THE IMPLICATIONS OF PHOSPHORUS LOAD REDUCTIONS TO LAKE ERIE

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Introduction

Based on an extension of the empirical relationship developed by Dobson, Gilbertson and Lee (1972) between the rate of oxygen depletion in the hypolimnion of the Central Basin and the external phosphorus loading to Lake Erie, the implications of a phosphorus reduction program can be postulated. The reasons for a phosphorus reduction program originated with the reports of the International Joint Commission (1970) and its Advisory Boards (1969 a, b & c). Intensive studies of Lake Erie (and Lake Ontario) carried out by the IJC over the years 1965 to 1969 outlined in considerable detail the deterioration of the lakes due to cultural eutrophication - the over-enrichment of these lakes by nutrients, particularly phosphorus. The principal manifestation of eutrophication was the production of massive growths of aquatic vegetation which created serious problems for water supply and recreational uses of a significant portion of Lake Erie. As a result of identifying this problem and the role of phosphorus, the IJC (1970) made specific recommendations for the control of phosphorus in order to reverse accelerating eutrophication.

The relationship developed by Dobson, Gilbertson and Lee (1972) was an adjunct to previous extensive studies of the hypolimnion of the Central Basin of Lake Erie described in Project Hypo (1972). The general objective of "Project Hypo" was to quantify, insofar as possible, the extent of oxygen depletion in the hypolimnion and to delineate the mechanisms responsible for the observed phenomenon, including the quantification of nutrient release rates

under oxic and anoxic conditions. Although anoxic conditions were anticipated and observed during the IJC studies, nutrient release rates were not studied in detail at that time.

"Project Hypo" involved extensive physical, biological and chemical studies in the Central Basin, and from these studies it was determined that oxygen depletion in the hypolimnion was produced by two main mechanisms, with the vast majority being caused by the bacterial oxidation of organic material which had settled to the bottom of the basin (Burns and Ross, 1972 (a)). The primary source of this material was the massive amount of algae produced by over-enrichment of the lake.

Dobson and Gilbertson (1971) showed that anoxic conditions of significant extent were probably first manifest in the Central Basin in 1960 and ten years later (Burns and Ross, 1972 (a)) found that these conditions extended over some 6,000 square kilometers or 40% of the *whole* Central Basin. The phosphorus release rate from sediments under these anoxic conditions was found to be about eleven times higher than when oxygen was present.

The principal finding of this project was that because of the vast increase in anoxic conditions in the hypolimnion "the Central Basin is now changing from being a settling basin to a production basin for phosphorus during the summer. This production of phosphorus at a critical period in the annual cycle of the lake occurs just prior to the turnover and fall blooms, and is the result of excessive phosphorus loadings earlier in the year" (Burns and Ross, 1972 (b)). The authors of "Project Hypo" concluded that "..... phosphorus input to Lake Erie must be reduced immediately; if this is done, a quick improvement in the condition of the lake can be expected; if it is not done the *rate of deterioration* of the lake will be much greater

than it has been in recent years" (Burns and Ross, 1972 (b)).

Thus, as a result of "Project Hypo", this regeneration of large quantities of nutrients from extensive anoxic conditions in the hypolimnion caused by the decay of massive quantities of algae was identified as a significant factor in the *acceleration* of the rate of deterioration of the water quality of Lake Erie. As a consequence, the prevention of the occurrence of anoxic conditions would be a significant *initial* step in the *prevention of further acceleration of the rate of deterioration* of the quality of the lake. Further, on the same basis, *any reduction* in present phosphorus inputs would thus presumably have a "multiplier effect" in reducing nuisance algal conditions.

A sufficient reduction of phosphorus inputs should lead to the elimination of bottom anoxic conditions and prevention of the regeneration of inorganic phosphorus from the sediments. In addition, since 75% of the phosphorus is removed from the lake by the sediments under oxic conditions (Burns and Ross, 1972 (b)), the available phosphorus should be reduced in close proportion to reductions in the external load.

The occurrence of anoxic conditions in the hypolimnion of the Central Basin of the lake should be predictable on the basis of the empirical linear relationship developed by Gilbertson, Dobson and Lee (1972) to which reference was made. Based on historical data Dobson and Gilbertson (1971) demonstrated an accelerating *trend* in oxygen depletion rates in the Central Basin from 1929 to 1970, and utilizing this information Gilbertson, Dobson and Lee (1972) postulated the linear relationship shown in Figure 1. The municipal portion of the external phosphorus loading was calculated on the basis of population estimates multiplied by factors which accounted for the

phosphorus contributed by human wastes and detergents. The authors concluded that "this graph suggests a possible significant relationship between the two parameters (i.e., rate of dissolved oxygen depletion and municipal phosphorus loading). The rate of oxygen depletion has increased with the increasing municipal loading." From this relationship the authors estimated that the municipal portion of the external phosphorus loading would have to be reduced to the order of 12,000 tons per year to avoid the occurrence of anoxic conditions (and subsequent large scale recycling of nutrients). This estimate is based on the assumption that the lake responds to a decrease in phosphorus loadings in a similar fashion as it appears to have responded to an increase in such loadings (i.e., that the postulated relationship is reversible).

It is recognized, however, that it is difficult to predict a year to year response because of the significant variation in the rate of dissolved oxygen depletion determined by Dobson and Gilbertson (1971) as depicted in Figure 2 which is reproduced from their work. They identified the trend and it is this relationship which was used to develop the subsequent relationship between phosphorus loadings and the rate of dissolved oxygen depletion.

For the purposes of this paper the phosphorus loading-hypolimnial oxygen relationship was extended to relate to the *total* external phosphorus loading to Lake Erie and this can be done if it is assumed that the non-municipal portion of the total external phosphorus loading has been *essentially constant* over the period 1931 to 1970. In the IJC Advisory Board Report (1969, b), the non municipal fraction of the total loading was estimated at about 11,000 tons per year. This extension of the Dobson, Gilbertson, Lee relationship is shown in Figure 1.

Using this postulated relationship for total loading, it can be seen that the Total external phosphorus loading to Lake Erie would have to be reduced to the order of 23,000 tons per year to just prevent the occurrence of anoxic conditions in the hypolimnion of the Central Basin at the end of the period of stratification. However, very low dissolved oxygen values and problem algae conditions would still be expected to prevail with this loading simply because the reduction is not sufficient to meet the proposed IJC water quality objective for phosphorus "to prevent the growth of nuisance algae, etc.". When this latter objective is achieved dissolved oxygen values in excess of 5 - 6 mg/l could be anticipated in the hypolimnion throughout the year.

In order to relate the impact of phosphorus reduction programs to the oxygen conditions in the hypolimnion of the Central Basin, projections of the total external phosphorus loading to Lake Erie can be made and related to the relationship in Figure 2.

Phosphorus Loadings

According to the IJC Board Report (1969, b)), approximately 78% of the phosphorus loading to Lake Erie was from sources in the United States, with 14% being from Canadian sources and 8% from Lake Huron.

In the IJC Report (1970) specific control measures were recommended for reducing the phosphorus loading to the lake. These included (a) replacement of phosphorus content of detergents with environmentally less harmful materials by December 31, 1972, (b) further reductions in the remaining phosphorus in municipal and industrial waste effluents, with a view to achieving at least an 80% reduction by 1975, and (c) reduction of

phosphorus discharged from land drainage activities. Subsequently, as a result of the findings of "project Hypo" previously described, the recommended date for the reduction of phosphorus in municipal and industrial waste effluents was advanced to 1973 from 1975. This new date was included in the report of the Ministerial Meeting on Great Lakes Pollution in Washington, D.C. in June, 1971.

Based on these above recommendations, phosphorus reduction programs were initiated in both the United States and Canada. The impact of these programs on Lake Erie can be compared by (a) assessing the probable effect on the oxygen conditions of the hypolimnion of the Central Basin and noting whether the recommended specific water quality objective for dissolved oxygen in hypolimnetic waters will be met; (b) determining whether such loadings will meet (i) the target phosphorus loadings that can be derived from the programs for 1975 recommended by the IJC (1970), and (ii) the recommended IJC (1970) specific water quality objective for phosphorus "to prevent nuisance growths of algae, weeds and slimes which are or may become injurious to any beneficial water use".

Phosphorus Reduction Programs

In cooperation with personnel from the U.S. Environmental Protection Agency and the Ontario Water Resources Commission (now Ministry of the Environment) estimates of the external phosphorus loading to Lake Erie were prepared for the period 1970 through 1976. The following phosphorus reduction programs were considered:

1. A program to control phosphorus in detergents only assuming that no phosphorus removal facilities would be constructed at municipal plants (Table 2).

2. United States and Canadian programs for the construction[1] of phosphorus removal facilities at municipal sewage treatment plants and programs to reduce the phosphorus content of detergents (Table 3 & 4).
3. For comparison purposes, estimates were also made of the external phosphorus loading assuming that no remedial measures or programs would be implemented after 1970 (Table 5).

The municipal portion of the total external phosphorus loading to Lake Erie was calculated for each country on the basis of measured sewage flows and measured concentrations of phosphorus in these flows from localities where this information was available, with projections being made accordingly. Where this was not possible, various assumptions were made with respect to the loading estimate and details of the methodology are outlined in Appendices A and B.

In order to calculate total external phosphorus loadings to Lake Erie, estimates were made of the non municipal portion of the total phosphorus loading. This loading includes the contribution from industrial and land drainage sources as well as the total contribution from Lake Huron. Estimates of the non municipal portion of the total external loadings are based essentially on data presented in the IJC Advisory Boards Report (1969, b) and modified somewhat to account for known reductions in industrial loadings. Estimates of the total external phosphorus loading, which include the municipal and non-municipal portions, are presented throughout.

Discussion and Comparisons

The total external phosphorus loadings which would be attained if the foregoing programs were implemented are compared with the following:

(1) As known in early 1972 at the time of negotiation of the Canada-United States Agreement on Great Lakes Water Quality.

1. The phosphorus loading to prevent the occurence of anoxic conditions in the hypolimnion of the central basin. This external loading is estimated to be 23,000 tons. (Figure 1)
2. Specifically, for dissolved oxygen in the IJC Report (1970) it was proposed that "in connecting channels and in the upper waters of the lake not less than 6.0 mg/l at any time; in the hypolimnetic waters not less than the concentrations necessary for the support of fish life, particularly cold water species". Although no specific level was suggested for the value of oxygen in the hypolimnetic waters, 6.0 mg/l may be considered optimal, with perhaps 4 mg/l considered marginal, but adequate over a short time span.
3. The 1975 "target loading" as derived from the programs proposed in the IJC Report (1970) which recommended the elimination of phosphorus in detergents by December 31, 1972, and an 80% reduction of the remainder of the phosphorus in municipal and industrial wastewater by 1975. This load was calculated to be about 13,465 tons (Appendix C). It was agreed by a Canada-U.S. Working Group which reported to the Ministerial Meeting in June 1971 that this latter target date should be moved forward to 1973.

However, the Canadian government limited the content of phosphorus in detergents to 5% P_2O_5 (2.2% P) as of December 31, 1972. In addition, because of limitations in the available data on the phosphorus loading from industrial sources in the United States, it was difficult to estimate the possible reductions that could be made in this load although a suggested decrease is outlined in Appendix C. With consideration of these two factors an estimate of a total external loading which might be considered as that resulting from the use of

"best practicable technology" was prepared. This estimate, depending upon the assumptions made (Appendix C), was about 14 - 15,000 tons per year. Given the inherent limitations in the data involved in the computations a more realistic estimate is probably about 15,000 to 16,000 tons per year, and this was the figure used for comparative purposes.

4. The proposed specific water quality objective recommended in the IJC Report (1970) for phosphorus corresponds to a total phosphorus loading of about 11,160 tons per year (0.39 $g/m^2/yr$).

Estimates of the phosphorus loadings that would occur as a result of the implementation of the phosphorus reduction programs are briefly summarized below, and in Figure 3 the phosphorus loadings as developed are presented for all of the programs and comparisons made with the various objectives.

(a) Programs involving only detergent reformulation. These loading data are presented in Table 2. The total phosphorus loading increases from 30,511 tons in 1970 to 31,866 in 1972. With reformulation to the 5% P_2O_5 level the total load decreases to about 23,957 tons, increasing yearly thereafter.

This reduction in phosphorus loading would be nearly sufficient to prevent the formation of anoxic conditions, and would, it is expected, greatly reduce the extent of these conditions in area and duration. The total loading would remain, of course, well in excess of that proposed as the specific IJC Water Quality Objective.

(b) United States and Canadian programs are presented in Tables 3 and 4. The total phosphorus loading decreases from 30,511 tons in 1970 to a minimum of 16,141 tons in 1976. The load reduction is such that by 1973 this would appear to be sufficient to eliminate anoxic conditions in the bottom waters.

The following tabulation summarizes the results of the various programs and relates them to the recommendations of the IJC report (1970).

TABLE 1

COMPARISON OF PHOSPHORUS CONTROL PROGRAMS

Control Programs	Date Loading Reduced To Attain Oxic-Anoxic Transition (Year)	Maximum D.O. Levels in Hypolimnion (1976) (mg/l)	Estimated* 1974 Loading 1975 Minimum Practicable 15-16,000 Tons (Tons)	Estimated 1975 Loading IJC Objective 0.39 g/m^2/yr. or 11,160 Tons (Tons)	(g/m^2/yr)
1. Detergent Reformulation only (Table 5)	--	Anoxic	24,411	24,679	0.86
2. Canadian and Proposed U.S. Program (Tables 3 and 4)	1973	2-3	16,985	16,849	0.59

*The 1974 loading results from programs implemented in 1973. The loading, 15 - 16,000 tons, is felt to represent the loading resulting from the implementation of the "best practicable technology" and may be considered to be comparable to that which would be obtained by implementation by 1975 of the programs recommended in the IJC Report (1970).

In the report of the IJC [1969 (b)p262] a figure is presented relating the external phosphorus surface loading and lake depth to the degree of eutrophication. This figure is reproduced here as Figure 4 and the pertinent information for Lake Erie has been included. For comparison purposes the 1975 phosphorus loading projected for each of the proposed control programs has been noted.

As suggested on page 66 of the same report, the achievement of the objective of 0.39 g/m^2/yr. phosphorus loading is expected to restore Lake Erie to a condition near mesotrophy.

Conclusions

On the basis of the preceding analysis and in light of the various assumptions that have been made, it can be concluded that:

(1) A program of detergent reformulation alone would achieve a significant decrease in the phosphorus loading with an expected important improvement in the condition of Lake Erie.

(2) By 1973 the phosphorus loading reductions under Canadian and United States programs might have been sufficient to maintain oxic conditions in the hypolimnetic waters of the central basin. The elimination of anoxic conditions would be a significant achievement because of the large multiplier effect which these conditions appear to have on nutrient availability and consequent algal growth. Similarly, anoxic and near-anoxic conditions are detrimental to cold water fish populations as was observed during "Project Hypo" (Burns and Ross, 1972 (b)). The biological changes brought on by the occurrence of anoxic conditions are not fully understood but are known to cause, in addition to the effects on fish, drastic changes in the bottom fauna of the lakes. These effects in particular should be diminished.

However, both of these latter programs will fall short of meeting the IJC proposed specific water quality objective for phosphorus, although the level of "best practicable treatment technology" for municipal and industrial wastewater treatment should be approached by 1976. It is obvious that in order to further reduce the phosphorus loadings to meet the water quality objectives, additional controls on industrial sources of phosphorus must be implemented and controls on the input of phosphorus from land drainage sources will be required.

Further, in order to *eliminate* eutrophic conditions as depicted in Figure 4, a load reduction to decrease the external phosphorus loading to about 8,000 tons per year would be required. This is several thousand tons below the loading suggested for the IJC objective for phosphorus (IJC Report, 1970) and approximately 50% of the projected 1976 phosphorus loading. As stated above, obviously, much yet needs to be done to reduce the phosphorus loadings to Lake Erie to even lower levels.

ACKNOWLEDGMENT

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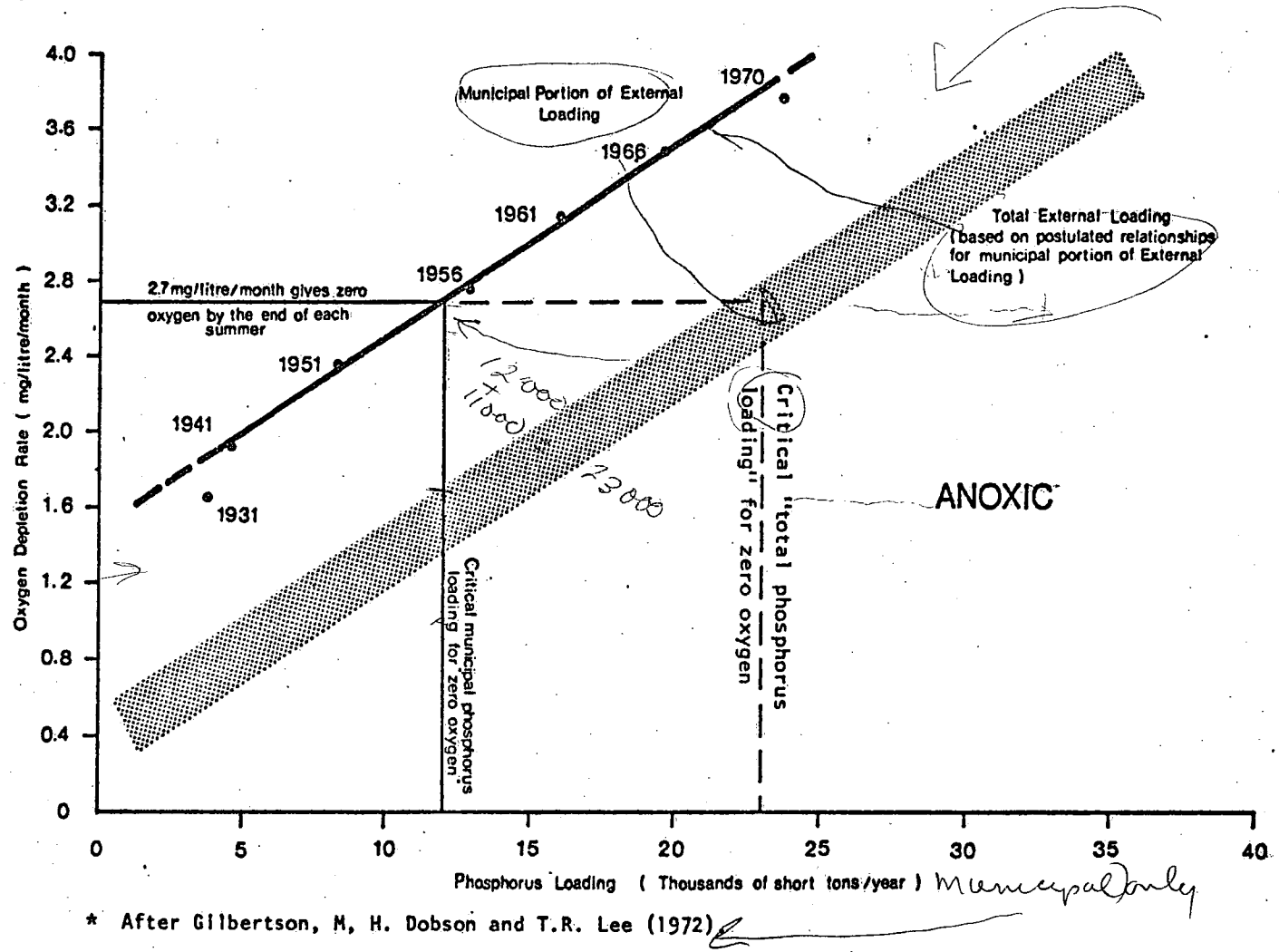
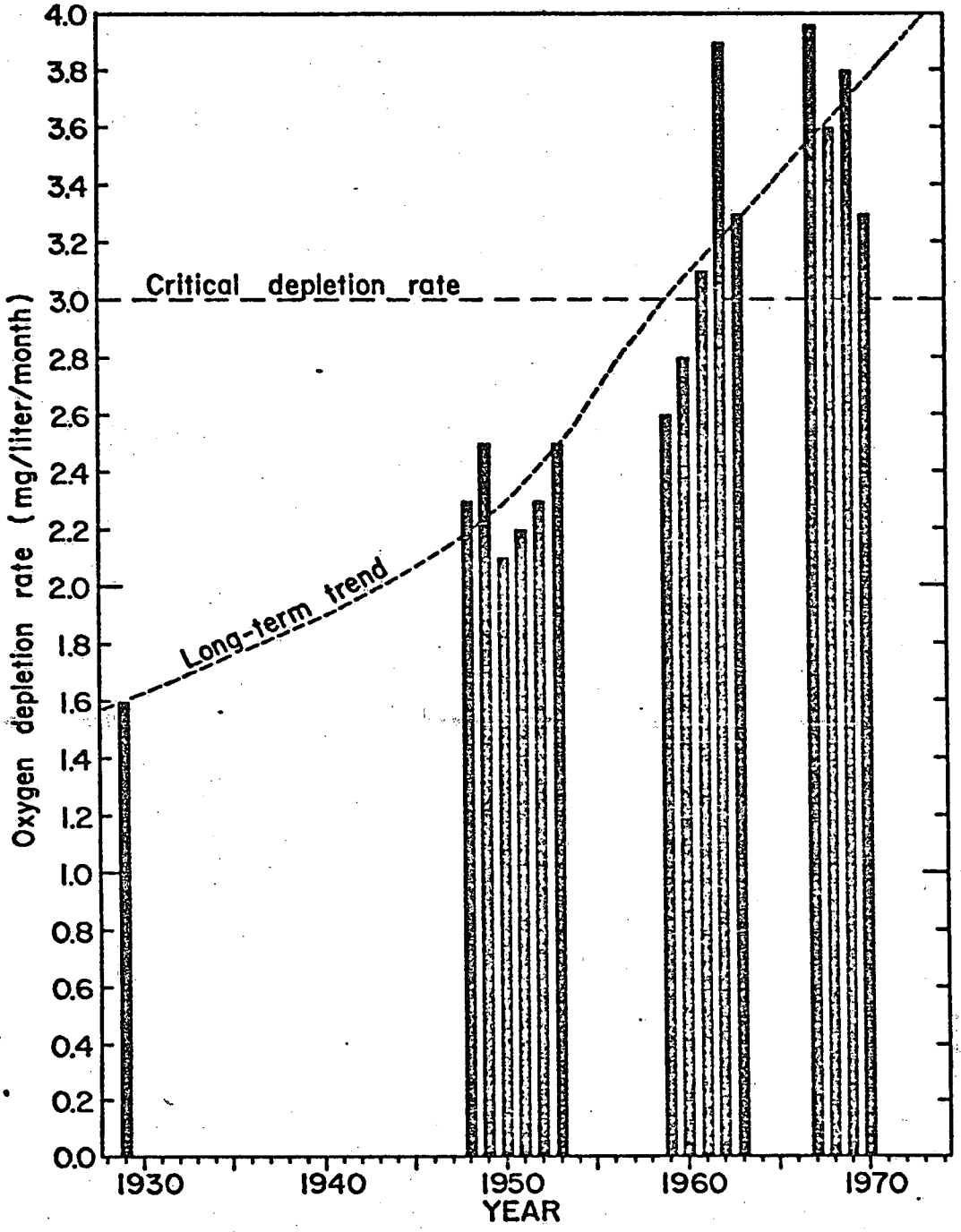
RELATIONSHIPS BETWEEN PHOSPHORUS LOADING TO LAKE ERIE AND THE TREND OF THE RATE OF OXYGEN DEPLETION IN THE CENTRAL BASIN HYPOLIMNION



* After Gilbertson, M, H. Dobson and T.R. Lee (1972)

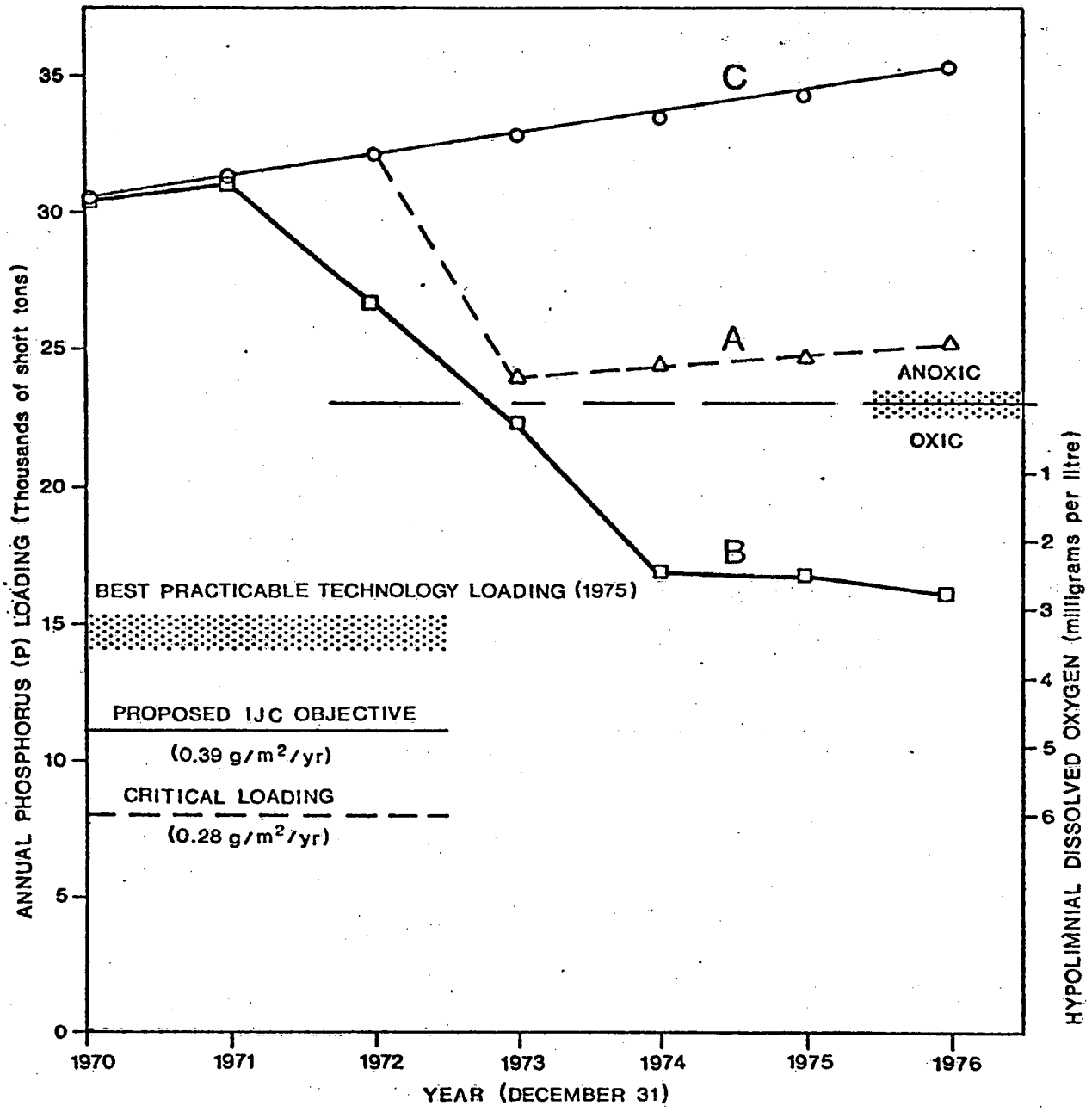
FIGURE 1



Mean depletion rates for dissolved oxygen during summer in the bottom-water of central Lake Erie. Note that the critical rate of 3.0 mg/liter/month, reached in 1961, produces zero oxygen levels before the end of summer stratification. (Dobson & Gilbertson, 1971)

FIGURE 2

ESTIMATED TOTAL PHOSPHORUS LOADINGS TO LAKE ERIE
1970 - 1976



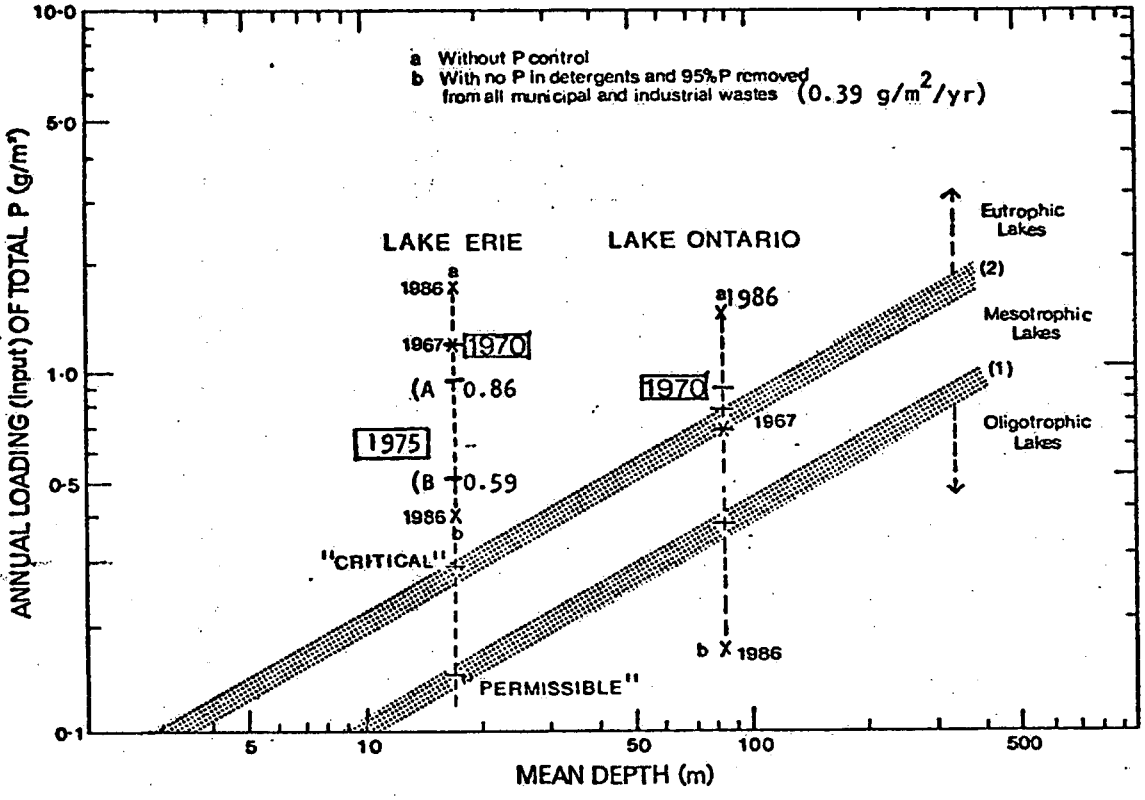
NOTES: A. Program involving detergent reformulation alone to 5% P_2O_5 (2.2% P).

B. Present Canadian program and planned U.S. program. Both programs include phosphorus removal facilities at municipal plants and some industrial plants. In Canada the program includes restrictions on the P content of detergents, and in the U.S. some States also have programs to restrict the

C. Program involving no reduction in phosphorus inputs.

FIGURE 3

STATE OF EUTROPHICATION OF THE LOWER GREAT LAKES
(Abridged from the IJC Advisory Boards Report, Vol. 2, p. 262, 1969)
[Originally from Vollenweider, R.A., 1968]



NOTES

1. Residual phosphorus loading after implementation of the following programs.

   A. Program involving detergent reformulation alone to 5% P_2O_5 (2.2% P) in 1972. Condition of Lake Erie should be comparable to what it was in the mid 1950's (based on Figure 1).

   B. Canadian program and proposed United States program. Condition of Lake Erie should be comparable to what it was in the mid 1940's (based on Figure 1).

2. "Critical" and "Permissible" loadings are as suggested in the IJC Report (1970, p 52) and are 0.28 and 0.13 g/m²/yr. respectively for Lake Erie.

FIGURE 4

TABLE 2

ESTIMATED PHOSPHORUS LOADINGS[1] TO LAKE ERIE

WITH DETERGENT REFORMULATION TO 5% P_2O_5 (2.2% P)

AS OF DECEMBER 31, 1972 AND NO PHOSPHORUS REMOVAL FACILITIES

(Short tons per year)

	1970	1971	1972	1973	1974	1975	1976
MUNICIPAL							
United States	19,035	19,548	20,076	12,350	12,641	12,768	13,019
Canada [2,3]	1,345	1,400	1,420	1,116	1,147	1,147	1,165
Sub-Total	20,380	20,948	21,496	13,466	13,788	13,915	14,184
NON MUNICIPAL	10,131	10,247	10,370	10,491	10,623	10,764	10,901
TOTAL EXTERNAL LOAD	30,511	31,195	31,866	23,957	24,411	24,679	25,085

NOTES:

1. See Appendix B for computational procedure.
2. In August, 1970, Federal regulations restricted the content of phosphorus in detergents to 20% P_2O_5 (8.7% P) and this factor is accounted for in the 1970 loading estimate.
3. Approximate estimate. The figures for population used in the calculations were not for the sewered population but for the population living in urban areas with a population greater than 2,500.

TABLE 3

ESTIMATED PHOSPHORUS LOADINGS TO LAKE ERIE
(short tons per year)

	1970	1971	1972	1973	1974	1975	1976
MUNICIPAL							
United States	19,035	19,469	14,894	10,845	6,052	5,770	4,915
Canada	1,345	1,400	1,420	1,060	310	315	325
Mun. Sub-Total	20,379	20,869	16,314	11,905	6,362	6,085	5,240
NON MUNICIPAL							
1. Industrial							
United States	1,207	1,248	1,290	1,334	1,380	1,428	1,478
Canada	95	100	105	110	115	120	125
Ind. Sub-Total	1,302	1,348	1,395	1,444	1,495	1,548	1,603
2. Land Drainage							
United States	4,927	4,966	5,005	5,046	5,086	5,127	5,168
Canada	1,615	1,630	1,650	1,665	1,690	1,720	1,745
L.D. Sub-Total	6,542	6,596	6,655	6,711	6,776	6,847	6,913
3. Lake Huron	2,287	2,303	2,320	2,336	2,352	2,369	2,385
Non Mun. Sub-Total	10,131	10,247	10,370	10,491	10,623	10,764	10,901
TOTAL EXTERNAL LOAD	30,511	31,116	26,684	22,397	16,985	16,849	16,141

NOTES:

1. U.S. - Proposed municipal program
   The program accounts for local restrictions on the content of phosphorus in detergents in the U.S. and the installation of phosphorus removal facilities at municipal treatment plants.

2. The Canadian program reflects a further reduction in the phosphorus content of detergents from 20% P_2O_5 as of December 31, 1972 and the installation of phosphorus removal facilities at municipal treatment plants by December 31, 1973.

TABLE 4

ESTIMATED PHOSPHORUS LOADINGS TO LAKE ERIE
(short tons per year)

	1970	1971	1972	1973	1974	1975	1976
UNITED STATES							
Municipal	19,035	19,469	14,894	10,845	6,052	5,770	4,915
Industrial	1,207	1,248	1,290	1,334	1,380	1,428	1,478
Land Drainage	4,927	4,966	5,005	5,046	5,086	5,127	5,168
Total	25,169	25,683	21,189	17,225	12,518	12,325	11,561
CANADA							
Municipal	1,345	1,400	1,420	1,060	310	315	325
Industrial	95	100	105	110	115	120	125
Land Drainage	1,615	1,630	1,650	1,665	1,690	1,720	1,745
Total	3,055	3,130	3,175	2,835	2,115	2,155	2,195
LAKE HURON	2,287	2,303	2,320	2,336	2,352	2,369	2,385
TOTAL EXTERNAL LOAD	30,511	31,116	26,684	22,397	16,985	16,849	16,141

TABLE 5

ESTIMATED PHOSPHORUS LOADINGS TO LAKE ERIE

IF NO REDUCTIONS IN PHOSPHORUS INPUT

("BASELINE LOADING")

	1970	1971	1972	1973	1974	1975	1976
MUNICIPAL							
United States	19,035	19,548	20,076	20,618	21,175	21,747	22,182
Canada	1,480	1,525	1,565	1,610	1,665	1,690	1,740
Municipal Tot.	20,515	21,073	21,641	22,228	22,840	23,437	23,922
NON MUNICIPAL	10,131	10,247	10,370	10,491	10,623	10,764	10,901
TOTAL EXTERNAL LOAD	30,646	31,320	32,011	32,719	33,463	34,201	34,823

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APPENDIX A

METHODOLOGY FOR COMPUTATION OF PHOSPHORUS LOADINGS

Information on the phosphorus loadings from sources in the United States was provided by the United States Environmental Protection Agency and from sources in Canada by the Ontario Water Resources Commission (presently Ministry of the Environment). A joint "Ad Hoc Working Group" consisting of personnel from United States Federal and State agencies, the Canadian government and the Ontario Water Resources Commission developed an "agreed methodology" for the computation of the phosphorus loadings.

UNITED STATES

Municipal Loadings

Municipal loadings were calculated on the basis of flows at sewage treatment plants and measured effluent phosphorus concentrations.

Where effluent information was not available, an influent concentration of 10 mg/l was assumed. This concentration was reduced according to the type of sewage treatment facility in operation at the locality. For primary plants a reduction of 15% was used; for secondary plants 27.5% was used.

To account for the contribution of phosphorus from uncontrolled municipal sources such as combined sewer overflows an additional 5% of the above municipal loading was added. In order to determine the reduction due to restrictions on the phosphorus content of detergents, it was assumed that 70% of the phosphorus content was from detergent sources.

In several states an additional percentage was added to the municipal load computed above in order to account for the existence of plants not covered in the preliminary analysis.

When phosphorus removal facilities were to be incorporated in the analysis, an effluent concentration of 1 mg/l was assumed for secondary plants and 1.75 mg/l for primary plants.

The above loadings were calculated for 1970 and projected at a rate of increase of 3.3% per year. This rate is based on a rate of growth of population of 1.3% per year and a rate of growth of detergent phosphorus use of 2% per capita per year to 1975 and at 1% per year thereafter.

Industrial Loadings

The industrial loading was based on the IJC Advisory Boards Report (1969, b) and was calculated to be 1,207 tons in 1970. This was increased at the rate of 4% per year plus an additional 182 tons from a known discharge.

Land Drainage Loading

The land drainage loading projection was based on information in the IJC Boards Report (1969, b) and was calculated to be 4,927 tons in 1970 and was projected at the rate of .8% per year.

CANADA

Municipal Loadings

(a) Direct Discharges - For direct discharges the loading was calculated on the basis of measured flows at sewage treatment plants and measured effluent phosphorus concentrations. Projections were made on the basis of:

(i) Projected population growth on a regional basis (about 1.6% per year),

(ii) Increased per capita detergent use at a rate of 2% per capita per year to 1975 and at 1% per year thereafter.

(b) Tributary Loadings - Tributary loadings, prior to the initiation of phosphorus removal at treatment plants, were calculated on the basis of an average per capita phosphorus loading figure (derived for the Lower Great Lakes from the direct discharge calculations), and the assessed population (or sewered population where known) of each tributary municipality.

In order to estimate the effect of the implementation of phosphorus removal technology to these loadings, a per capita flow of 100 Imperial gallons per day was assumed. Using this flow rate, the appropriate population figures and the appropriate treatment plant effluent concentration, a loading figure was calculated.

Projections were made on the same basis as for direct discharges.

(c) Industrial Loadings - The phosphorus loadings from industrial sources were calculated from measured effluent flows and phosphorus concentrations for the year 1970 the total was found to be 97 tons. This was projected at the rate of 4% per year. These figures are less than those projected in the IJC Advisory Boards Report (1969, b), primarily, as a result of significant load reductions by two main industries in the basin.

(d) Land Drainage Loading - For the Land Drainage loading a base figure of 1,613 tons was used. This figure is based on more recent measurements than those reported in the IJC Advisory Boards Report (1969, b). This base Land Drainage loading was computed by subtracting the 1970 municipal and industrial loads on each tributary from the measured 1970 tributary discharge load. This figure was then projected at a rate of 0.8% per year.

LAKE HURON CONTRIBUTION

The Lake Huron contribution is based on the IJC Advisory Boards Report (1969, b) and was calculated to be 2,287 tons in 1970. This loading was projected at a rate of 0.8% per year.

APPENDIX B

COMPUTATIONAL PROCEDURE FOR PHOSPHORUS LOADINGS AFTER DETERGENT REFORMULATION

In Canada and the United States a per capita detergent phosphorus contribution was calculated based on known data concerning phosphorus in detergents. This per capita figure was then adjusted to comply with the proposed 5% P_2O_5 (2.2% P) level in detergents and a per capita reduction calculated. This reduction was then combined with the appropriate population figures to calculate a detergent phosphorus load reduction which was then subtracted from the "baseline loadings" presented in Table 5. This residual municipal load after detergent reformulation to 5% P_2O_5 (2.2% P) was then added to the non municipal load to calculate the total external phosphorus loading.

Specifically for each country the loading was calculated as follows:

(1) United States

It was assumed that in 1970 detergents contained 12% phosphorus (as P) by weight and that this was equivalent to an annual per capita use of 2.45 lbs. This per capita usage for any given region was then reduced to a level equivalent to a detergent phosphorus content of 2.2% P (5% P_2O_5) and a per capita phosphorus reduction calculated. This per capita use was projected at a rate of increase of 2% per year to 1975 and at 1% per year thereafter. This increase was combined with a population growth rate of 1.3% per year. The contributing population in 1970 was assumed to be 7,508,000.

(2) Canada

It was assumed that in 1970 the per capita use of detergents was approximately 13 lbs. This was reduced to its equivalent phosphorus content assuming that this was 20% P_2O_5 (8.7 % P), as per Federal regulations. This

per capita usage was then reduced to a level equivalent to a detergent phosphorus content of 5% P_2O_5 (2.2% P) and a per capita phosphorus reduction calculated.

The per capita usage of detergents was projected at a rate of increase of 2% per year to 1975 and at 1% per year thereafter. This increase was combined with a population growth rate of 1.6% per year. In 1970, the contributing population was estimated at 1,045,900.

APPENDIX C

"BEST PRACTICABLE TECHNOLOGY LOADING"

The phosphorus loading to Lake Erie which might be considered as attainable utilizing the "best practicable technology" can be calculated from the data provided in Tables 2 and 5.

1. Assumptions

A number of assumptions are involved and these are the following:

(a) Municipal Loading

(i) The concentration of phosphorus in the effluent from all municipal plants with phosphorus removal facilities is 1 ppm.

(ii) The concentration of phosphorus in the uncontrolled municipal sources such as combined sewer overflows is 10 ppm with 70% being from detergent phosphorus in the United States and 50% in Canada.

(b) Industrial Loading

It was assumed that in Canada the industrial load was reduced to a new minimum.

In the United States insufficient data were available so that the figures in Table 2 were used. Conceivably significant reductions might be obtained, and an optimistic estimate was a reduction of 800 tons in 1975.

(c) Land Drainage and Lake Huron Contributions

The land drainage and Lake Huron contributions were assumed to be as given in Table 2.

2. Loadings

(a) In Table 6 these data are presented and the estimated 1975 "best practicable technology" loading calculated was 15,335 tons.

(b) As indicated, if the phosphorus content of detergents was reduced to 5% P_2O_5 (or 2.2% P) the uncontrolled (combined sewer overflows, etc.) loading might be further reduced by some 725 tons to a residual loading of approximately 695 tons. This would then give a total loading of 14,610 tons.

(c) If additional reductions could be obtained in the U.S. industrial load, as suggested previously, then the preceding load might be reduced to 13,810 tons. This, then, might be considered as an optimistic lower bound for the phosphorus loading produced using "best practicable technology".

(d) If, as recommended in the IJC Report (1970), the industrial loading were reduced by 80% in the United States, then a calculated residual load of 13,465 tons would result.

TABLE 6

PHOSPHORUS LOADING TO LAKE ERIE (1975)

(ASSUMING UTILIZATION OF "BEST PRACTICABLE TECHNOLOGY")

	Phosphorus (tons)			
	1.	2.	3.	4.
UNITED STATES				
Municipal	2,845			
Mun. - Uncontrolled (combined sewer overflows, etc.)	1,420	(695)		
Industrial	1,428		(628)	(283)
Land Drainage	5,127			
CANADA				
*Municipal	230			
*Mun. - Uncontrolled (combined sewer overflows, etc.)	75			
Industrial	120			
Land Drainage	1,720			
LAKE HURON	2,370			
TOTALS - 1. Present plans	15,335			
2. Reduction in P content of detergents in U.S. to 5% P_2O_5 (2.2% P)		14,610		
3. Additional reduction in U.S. industrial load. (including reduction in 2)			13,810	
4. Reduction in U.S. industrial loading by 80% from 1975 values (IJC recommendation for 1975)				13,465

* Approximate