urgency within the framework of the existing International Joint Commission pollution reference dated October 7, 1964, on Lake Erie, Lake Ontario and the International Section of the St. Lawrence River to investigate and to make a special report at the earliest possible date on the following matters:

- (1) The adequacy of existing safety requirements and procedures in Canada and in the United States applicable to drilling and production operations in Lake Erie to prevent oil from escaping into the Lake so as to produce serious transboundary oil pollution conditions;
- (2) The adequacy of existing mechanical, chemical and other methods of confining, removing, dispersing and cleaning up any major oil spill that may occur in Lake Erie from any source, bearing in mind the damage that such methods may cause to marine life, domestic water supplies or to other beneficial uses of the Lake in both countries; and
- (3) The adequacy of existing contingency plans and the action taken to implement them to confine and clean up transboundary pollution and to prevent or mitigate the destructive transboundary effects of any major oil spill from any source that may occur in Lake Erie.

If the Commission finds that any of the existing safety requirements, methods or plans referred to in clauses numbered (1), (2) and (3), respectively are inadequate, the Commission is requested to make recommendations as to what action should be taken to correct any such inadequacy.

Moreover if after preliminary investigation the Commission is of the opinion that certain interim measures are necessary with respect to one or more of the matters being herein referred to it, the Commission is requested to make recommendations concerning any such measures in advance of submitting its main report and recommendations.

The Governments of Canada and the United States are equally concerned about the risk of serious oil pollution in the Great Lakes from other sources, notably major oil spills from marine or industrial mishaps such as those referred to in your letter of April 11, 1968. The discharge of oil from land-based sources and from normal vessel operations is already being studied by the Commission. The threat of major oil pollution as a result of a disaster to a vessel in the Great Lakes involves broader international consideration. This aspect of the overall problem is under study by the two Governments through other appropriate channels.

MEMBERSHIP OF THE BOARDS AND THEIR COMMITTEES

The International Joint Commission appointed the International Lake Erie Water Pollution Board and the International Lake Ontario-St. Lawrence River Water Pollution Board on December 2, 1964. When the Board submitted their report to the Commission in September 1969, membership of the Boards consisted of the following:

INTERNATIONAL LAKE ERIE WATER POLLUTION BOARD

Canadian Section

- Dr. E. A. Watkinson, Director General, Health Services Branch, Department of National Health and Welfare, *Chairman*.
- Dr. W. M. Cameron, Director, Marine Sciences Branch, Department of Energy, Mines and Resources.
- D. S. Caverly, General Manager, Ontario Water Resources Commission.
- P. M. Higgins, Public Health Engineering Division, Department of National Health and Welfare.
- Dr. W. M. Sprules, Director, International Fisheries Branch, Department of Fisheries and Forestry.
- F. A. Voegelé, Assistant General Manager, Ontario Water Resources Commission.

United States Section

- H. W. Poston, Regional Director, Federal Water Pollution Control Administration, Department of the Interior, *Chairman*.
- G. H. Eagle, Chief Sanitary Engineer, Ohio State Department of Health.
- J. F. Hendrickson, International Affairs Officer, Federal Water Pollution Control Administration, Department of the Interior.
- W. A. Lyon, Director, Bureau of Sanitary Engineering, Commonwealth of Pennsylvania, Department of Health.
- D. F. Metzler, Deputy Commissioner, New York State Department of Health.
- R. Purdy, Executive Secretary, Michigan Water Resources Commission.

INTERNATIONAL LAKE ONTARIO—ST. LAWRENCE RIVER
WATER POLLUTION BOARD*Canadian Section*

- Dr. E. A. Watkinson, Director General, Health Services Branch, Department of National Health and Welfare, *Chairman*.
- Dr. W. M. Cameron, Director, Marine Sciences Branch, Department of Energy, Mines and Resources.
- D. S. Caverly, General Manager, Ontario Water Resources Commission.

- P. M. Higgins, Public Health Engineering Division, Department of National Health and Welfare.
- Dr. W. M. Sprules, Director, International Fisheries Branch, Department of Fisheries and Forestry.
- F. A. Voegel, Assistant General Manager, Ontario Water Resources Commission.

United States Section

- H. W. Poston, Regional Director, Federal Water Pollution Control Administration, Department of the Interior, *Chairman*.
- J. F. Hendrickson, International Affairs Officer, Federal Water Pollution Control Administration, Department of the Interior.
- D. F. Metzler, Deputy Commissioner, New York State Department of Health.
- R. J. Van Derwerker, Sanitary Engineer Director, Department of Health, Education and Welfare.

FORMER BOARD MEMBERS

Canada

- W. R. Edmonds (deceased), Department of National Health and Welfare.
- W. K. Sharpe, Department of National Health and Welfare.

United States

- L. F. Warrick, Department of Health, Education and Welfare.
- S. C. Martin, Department of Health, Education and Welfare.
- G. A. Hall, State of Ohio.
- Dr. M. H. Thompson, State of New York.
- K. S. Krause, Department of the Interior.
- E. J. Anderson, Department of the Interior.
- Dr. A. Hirsch, Department of the Interior.
- L. F. Oeming, Michigan Water Resources Commission.

As authorized by the Commission, the Boards established a number of Committees. When the Boards submitted their report to the Commission the Committees consisted of the following members:

EDITORIAL COMMITTEE

- Dr. N. J. Campbell, Marine Sciences Branch, Department of Energy, Mines and Resources, *Chairman*.
- J. F. Hendrickson, International Affairs Officer, Federal Water Pollution Control Administration, Department of the Interior.
- C. Pemberton, Jr., Federal Water Pollution Control Administration, Department of the Interior.

- Dr. J. R. Vallentyne, Fisheries Research Board, Freshwater Institute.
W. A. Steggle, Water Quality Surveys Branch, Ontario Water Resources Commission.
J. P. Bruce, Inland Waters Branch, Department of Energy, Mines and Resources.
P. M. Higgins, Environmental Health Directorate, Department of National Health and Welfare.

REPORT COMMITTEE

- H. W. Poston, Federal Water Pollution Control Administration, Department of the Interior, *Chairman*.
J. F. Hendrickson, International Affairs Officer, Federal Water Pollution Control Administration, Department of the Interior.
Dr. N. J. Campbell, Marine Sciences Branch, Department of Energy, Mines and Resources.
W. K. Sharpe, Environmental Health Directorate, Department of National Health and Welfare.
F. A. Voegelé, Ontario Water Resources Commission.

WATER QUALITY OBJECTIVES COMMITTEE

- C. Pemberton, Jr., Federal Water Pollution Control Administration, Department of the Interior, *Chairman*.
F. A. Voegelé, Ontario Water Resources Commission.
J. H. Neil, Ontario Water Resources Commission.
L. Miller, Pennsylvania Department of Health.
W. A. Steggle, Water Quality Surveys Branch, Ontario Water Resources Commission.
W. K. Sharpe, Environmental Health Directorate, Department of National Health and Welfare.
D. B. Stevens, New York Department of Health.

VESSEL WASTE COMMITTEE

- J. F. Hendrickson, International Affairs Officer, Federal Water Pollution Control Administration, Department of the Interior.
F. A. Voegelé, Ontario Water Resources Commission.

PARTICIPATING AGENCIES

Valuable and cooperative assistance was provided by the following agencies:

In Canada

Ontario Water Resources Commission
Department of National Health and Welfare
Department of Energy, Mines and Resources
Fisheries Research Board

In the United States

Federal Water Pollution Control Administration
New York State Department of Health
Pennsylvania Department of Health
Ohio Department of Health
Michigan Department of Health
Michigan Water Resources Commission

PERSONS PRESENTING BRIEFS OR TESTIMONY
AT THE
INTERNATIONAL JOINT COMMISSION PUBLIC HEARINGS

Where witnesses testified at more than one hearing only one appearance is recorded hereunder.

December 2, 1969 at Toronto, Ontario

K. Burbridge, Counsel for Canada
 R. E. Stein, Counsel for the United States
 D. L. Tough, Department of Energy, Mines and Resources (Canada)
 J. Bruce, Canada Centre for Inland Waters
 F. Boyce, Canada Centre for Inland Waters
 E. Sherwin, Department of Energy, Mines and Resources (Canada)
 J. Birtwhistle, Department of Transport (Canada)
 D. Sharp, Department of Energy & Resources Management (Ontario)
 W. A. Steggle, Ontario Water Resources Commission
 J. F. Downing, Commissioner of Public Works, Buffalo, N.Y.
 H. M. Baumler, Town Attorney, Hamburg, N.Y.
 H. Townsend for Ontario Petroleum Institute
 B. J. Wallace, The Consumers' Gas Company
 R. G. Quillian, Atlas Oil & Gas Limited and Canadian Industrial Gas & Oil Limited
 R. P. Cummer, Amerada Hess Corporation
 E. G. Bulmer, Ont-Hio Gas & Oil Incorporated
 E. L. Morris, Consolidated West Petroleum
 D. D. Barkwell, Canadian Industrial Gas & Oil Limited
 S. P. Spisiak for New York State Conservation Council, Buffalo, N.Y.
 Alderman A. E. O'Donohue for Group Action to Stop Pollution, Toronto

December 3, 1969 at Cleveland, Ohio

Representative Thaddeus J. Dulski, United States Congress
 Representative Richard D. McCarthy, United States Congress
 Representative George V. Voinovich, Ohio House of Representatives, Cleveland
 Mrs. Vera Spooner for City Council, Rocky River, Ohio
 John E. Workley, Town Clerk, West Seneca, N.Y.
 K. E. Biglane, United States Federal Water Pollution Control Administration
 H. W. Poston, United States Federal Water Pollution Control Administration
 J. F. Hendrickson, United States Federal Water Pollution Control Administration
 Robert M. Acker, Department of Natural Resources, Michigan
 David E. Barry, Erie County Health Department, Buffalo, N.Y.
 Mrs. Howard T. Moore for League of Women Voters, Chardon, Ohio
 Mrs. J. L. Hanna for League of Women Voters, Euclid, Ohio
 Mrs. Jean Cornelius for Avon Lake Anti-pollution Group, Ohio
 Thomas F. Carson for Associated Yacht Clubs, Toledo
 Lawrence E. Stevens for Academic Council on Environmental Problems, Rocky River,
 Ohio
 Mrs. Ellen Knox for Academic Council on Environmental Problems, Rocky River, Ohio
 Mrs. Charles Stebbins for Citizens for Clean Air and Water, Cleveland
 Albert H. McClelland for Northern Ohio Group, Sheffield Lake
 Mrs. Paul Aiken for Park Conservation Committee of Greater Cleveland
 John Chascsa for Lake Erie Clean-up Committee and Munroe County Rod and Gun
 Club, Dearborn, Michigan

Arthur Wooton, The Consumers' Gas Company
Miss June M. Brown for Pollution Control Advisory Board, Toledo
Seba H. Estill for Izaak Walton League, Cleveland
Vice-Admiral James A. Hirshfield for Lake Carriers Association
Harold Townsend, St. Lawrence Production Inc., Massena, New York
Harold J. Zimmerman for Burroughs Nature Club and The Nature Conservancy,
Willoughby, Ohio
Professor Arnold W. Reitze, Case Western Reserve University, Cleveland
Dr. David Gitlin, Berea, Ohio

January 20, 1970 at Erie, Pennsylvania

Representative Joseph P. Vigorito, United States Congress
Representative Reid L. Bennett, House of Representatives, Commonwealth of Pennsylvania
Representative Wendell Good, House of Representatives, Commonwealth of Pennsylvania
Representative David S. Hayes, House of Representatives, Commonwealth of Pennsylvania
Bernard J. Harkins, City Councilman, City of Erie
H. C. Kingstone, Counsel for Canada
Carlyle Pemberton, Jr., United States Federal Water Pollution Control Administration
Colonel Leonard Goodsell, Great Lakes Commission
Walter A. Lyon, Bureau of Sanitary Engineering Department of Health, Commonwealth of Pennsylvania
Robert Hesser, Pennsylvania Fish Commission
Thomas C. West, Erie County Department of Health
Dr. Richard W. Brown, Hammermill Paper Company
Rowell Chase, Procter & Gamble Company and member of The Soap & Detergent Association
Dr. Frank H. Healey, Lever Brothers Company and member of The Soap & Detergent Association
Theodore E. Brenner, The Soap and Detergent Association
John A. Bruck, Procter & Gamble Company
Dr. Clayton F. Callis, Monsanto Company
George F. Marion, Colgate-Palmolive Company
Dr. John Singer, Hampshire Chemical Division, W. R. Grace Company
John Robert Glavis for Society of the Societies, Kent State University
Richard Curry, Grand River Academy
Gene Heuser, Erie
Kenneth C. Hill, Chesterland, Ohio
Preston Sauerbrei, Aurora, Ohio
Ned V. Collander, Northwest Pennsylvania Regional Planning and Development Commission, Oil City, Pennsylvania
Bruce Lev, Youngstown, Ohio
James H. Gill, Columbus, Ohio
Jeffrey Perry, Columbus, Ohio
Frank John Schiller, Presque Isle Chemical Company
Robert A. Sweeney, Great Lakes Laboratory, State University College, Buffalo, N.Y.
Ashtabula County Scenic River Committee, Jefferson, Ohio
David DeHaven for Pennsylvania Federation of Sportsmen's Clubs, Inc., Erie

January 21, 1970 at Toledo, Ohio

The Hon. Wm. J. Ensign, Mayor of Toledo
Ralph W. Purdy, Michigan Water Resources Commission
John E. Richards, Engineering Division, Ohio Department of Health

Richard E. Midden, Ohio Department of Natural Resources
 Gerald Remus, Detroit Metropolitan Water System
 Ben. S. Stefanski, II, Department of Public Utilities, City of Cleveland
 Resolution by Council of the City of Toledo
 Frederick O. Rouse, Great Lakes Basin Commission
 D. J. Collins, Ontario Water Resources Commission
 David S. Caverly, Ontario Water Resources Commission
 Douglas W. Scott for Environmental Action for Survival, University of Michigan
 John Turner for Environmental Action for Survival, University of Michigan
 Dr. Willy Lange, The Tanner's Council Laboratory, University of Cincinnati
 Mrs. Neil Waterbury for Maumee Valley Inter-League Group, League of Women Voters
 Neil Waterbury for Northwestern Ohio Natural Resources Council
 Frank T. Knapp for Neighborhood Foundation of Toledo
 Mrs. June M. Brown for League of Women Voters of Toledo

January 23, 1970 at London, Ontario

The Rev. Kenneth Bolton, Member of the Ontario Legislature
 Douglas Fisher, Economic Council, Erie Region
 D. J. Matthews for the parks enthusiasts
 Professor E. G. Pleva, Department of Geography, University of Western Ontario,
 London
 Greg Morley, Law Faculty, University of Western Ontario, London
 Al Campbell for Local 27, United Auto Workers Union, London
 Mrs. Elizabeth Futer, London
 Mrs. R. W. Tracy, London
 Gordon Ferrar, London

February 2, 1970 at Hamilton, Ontario

The Hon. George Kerr, Minister of Energy and Resources Management, Province of
 Ontario
 Ian Deans, Member of the Ontario Legislature
 His Worship, Mayor E. A. Horton, Etobicoke, Ontario
 Alderman R. Wilson, Niagara Falls, Ontario
 Dr. J. R. Vallentyne, Fisheries Research Board of Canada
 D. Ross, Legal Department, Metropolitan Toronto
 D. Clough, Water Pollution Section, Works Department, Metropolitan Toronto
 R. W. Rodman, City Engineer, Niagara Falls, Ontario
 C. H. Eidt, Regional Municipality of Niagara, St. Catharines
 J. B. Bryce, The Hydro-Electric Power Commission of Ontario
 A. Rae, Canadian Detergent Industry Committee for Water Quality
 J. Dixon, Canadian Detergent Industry Committee for Water Quality
 J. Duthie, Procter & Gamble Company, Cincinnati
 H. H. Clare, Imperial Oil Limited
 Professor J. D. Norman, McMaster University, Hamilton
 N. R. Mitchinson for "Committee for a Thousand," Niagara Falls, Ontario
 W. A. Scott for Long Point Ratepayers Association, Port Rowan, Ontario
 P. Doran for "Clear Hamilton of Pollution," Dundas, Ontario
 H. Harper for Lakefront Owners Association, Toronto
 Mrs. R. Simmons for Consumers Association of Canada, Hamilton
 J. W. Argo, Ontario Branch, Canadian Institute of Pollution Control
 C. E. Goodwin for Conservation Council of Ontario
 W. Stewart, Dundas, Ontario
 B. Kelly for Pollution Probe, University of Toronto

Professor J. R. Kramer, McMaster University
J. B. Kingdon for "Clear Hamilton of Pollution," Dundas, Ontario
S. Hilts, University of Western Ontario

February 4, 1970 at Rochester, New York

Christian A. Herter, Jr., United States Department of State
F. T. Mayo, United States Federal Water Pollution Control Administration
Col. Ray S. Hansen, United States Corps of Engineers, Buffalo District
T. W. Pearson (for E. F. Seebald), New York State Department of Health
Frank E. Van Lare for Monroe County Pure Waters Agency, Rochester
W. M. Harris for Monroe County Conservation Council, Rochester
Dr. H. S. Forest for Rochester Committee for Scientific Information, two statements:
 one on behalf of Conservation Council, the other on his own behalf
E. D. Wattles for National River & Harbour Contractors Association
Dr. L. E. Kuentzel, Wyandotte Chemicals Corporation
Charles G. Bueltman for The Soap and Detergent Association
Dr. J. Shapiro, Limnological Research Centre, University of Minnesota
Dr. I. A. Eldib, Eldib Engineering & Research Inc., Newark, N.J.
Edward B. Nool, Cleveland Hts., Ohio
Bernard D. Sutor for Izaak Walton League of America, Kenmore, N.Y.

February 6, 1970 at Brockville, Ontario

The Hon. James Auld, Minister of Tourism and Information, Ontario
His Worship Mayor John Broome, Brockville
Alderman Frances MacOdrum, Brockville
Dr. Alan Prince, Department of Energy, Mines and Resources (Canada)
W. A. Pearce, New York State Conservation Department
Dr. P. H. Jones, University of Toronto
Dr. Herman F. Hoerig, Du Pont of Canada Limited
Robert B. Shaad, Watertown, N.Y.
R. F. Mucklestone, Brockville
J. J. Burke for Canadian Chamber of Shipping
Capt. P. R. Hurcomb for Dominion Marine Association

In addition to the above, over 200 statements were submitted on behalf of individuals and organizations either at the hearings or through the mails, most of them relating to potential oil pollution in Lake Erie.

