EPA-660/3-74-029
DECEMBER 1974

Ecological Research Series

Future Dredging Quantities in the Great Lakes

National Environmental Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Corvallis, Oregon 97330

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FUTURE DREDGING QUANTITIES

IN THE GREAT LAKES

By

C. Nicholas Raphael
Eugene Jaworski
Carl F. Ojala
Daniel S. Turner

Grant Number R-801062
Program Element 1BA026
ROAP/Task No. 25ADX/03

Project Officer

Michael D. Mullin
Grosse Ile Laboratory
National Environmental Research Center
Grosse Ile, Michigan 48138

NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97330

ABSTRACT

Based on historical records, an overview and projection of U.S. and Canadian dredging quantities in the Great Lakes are presented. Using current pollution criteria, future quantities of polluted maintenance dredging are estimated for each lake. Recent environmental policies have influenced dredging and particularly disposal practices. These policies, as well as sedimentation, lake levels, and economics are discussed in relation to dredging.

During the next decade, maintenance and private dredging volumes will not change significantly, whereas new work will decrease. As in the past, most maintenance dredging will occur in U.S. projects, particularly in Lake Erie.

A factor which will determine future U.S. maintenance dredging is the availability of confined disposal sites. If the 62 sites are completed for commercial harbors as planned, 300,000 of the 6.45 million cubic yards of annual projected polluted spoil will not have disposal facilities. Where pollution elimination systems are in use, shoaling in some industrial harbors may be decreasing. Although long-term lake levels are not predictable, an inverse relationship between maintenance dredging and lake levels is evident.

This report was submitted in fulfillment of Project Number R-801062 and Grant Number R-801062 by Eastern Michigan University under the sponsorship of the Environmental Protection Agency. Work was completed as of July 1974.

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ACKNOWLEDGMENTS

Data for this study were made available by numerous agencies to which the investigators are grateful. Dredging statistics were obtained from the Buffalo, Detroit, Chicago, and St. Paul Districts of the Corps of Engineers, Operations and Maintenance Branch, as well as the Division office in Chicago. In Canada, the D.P.W. and M.O.T. regional offices furnished us with comparable data. The E.P.A. and M.O.E. made their respective pollution information available. Other agencies deserving our thanks include National Biocentrics Inc., St. Paul, The Great Lakes Commission, Ann Arbor, and the St. Lawrence Seaway Authority, Ottawa. The investigators are particularly appreciative for the assistance provided by many individuals too numerous to mention specifically. But to David Kraus, E.P.A., Chicago, and Peter Logan, D.P.W., Ottawa, we extend special thanks for their many hours of fruitful input.

SECTION I

CONCLUSIONS

Based on the findings of this study, the following conclusions have been reached:

1. Future private, maintenance, and new work dredging quantities in the Great Lakes are projected to average 15.56 million cubic yards (CY) annually. Of this total, 78 percent will be removed from American harbors and connecting channels.

2. Of the future annual volume to be removed from United States' public dredging projects, 64 percent involves maintenance dredging, 19 percent consists of new work, and 17 percent involves private dredging. In Canada, these percentages are 31, 54, and 15, respectively.

3. Based on data of the U.S. Environmental Protection Agency (E.P.A.), 80 of the 117 American harbors and connecting channels sampled are polluted or partially polluted. According to the Ministry of Environment of Ontario (M.O.E.), 21 of the 31 Canadian navigation projects sampled contained polluted bottom sediments. Total polluted volumes for both countries are 6.45 and 1.01 million CY, respectively.

4. In the U.S. during the next decade, private dredging of non-federal projects is anticipated to average 2.01 million CY. Private spoil, routinely considered polluted by the E.P.A., is usually confined on the permitee's own land. In the future, private interests may dispose some of their spoil in federal disposal sites.

5. Maintenance dredging of public projects in the U.S. is projected to amount to 7.78 million CY annually. Approximately 83 percent of this total, i.e., 6.45 million CY, will involve polluted spoil which must be confined. Nearly 62 percent of this polluted volume will be derived from Lake Erie, including the Detroit River.

6. During periods of relatively low lake levels, as in the middle 1960's, annual maintenance dredging volumes are above average, particularly in Lakes Huron and Michigan.

7. New work projects scheduled for public harbors and waterways in the U.S. are expected to yield 2.25 million CY of dredging annually. Most of these projects involve new recreational harbors, not commercial harbors. Compared to the past decade, future new work will decline sharply. Because most new work dredgings consist of glacial till and/or bedrock, these materials usually need not be disposed in confined sites.

8. As of July 1974, there are 62 public harbors and waterways in the 10-year confined disposal program of the U.S. Army Corps of Engineers (C.E.). Eighteen other public harbors with polluted spoil were either dropped from the program or were not among the 73 projects initially selected. However, the total annual volume of polluted spoil from these 18 harbors averages only approximately 110,000 CY. A few heavily polluted projects, such as Toledo Harbor and Rouge River, have had confined disposal sites in operation prior to Public Law 91-611.

9. For 34 of the 62 navigation projects in the confined disposal program, selection of disposal sites has been completed and design of the confined facilities is progressing. Most of these projects involve large commercial harbors (e.g., Buffalo, Lorain, Milwaukee).

10. Some delays in the confined disposal program of the C.E. have been caused by the reluctance of local interests to provide land for disposal sites and by site approval difficulties. For 20 of the 62 navigation projects, there are neither existing confined disposal facilities, nor

has site selection been accomplished for the 10-year program. However, the polluted volume of these projects totals only about 300,000 CY annually, which is 5 percent of the total polluted volume (6.45 million CY). Recent high lake levels have reduced the problem of groundings at those harbors where maintenance dredging has been temporarily postponed while confined facilities are being designed.

11. Even though there is a trend toward larger lake carriers and extension of the navigation season, future maintenance dredging volumes are projected to increase only slightly, while new work volumes will decline.

12. Since the enactment of PL 91-611, disposal of polluted spoil in open-water sites has generally been discontinued in Lakes Superior, Michigan, Huron, and St. Clair. In the Buffalo District of the C.E., small quantities of polluted spoil are being open-lake disposed from harbors requiring maintenance dredging for which confined disposal sites have not yet been constructed.

13. At present, there is no specific legislation in the U.S. which prohibits the open-lake disposal of polluted spoil during times of economic stress. The governors of the states of Ohio, Pennsylvania, and New York have indicated to the C.E. that they will not object to open-lake dumping of polluted dredgings when suspension of maintenance dredging operations would jeopardize commercial navigation.

14. Dredging policies of Ontario, Canada, do not restrict the use of private land for confined disposal sites. In many instances, as in Toronto Harbor, the confined polluted spoil is utilized as a resource.

15. Where pollution elimination systems (under PL 92-500) have reduced artificial sedimentation, as in Calumet and Chicago Harbors, future maintenance and private dredging volumes may be lower than that of the past decade.

16. Although a very small increase in future average annual maintenance dredging is projected over the past decade, the proportion of polluted

spoil is expected to decrease slightly.

17. New guidelines by the E.P.A., governing the disposal of dredged materials in inland waters, will probably broaden the criteria for determining the eligibility of spoil for open-lake disposal. Although these guidelines may change the pollution status of several small recreational harbors currently classified as partially polluted, the future volume of polluted spoil which must be confined will not change significantly.

18. In partially polluted harbors, generally the inner harbor is polluted, whereas the outer harbor near the jetties and/or breakwater is unpolluted.

19. In rivermouth harbors, annual maintenance dredging volumes cannot be predicted on the basis of the sediment load being transported by the stream. For most harbors in the Great Lakes, the primary sources of the dredged sediments are industrial-municipal effluents, littoral drift, and alluvial deposition.

20. Wetlands, specifically coastal marshes, appear to be threatened less by C.E. spoil disposal than by high lake levels, filling by utilities and industries as well as by residential and recreational encroachment.

SECTION II

RECOMMENDATIONS

Based on data obtained and analyzed in this report, the following recommendations are presented:

1. Because of the relatively high cost of confined disposal, open-lake disposal of unpolluted dredged spoil should not be discontinued.

2. As in the Detroit District, other C.E. districts should distinguish, in their dredging records, between polluted and unpolluted maintenance dredging quantities.

3. Private dredging records, i.e., Section 10 and NWPA permit files, could be improved through standardization and higher priority.

4. The Department of Public Works of Canada (D.P.W.) should clearly distinguish, in their records, between maintenance and capital dredging.

5. As a first step in sediment abatement, the primary sources of sediment accumulation in each dredging project should be identified.

6. To reduce the future volume of polluted maintenance dredging, abatement of industrial and sewage inputs should be expanded.

7. Because pollution elimination systems have begun to reduce man-made sedimentation in some harbors, i.e., Calumet Harbor and River, the 10-year confined disposal program of the C.E. warrants continued support.

8. To improve the sampling of maintenance dredging projects, the D.P.W. and the C.E. should provide harbor shoaling maps to the M.O.E. and to

the E.P.A. In return, on the basis of their analyses, the M.O.E. and the E.P.A. should subdivide dredging projects into polluted and unpolluted sections. The M.O.E. should sample all public harbors which require maintenance dredging.

9. Practical uses of dredged spoil and of filled disposal sites should be emphasized in the U.S. as in Canada.

10. To facilitate the confinement of polluted spoil in the United States, disposal on private land should be further encouraged.

11. The filling of coastal wetlands with industrial wastes, and to some extent by dredged spoil, appears to be significant. These Great Lakes wetlands should be identified, mapped, and zoned to better facilitate future confined disposal site selection.

12. Because the cost of dredging operations in the Great Lakes' projects has increased considerably over the past decade, the C.E. should continue to perform public maintenance dredging so that competitive bidding with private dredgers may continue.

SECTION III

DREDGING QUANTITIES IN THE GREAT LAKES

INTRODUCTION

Objectives of this section are to inventory the historical and current dredging volumes and to project future dredging quantities to be removed from private and public waterways of the Great Lakes in the United States and Canada. Dredging volume data were obtained from the district offices of the C.E., to include Buffalo, Chicago, Detroit and St. Paul, from the D.P.W. in Ottawa, Toronto, Sault Ste. Marie, Thunder Bay and London, and from district offices of the Ministry of Transport (M.O.T.) at Prescott and Parry Sound. In the Buffalo District, some data were derived through a review of private dredgers' field records. Finally, the E.P.A., Region V, Chicago, furnished some information regarding private dredging quantities.

In the Great Lakes, dredging operations are subdivided into three categories. New work, or capital dredging as it is referred to in Canada, involves deepening and/or widening of a pre-existing project, or the initiation of a new harbor or waterway. Maintenance dredging involves the removal of unconsolidated sediments which have been deposited in a navigation project since the last dredging operation. The D.P.W. of Canada does not always distinguish between capital dredging and maintenance dredging which, in some cases, may account for high maintenance dredging volumes in Canadian projects. Both new work and maintenance dredging operations in federal harbors and waterways are regulated by the C.E. and the D.P.W. In Canada, all dredging in the Great Lakes is contracted out by the D.P.W. to public tenders, whereas in the United States the C.E. does perform some of the maintenance and new work dredging.

A third category of dredging is private, or permit dredging, which is done by private contractors in private harbors and in private approach channels and docks adjacent to federally-maintained channels of public harbors. Private dredging is regulated through the issuance of Section 10 and NWPA permits by the district offices of the C.E. and the M.O.T., respectively. In most districts, private dredging records are incomplete or were retained only for a few years before being destroyed. It was estimated that Section 10 files in the Chicago District of the C.E. are only 40 percent complete. In the past, high priority was not assigned to private dredging permits, especially with regard to remote areas of the Great Lakes. Thus, it was not possible to accurately determine the quality of spoil removed by private interests in the past. Therefore, all private dredging volumes in this section represent minimum quantities.

To present a uniform appraisal of dredging volumes for all the Great Lakes, this study presents all dredging quantities, however originally recorded, as place measure volumes. Because private and new work dredging volumes were generally recorded in place measure, conversion factors apply primarily to maintenance dredging volumes. Most Canadian data were recorded in place measure and few conversions were necessary. From the Corps of Engineers' Districts, conversion factors were obtained as indicated in Table 1. Based on their own specific operational function and dredging plant type, each Corps of Engineers' District uses a conversion factor which best represents the equivalent place measure volume. Bin measures are applicable to hydraulic and hopper dredge plants, whereas scow measures refer to dipper and clam shell dredges. Because of conversion to place measure, spoil volumes for individual harbors, projects

Table 1. CONVERSION FACTORS TO PLACE MEASURE (46)

Lake	Bin measure	Scow measure
Ontario	1 p.m. = 1.20 b.m.	1 p.m. = 1.20 s.m.
Erie	1.p.m. = 1.20 b.m.	1 p.m. = 1.20 s.m.
Huron	1 p.m. = 1.20 b.m.	1 p.m. = 1.20 s.m.
Michigan	1 p.m. = 1.50 b.m.	1 p.m. = 1.20 s.m.
Superior	1 p.m. = 1.05 b.m.	1 p.m. = 1.05 s.m.

or districts may not agree with the raw data available in the records of the C.E.

Estimates of future new work dredging quantities represent maximum volumes as all scheduled new work projects were tabulated. Projections of private and maintenance dredging quantities were based on dredging histories during the past decade. Although the effect of new work projects on the future maintenance dredging requirements of a given harbor was incorporated into projections of maintenance dredging volumes, other relevant factors such as federal funding, scheduling of dredging plants, lake levels, and availability of disposal sites were not. Because of the uniqueness of each dredging project and the affects of unknown variables such as future lake levels and federal funding, a single projection equation could not be applied to all harbors and waterways of the Great Lakes. Projections of future maintenance dredging by harbor has also been estimated by the C.E. for federal harbors in the United States (1). Both projections were compared and significant differences between the two are discussed below in the subsections on the individual lakes.

DREDGING QUANTITIES IN LAKE ONTARIO

Lake Ontario is unique in its dredging requirements in that more material is removed from Canadian projects than from American projects. From 1961 to 1970, of the total amount of spoil dredged from Lake Ontario, 58 percent came from Canadian projects and 42 percent from projects completed by the C.E. The dredging demand for Canadian projects is greater; 7 projects required removal of a total of more than 100,000 cubic yards of spoil from 1961 to 1970. Only 4 American projects were dredged of at least 100,000 cubic yards of material in that period. The highest volumes on the Canadian side are generated primarily by the large commercial projects of Toronto and Hamilton, each with an annual average of more than 100,000 cubic yards of spoil removed. The only U.S. project with a comparable volume of spoil is Rochester. In addition to maintaining these and other smaller commercial harbors, a number of recreational/harbor refuge facilities on Lake Ontario are dredged. Nine projects on the Canadian side and 6 American harbors require dredging, at least periodically (Figure 1).

Average annual commerce at 3 American harbors on Lake Ontario is substantial enough so that the cost of their maintenance is unequivocally justified by the C.E. (2) (Figure 1). However, no American harbor on the lake is dredged to maintain the 27-foot St. Lawrence Seaway channel depth. Three Canadian harbors are dredged to Seaway depth. Other harbors with less commercial traffic, i.e., those with lower benefit/cost ratios, have frequently been dredged in the past. However, reductions in money allocations or port status changes could cause cessation of dredging operations at more marginal harbors such as Wilson, Olcott, or Little Sodus.

In terms of dredging volume, the most important American maintenance dredging projects are at Rochester and Oswego, which require removal of an average of 267,000 and 54,000 cubic yards of spoil every year respectively (Figure 2). The Canadian volume leaders are Toronto, Hamilton,

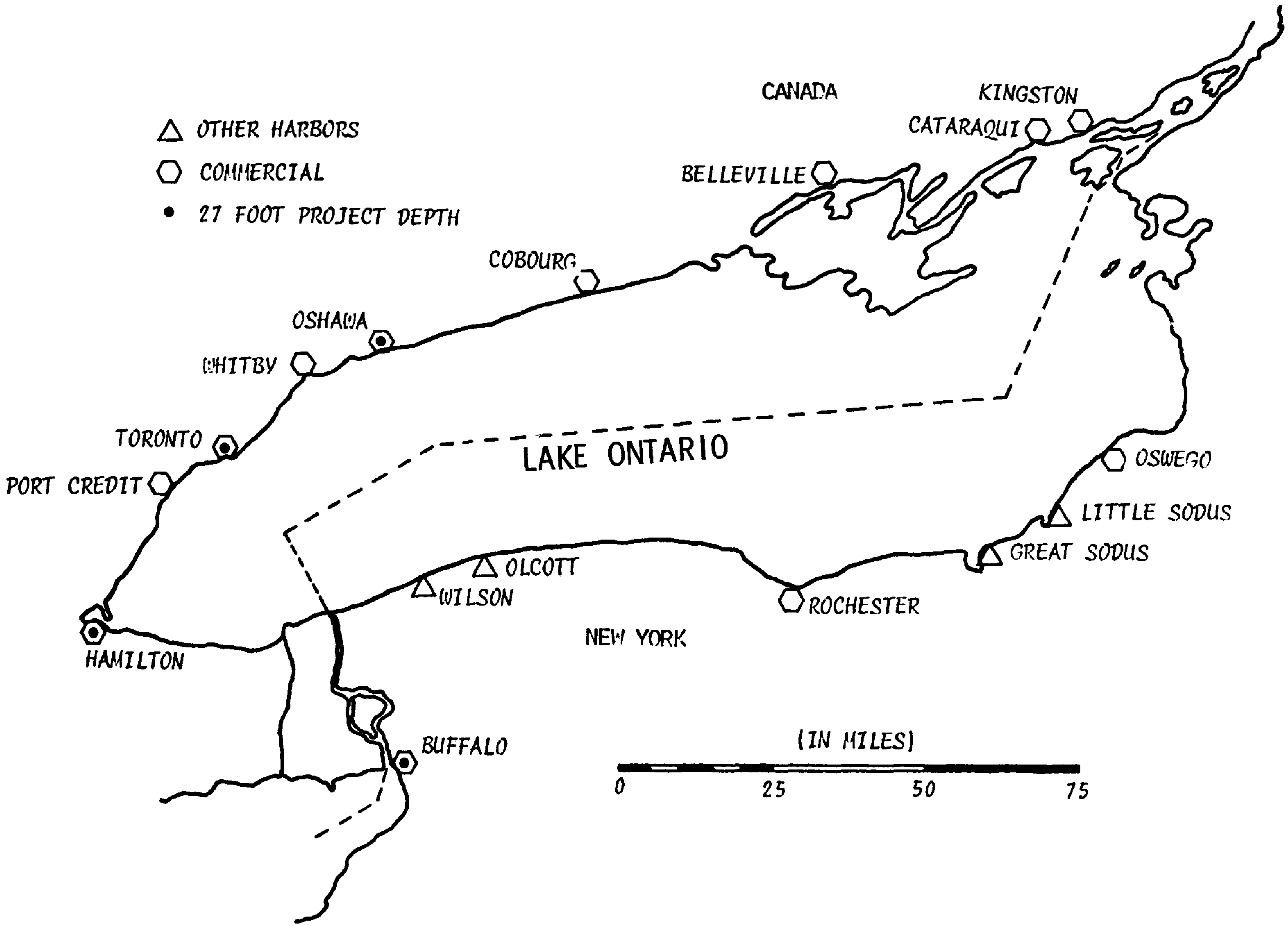


Figure 1. PRINCIPAL DREDGING PROJECTS IN LAKE ONTARIO

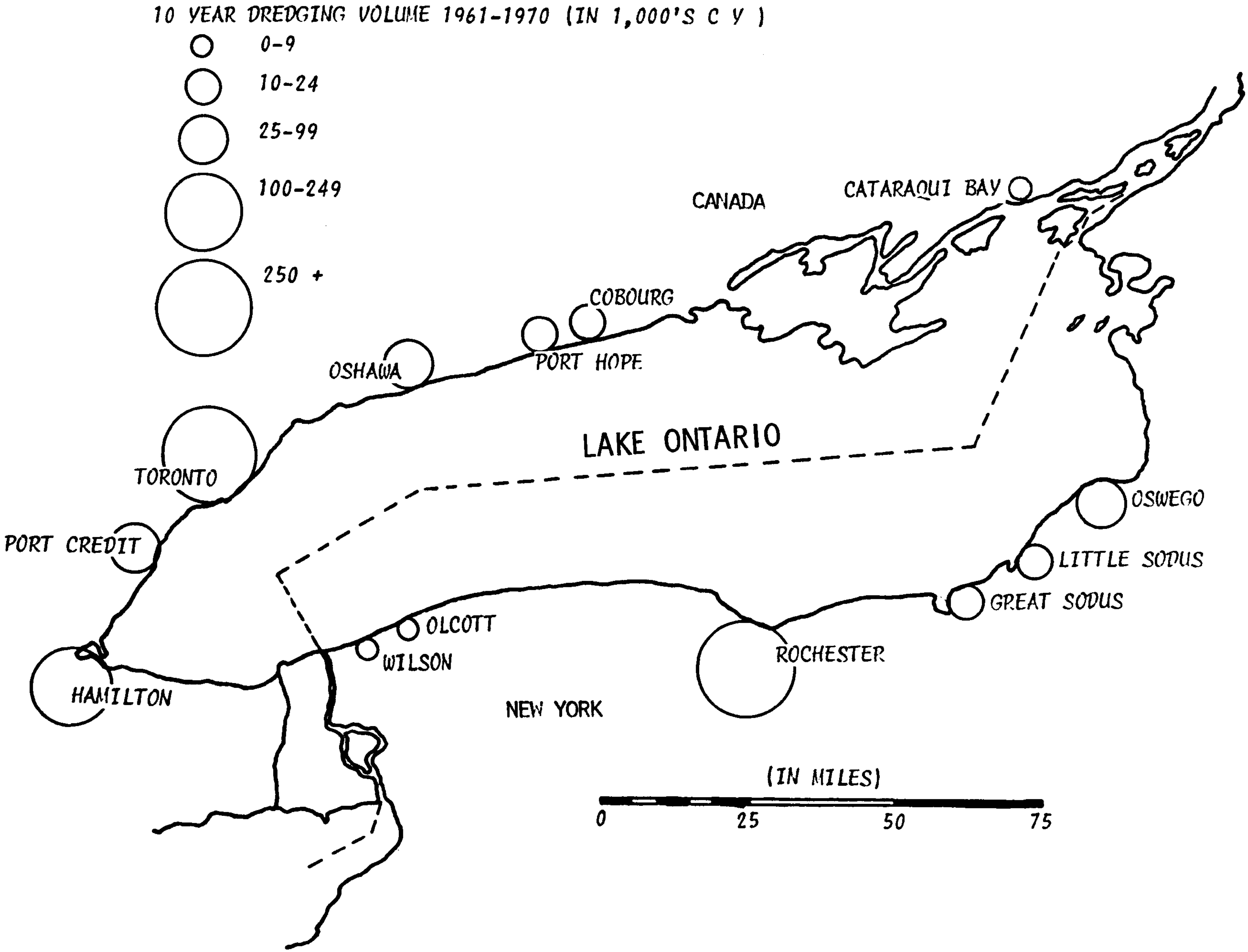


Figure 2. *AVERAGE ANNUAL MAINTENANCE DREDGING VOLUMES IN LAKE ONTARIO, 1961-1970*

Oshawa, and Port Credit, all requiring annual removal of more than 34,000 cubic yards of material. From 1961 to 1970, Rochester was the dredging volume leader, averaging 15,000 cubic yards more per year than Toronto.

United States Dredging History in Lake Ontario

Lake Ontario has been dredged for decades, but complete, meaningful, and comparable volume data for Buffalo District C.E. projects are available only from 1951. Prior to that time, records on actual volumes dredged become sketchy to non-existent for some harbors, even in C.E. *Annual Reports*. In many cases, dollar cost figures were reported in lieu of volume data. Because of differences in types of material being removed, types and cost of dredging operations, accurate conversion of cost figures to volume figures was not possible for many of those earlier years. However, complete and meaningful maintenance and new work dredging data since 1951 were collected and collated (Table 2).

Table 2. HISTORICAL DREDGING IN LAKE ONTARIO BY HARBOR/WATERWAY, 1951-1972 (47)
(cubic yards)

Harbor/waterway	Maintenance	New work	Total
Great Sodus	459,910	0	459,910
Little Sodus	262,723	0	262,723
Ogdensburg	22,151	0	22,151
Oswego	1,113,538	355,561	1,469,099
Rochester	5,582,985	852,500	6,435,485
Wilson	16,139	0	16,139
Olcott	29,490	0	29,490
Totals	7,486,936	1,208,061	8,694,997

Since 1951 approximately 8.7 million cubic yards of spoil has been removed from Lake Ontario by the C.E. (Table 2). About 85 percent of the total was removed in maintenance dredging and 15 percent in new work projects. Of all material removed in maintenance projects since 1951, about nine-tenths came from Rochester and Oswego combined. In fact, almost three-fourths came from Rochester alone. The only new work dredging accomplished during the same period occurred at these two harbors.

Maintenance Dredging--

In the past decade, maintenance dredging has accounted for approximately 65 percent of all dredging on the American side of Lake Ontario. In terms of volume removed over a longer period, i.e., 1951 to 1972, the C.E. dredged an average of approximately 340,000 cubic yards of spoil from Lake Ontario projects annually. Absolute amounts ranged from a low of 182,000 cubic yards in 1971 to a high of 567,000 cubic yards in 1967 (Table 3). Thus, volumes of spoil removed from the American side of Lake Ontario have been fairly constant in recent years (Figure 3). Since 1951, the C.E. has been responsible for removing more than 7 million cubic yards of spoil from the lake in maintenance dredging projects.

New Work Dredging--

In the past decade, new work dredging has accounted for approximately 25 percent of all dredging activity on the American side of Lake Ontario. Over the longer term, i.e., 1951 to 1972, only about 1.2 million cubic yards of spoil were removed in new work dredging projects. However, unlike maintenance dredging, new work volumes display very little regularity from year to year. They range from a low of no new work in most years since 1951 to a high of more than 400,000 cubic yards of spoil removed in new work projects in 1963 (Table 4). No new work has occurred on the American side of Lake Ontario since 1966. For the most

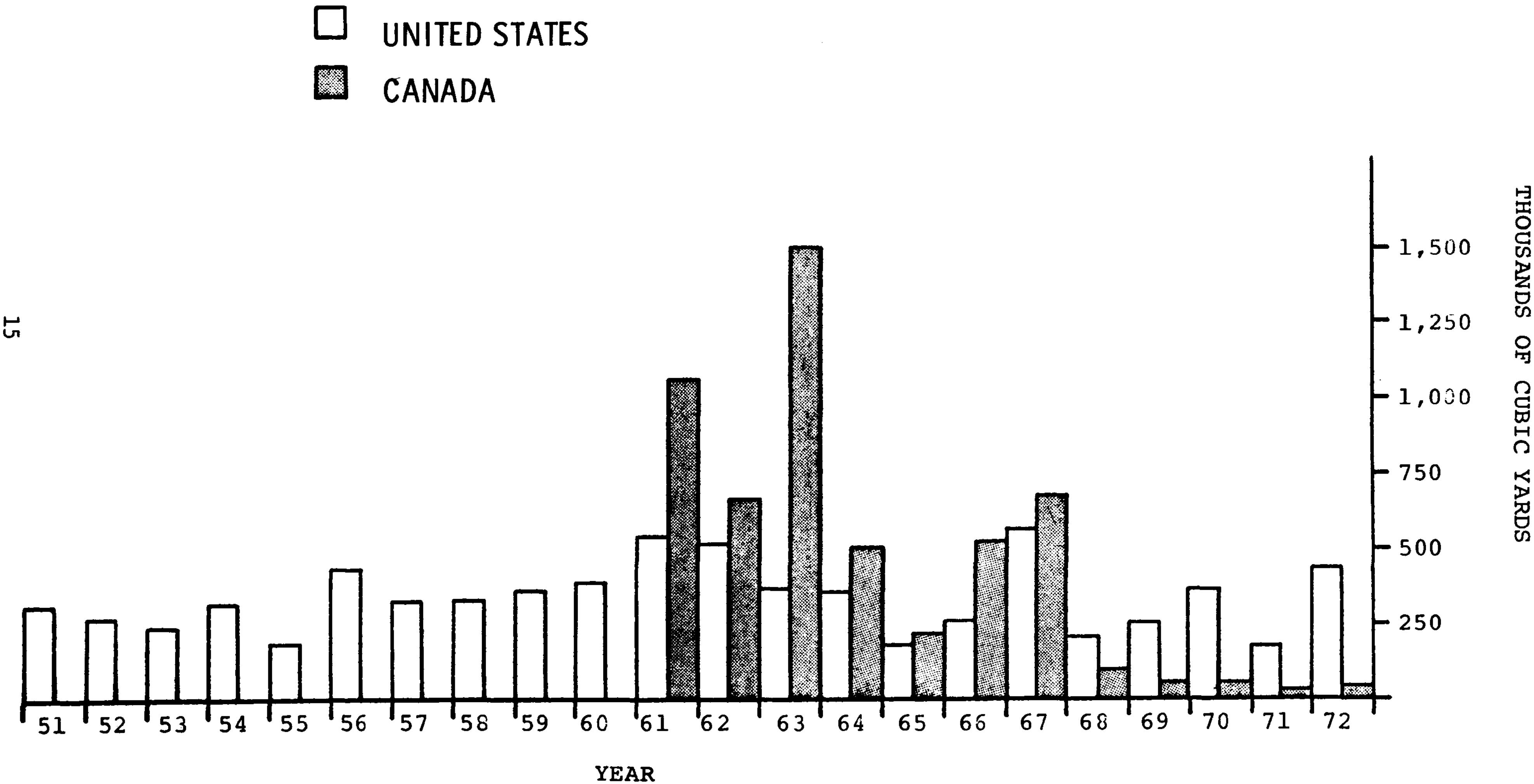


Figure 3. MAINTENANCE DREDGING VOLUMES IN LAKE ONTARIO, 1951-1972

Table 3. ANNUAL MAINTENANCE DREDGING IN LAKE ONTARIO, 1951-1972 (47)
(cubic yards)

Year	Total volume
1972	439,803
1971	182,019
1970	364,488
1969	256,050
1968	214,610
1967	567,766
1966	253,800
1965	188,273
1964	353,912
1963	376,429
1962	515,741
1961	548,480
1960	390,660
1959	366,636
1958	333,309
1957	343,114
1956	444,870
1955	186,885
1954	324,927
1953	245,879
1952	274,522
1951	314,763
Total	7,486,936

Table 4. NEW WORK DREDGING IN LAKE ONTARIO, 1951-1972 (47)
(cubic yards)

Year	Total volume
1972	0
1971	0
1970	0
1969	0
1968	0
1967	0
1966	284,860
1965	28,618
1964	278,583
1963	439,751
1962	134,166
1961	0
1960	0
1959	0
1958	35,416
1957	0
1956	6,667
1955	0
1954	0
1953	0
1952	0
1951	0
Total	1,208,061

part, this was due to the deepening and widening of harbors and waterways to accommodate new commerce generated by the 1959 completion of the St. Lawrence Seaway.

The largest new work project since 1951 occurred at Rochester in 1963, when more than one-half a million cubic yards of spoil were generated.

Permit Dredging--

Dredging by non-federal interests may only be undertaken when authorization of the C.E. is obtained through permits. Data were gathered from the C.E. District Office in Buffalo, from the E.P.A., Chicago, and from the New York State Department of Environmental Conservation in Albany. Permit dredging in Lake Ontario has been traced thoroughly to 1963. It is felt that compilation of permit dredging volume data is as complete as possible, considering certain restrictions such as missing permit files, unreported volumes of spoil removed, and files lacking job completion notices. Therefore, the volumes presented in this report represent minimum figures.

Approximately 10 percent of all dredging on the American side of Lake Ontario is permit dredging. From 1963 to 1972, such projects resulted in the removal of about 480,000 cubic yards of spoil from the lake (Table 5). On the average, about 48,000 cubic yards of material are dredged from Lake Ontario ports by permittees each year. The volumes removed ranged from a low of only 3,000 cubic yards in 1968 to a high of 268,000 cubic yards in 1971. No apparent pattern has been established in the past decade.

Canadian Dredging History in Lake Ontario

Dredging data for Canadian harbors on Lake Ontario have been collected and presented in Table 6. Since 1961, almost 5.5 million cubic yards of spoil has been removed in maintaining Canadian channels on the lake

Table 5. PRIVATE DREDGING IN LAKE ONTARIO, 1963-1972 (47)
(cubic yards)

Year	Total volume
1972	40,093
1971	268,395
1970	62,100
1969	5,750
1968	3,080
1967	13,750
1966	18,875
1965	12,600
1964	47,770
1963	8,494
Total	480,907

Table 6. DREDGING HISTORY IN CANADIAN PROJECTS IN LAKE ONTARIO,
1961-1972 (48, 49)
(cubic yards)

Year	Maintenance	New work	Permit
1972	48,031	0	3,023,000
1971	29,032	0	1,130,500
1970	51,221	0	25
1969	52,251	0	15
1968	100,100	0	2,000
1967	686,453	0	N.A.
1966	523,610	0	N.A.
1965	216,505	0	N.A.
1964	499,938	0	N.A.
1963	1,500,819	1,612,925	N.A.
1962	667,864	248,000	N.A.
1961	1,059,383	4,088	N.A.
Total	5,435,207	1,865,013	4,155,540

N.A. Data not available.

(Figure 3). The volume removed ranged from a low of 29,000 cubic yards in 1971 to a high of 1.5 million cubic yards in 1963. However, volumes have significantly decreased in the 1970's.

New work (capital) dredging in Canadian projects of Lake Ontario was most important during the early 1960's. Adjustments in harbors and waterways were made for accommodation of deeper drafts generated by completion of the St. Lawrence Seaway. Most new work dredging occurred in 1963, when approximately 1.6 million cubic yards were removed. The largest new work projects in that year were dredged at Port Credit and Toronto, where one million cubic yards and 549,000 cubic yards were removed respectively.

Although data on historical private dredging are particularly sketchy for Canadian harbors, statistics for Lake Ontario were complete from 1968 to 1972. During that period, about 4 million cubic yards of material were removed by permittees. Since the sample period is short, no reliable pattern of permit dredging activity for Canadian Lake Ontario is discernible.

In terms of volume, the most significant maintenance dredging projects on the Canadian side of Lake Ontario have historically been at Toronto, Hamilton, Oshawa, Port Credit, and Cobourg (Table 7). Each of these harbors average at least 20,000 cubic yards of maintenance dredging annually. The volume leader, of course, is Toronto, with an average of approximately 250,000 cubic yards per year.

Projections of Future Dredging Volumes on the United States Side

Maintenance--

Estimations of the volume of material to be removed from Lake Ontario in maintenance dredging in the next decade have become possible based on knowledge gained through this research project. Three projections are

Table 7. HISTORICAL DREDGING: CANADIAN PROJECTS IN LAKE ONTARIO, 1961-1970 (48) (cubic yards)

Project	Total maintenance	Total new work
Toronto	2,521,940	549,000
Oshawa	475,391	63,925
Port Credit	347,000	1,048,000
Cobourg	238,146	0
Hamilton	1,524,079[a]	200,000
Port Hope	195,332	0
Cataraqui Bay	56,256	4,088
Total	5,358,144	1,865,013

[a]Includes 155,615 cubic yards for Burlington.

determined:

(1) a figure based on C.E. estimates made in 1968 (3),

(2) a figure based on relatively recent environmental effects on dredging in the Great Lakes, and

(3) a median figure projected in this report.

The latter will be based primarily on the dredging histories of the various projects in Lake Ontario and on developments anticipated in the near future, i.e., a drop in the present high lake levels, completion of confined disposal sites, and easing of present environmental constraints. Changes in shipping needs in the next decade and the potential of year-round navigation are not expected to affect dredging in Lake Ontario in the next 10 years.

In 1968, the C.E. projected dredging volumes in the major harbors and waterways of Lake Ontario, i.e., Rochester and Oswego (3). Where projections were not provided in 1968, data on annual average maintenance dredging have been provided by the C.E. in 1973. Utilizing these data, it is projected that approximately 3.7 million cubic yards of material will be removed from U.S. projects in Lake Ontario in the next decade (Table 8). Based on other projections of Lake Ontario, this figure represents a high estimate.

In the past few years, certain environmental policies (Section V) have occurred which may cause dredging volumes in Lake Ontario to decline in the next decade, particularly on the American side. It is generally felt by most environmental interests, that polluted spoil should be confined. Approximately 92 percent of the dredgings removed from U.S. projects of Lake Ontario are classed as polluted by the E.P.A. Confined disposal sites have been in use at major harbors in the Great Lakes for some time, but many more sites are necessary if polluted spoil is to be confined. Such sites are in various stages of development, from planning to actual construction. If a sufficient number of confined disposal

Table 8. C.E. PROJECTIONS AND ANNUAL MAINTENANCE DREDGING VOLUMES, LAKE ONTARIO (3, 47)
(cubic yards)

Project	Average annual dredging, 1960-1968	Projection, 1969
Great Sodus	35,686	8,000[a]
Little Sodus	18,724	8,000[a]
Oswego	64,000	64,000
Rochester	264,000	288,000
Wilson	1,423	1,600[a]
Olcott	3,174	1,600[a]
Total		371,000

[a]Reported as average annual dredging by the C.E. in 1970; used as projections for these smaller harbors.

sites become available, then dredging volumes may increase in the next decade. However, difficulty is being experienced in some areas for finding and developing suitable sites which are mutually agreeable to all concerned groups. In some cases, the cost to local parties is considered too great. Unless waivers of costs to local groups are obtained, site agreements are reached, and/or the E.P.A. modifies its pollution criteria, dredging at many harbors in the future may decline to some extent. In the interest of the regional and national economy, most major harbors and waterways will probably be dredged at any environmental cost, even if at a reduced scale. However, the smaller and more marginal commercial projects and all recreational and harbors of refuge would probably be downgraded. Thus, under these considerations, a lower figure for the C.E.'s dredging volume in Lake Ontario in the next decade is about 2.2 million cubic yards. This figure represents a decline in dredging volumes of approximately one standard deviation from the norm in the past decade.

Based primarily on the dredging history of Lake Ontario, a median estimate of the volume of material to be removed in the next decade is possible. The decade of the 1960's, i.e., 1960 to 1970, has been chosen as typical for the purposes of this project. The St. Lawrence Seaway was completed in 1959, and only in recent years higher than average lake levels and the E.P.A. constraints have had effects on dredging. In estimating future volumes then, the frequency at which individual projects were dredged during the 1960's has been utilized. Some harbors and waterways are dredged annually while others are maintained relatively infrequently (Table 9).

Between 1961 and 1970 the C.E. dredged only one of 5 projects every year in Lake Erie: the average per year was 3. During that decade the volume of material removed each year ranged from 188,000 cubic yards to 568,000 cubic yards: the average was 364,000 cubic yards per year. No significant correlation exists between number of jobs completed per year

Table 9. FREQUENCY OF DREDGING BY THE C.E., LAKE ONTARIO PROJECTS, 1961-1970 (47)

Project	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Great Sodus	x	x	x	x	x	x	x		x	
Little Sodus				x	x			x	x	
Oswego	x	x	x	x		x	x		x	
Rochester	x	x	x	x	x	x	x	x	x	x
Wilson		x								
Olcott		x								
Total projects per year	3	5	3	4	3	3	3	2	4	1

and the volume of spoil removed. Six projects were maintained on Lake Ontario between 1961 and 1970. Only Rochester was dredged a total of at least one million cubic yards of material during that time (Table 10). If the probable fall in lake levels actually occurs in the near future, if environmental constraints are relaxed in consideration of economics in the Great Lakes region, and/or if confined disposal sites under consideration at present actually become available, then dredging in the next decade may be slightly higher than normal. Volumes would be above average for a few years to allow for the removal of material which has accumulated during the past 3 years, a period of relatively lower than normal dredging activity. A return to average dredging volumes would probably occur within 3 or 4 years thereafter. Thus, a median estimate of the total volume of U.S. maintenance dredging in the next decade is approximately 3.6 million cubic yards of material. This figure, only slightly lower than the C.E. projection of 3.7 million for Lake Ontario, should be considered the projection provided by this report.

Table 10. FREQUENCY OF DREDGING AND VOLUME OF SPOIL REMOVED BY THE C.E., 1961-1970 (47) (cubic yards)

Project	Frequency dredged, 1961-1970	Maintenance volume
Great Sodus	8	237,630
Little Sodus	4	150,747
Oswego	7	546,830
Rochester	10	2,670,289
Wilson	1	9,484
Olcott	1	21,157
Total		3,636,137

Permit--

If permit dredging activity in the past decade can be considered typical of Lake Ontario, and if recent dredging cutbacks are balanced by greater volumes removed after disposal sites become available in the next few years, then it is estimated that a total of 300,000 cubic yards of material will be removed by permittees in the next decade. This projection, however, is based on minimal data. Dredging in some years may show many small volume permits approved, and the total may be significantly less than the projection. In other years, only a few permits may be approved, but because the jobs are large, volumes may be considerably greater than the projection posed herein.

Future New Work by the Corps of Engineers in Lake Ontario

Only Oak Orchard Harbor is scheduled for new work dredging in Lake Ontario in the next 10 years. The total amount of material to be removed is 61,000 cubic yards. However, actual completion of the project may be considered to be only reasonably certain. In fact, the possibility exists that any project presently scheduled may never develop beyond the planning stage. Completion of new work dredging is particularly difficult to determine due to economic and environmental feasibility factors. Money allocations and environmental impact must be appraised before any future new work projects are actually accomplished. Projects considered important at present may be delayed and even cancelled because they lose significance during processes of approval by various governmental agencies and other interest groups.

Projections of Canadian Dredging Volumes

Maintenance--

In the decade 1961 to 1970, a range of 2 to 7 maintenance dredging projects occurred annually in Canadian waters of Lake Ontario. The average annual number of jobs per year was 5. The total volume of material removed ranged from about 51,000 cubic yards to 1.5 million cubic yards: the average annual volume removed in that decade was 536,000 cubic yards (Table 11).

In terms of future spoil removal on the Canadian side of Lake Ontario, projections of maintenance dredging volumes from 1973 to 1977 were made available by the D.P.W. A total of approximately 435,000 cubic yards of spoil are scheduled to be dredged in maintaining Canadian harbors on Lake Ontario in the next 3 to 4 years (Table 12). Approximately half of the total in this time is expected to be removed from the harbor at Toronto.

Obviously, Canadian projections for maintenance dredging in the near future are lower than the average dredging volumes which occurred during the 1960's. However, expansion in the Toronto Harbor, involving about 8 million cubic yards of new work dredging, is expected to be completed

Table 11. CANADIAN DREDGING FREQUENCIES, LAKE ONTARIO PROJECTS, 1961-1970 (48)

Project	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Toronto	x	x	x	x	x	x	x	x		x
Oshawa	x	x		x	x	x	x	x		
Port Credit	x		x							
Burlington				x						
Cobourg	x	x	x	x		x	x		x	x
Hamilton	x	x	x	x		x	x	x	x	x
Port Hope	x	x	x	x	x	x	x	x		x
Cataraqui	x									
Total projects per year	7	5	5	6	3	5	5	4	2	4

Table 12. FUTURE DREDGING IN CANADA 1973-1977, LAKE ONTARIO (cubic yards) (48)

	Volume
Maintenance projects	
Bronte	15,000
Cobourg	50,000
Oshawa	140,000
Whitby	10,000
Toronto	220,000
Total maintenance volume	435,000
Private projects	
Port Weller (by S.L.S.A.)	85,000
Bowmanville (by Ontario Hydro)	221,000
Total private volume	306,000
New work projects	
Toronto	8,010,000
Total new work volume	8,010,000

within two years. This will increase maintenance dredging somewhat after 1975. Thus, considering Canadian projections primarily, it is estimated that an average of 500,000 cubic yards of material will be removed from the Canadian side of Lake Ontario every year for the next decade in maintenance dredging projects.

Private--

Permit dredging has fluctuated widely in terms of volumes on the Canadian side of Lake Ontario in recent years. More than 4 million cubic yards were removed by permit since 1968. In some years very little permit dredging activity has occurred. However, other projects have resulted in the removal of hundreds of thousands of cubic yards of spoil. Canadian data reveal that at least 306,000 cubic yards of spoil are already scheduled to be removed by private interests in Lake Ontario projects by 1977 (Table 12). Thus, in an attempt to generalize a projection on permit dredging in Canadian waters of Lake Ontario, it is postulated that an average of 100,000 cubic yards of material will be removed by permit every year in the next decade.

New Work--

In the decade of the 1960's about 1.9 million cubic yards of material were dredged in Canadian new work projects in Lake Ontario. All new work in the lake occurred in the early 1960's; none has occurred since 1963. In the research for this project, only one capital dredging project was projected by any Canadian authorities for Lake Ontario. At Toronto, port expansion is expected to result in the removal of approximately 8 million cubic yards of spoil by 1975. No other new work projects are scheduled for Canadian harbors on Lake Ontario.

Summary

The total volume of maintenance and permit dredging to occur in Lake

Ontario to 1983 is estimated to be almost 1.0 million cubic yards per year (Table 13). About 60 percent will occur on the Canadian side and 40 percent on the American side. Since most confined disposal sites planned for American projects in Lake Ontario will not be completed until 1975, 1976, or 1977, American volumes in the next few years will remain relatively low. However, after confined sites are ready to receive polluted spoil, all dredging activities may increase. By 1983 the average volumes being removed from Lake Ontario should be similar to those which were removed during the decade of the 1960's.

Table 13. ESTIMATES OF FUTURE AVERAGE ANNUAL DREDGING VOLUMES IN LAKE ONTARIO (cubic yards)

	U.S. projects	Canadian projects
Maintenance	360,000	500,000
Permit	30,000	100,000
Annual total	390,000	600,000
Total for Lake Ontario	990,000	
Future new work	61,000	8,100,000

DREDGING QUANTITIES IN LAKE ERIE

More dredging occurs in Lake Erie (including the Detroit and Rouge Rivers) than in any other part of the Great Lakes. High dredging volumes here are generated primarily at large commercial projects such as Buffalo, Cleveland, Toledo, and the Detroit River. In addition to maintaining these and other smaller commercial harbors, a few recreational and harbors of refuge on the lake are dredged. Twenty-one U.S. projects and 15 Canadian harbors in Lake Erie require dredging, at least periodically (Figur 4).

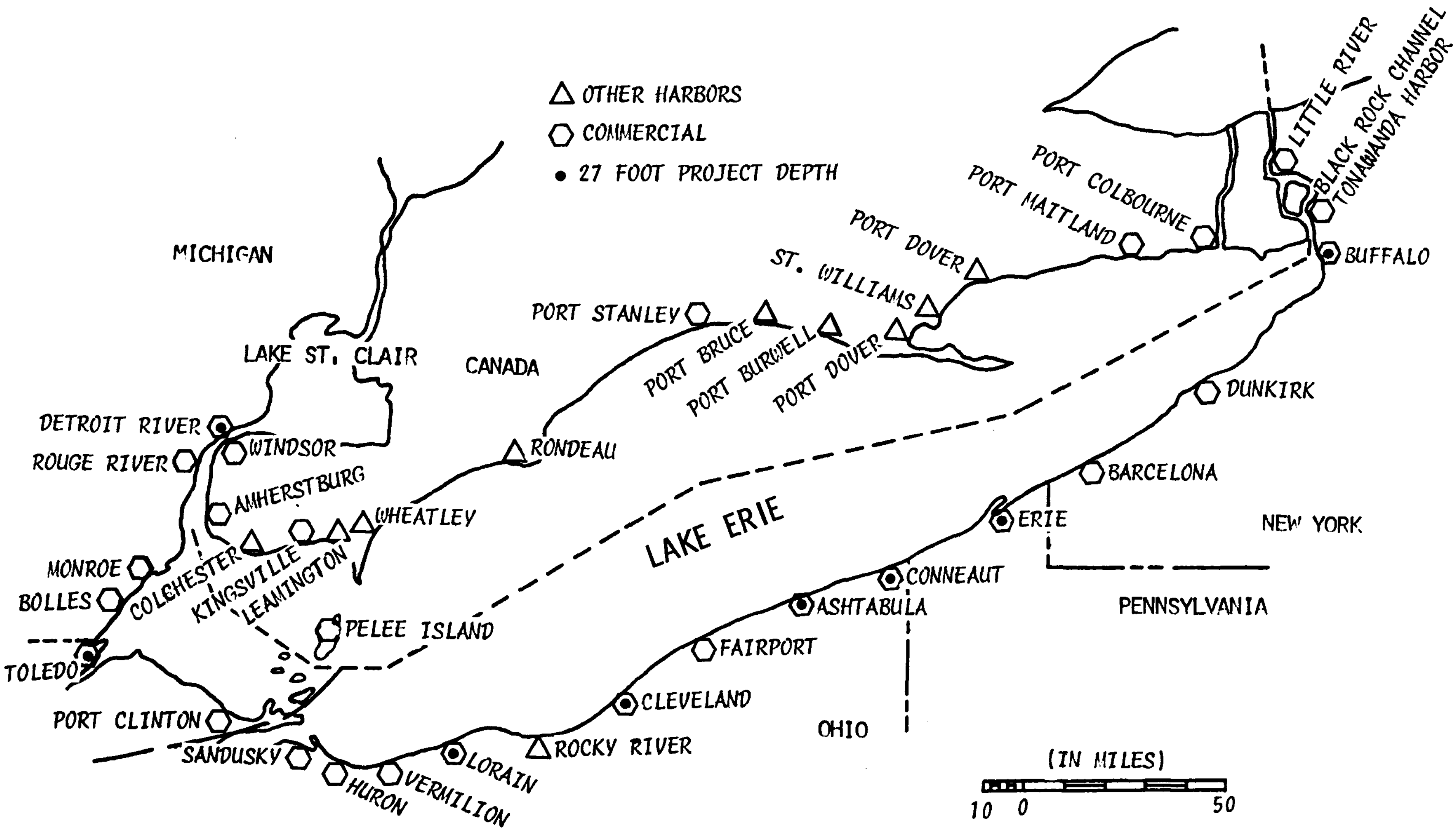


Figure 4. PRINCIPAL DREDGING PROJECTS IN LAKE ERIE

Average annual commerce at 14 American harbors is substantial enough so that the cost of their maintenance is classed as unequivocally justified by the C.E. (2). In fact, 8 American harbors and waterways on Lake Erie are dredged to maintain the 27-foot St. Lawrence Seaway channel depth (Figure 4). Other harbors with less commercial traffic, i.e., those with lower benefit/cost ratios, have continually been dredged in the past. However, reductions in money allocations or port status changes may cause cessation of dredging operations at the more marginal harbors such as Dunkirk, Barcelona, or Rocky River.

In terms of volume, the most important American maintenance dredging projects in Lake Erie are at Toledo, Cleveland, Buffalo, and Sandusky. All of these require removal of more than 400,000 cubic yards of spoil annually (Figure 5). Of the Canadian harbors, the volume leader has been Port Burwell, which averaged approximately 180,000 cubic yards per year until recently. However, a status change has occurred at Port Burwell, resulting in a reduction in project depth from 22 feet to 10 feet. Port Stanley, with an average of less than 90,000 cubic yards of spoil removed each year, is now the most important dredging project on Lake Erie. No Canadian harbor on the lake is dredged to the 27-foot St. Lawrence Seaway depth.

United States Dredging History in Lake Erie

Lake Erie has been dredged for decades, but complete, meaningful, and comparable volume data for C.E. projects are available only from 1951. Prior to that time, records on actual volumes dredged become sketchy to non-existent for some harbors, even in C.E. Annual Reports. In many cases, dollar cost figures were reported in lieu of spoil volumes. Because of differences in types of material being removed, types of dredging operations, and in value of the dollar over time, accurate conversion of cost figures to volume figures was not possible for many of

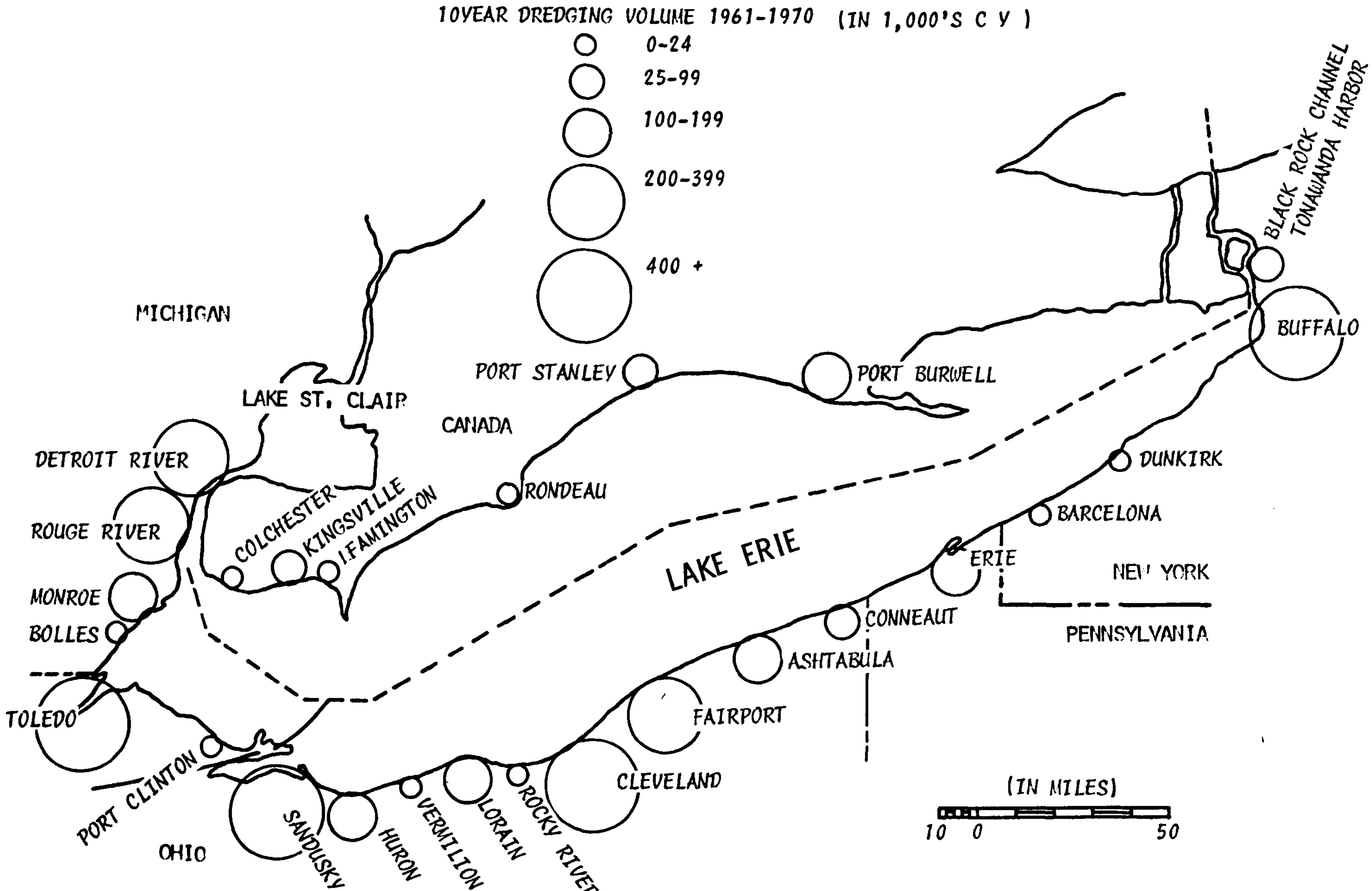


Figure 5. AVERAGE ANNUAL MAINTENANCE DREDGING VOLUMES IN LAKE ERIE, 1961-1970

those earlier years. However, complete and meaningful maintenance and new work dredging data since 1951 were collected and are presented in Table 14.

Since 1951, approximately 134 million cubic yards of spoil has been removed from Lake Erie and the Detroit and Rouge Rivers by the C.E. About 56 percent has been derived from Buffalo District projects and 44 percent from Detroit District projects. Seventy percent of the total volume involved was removed in maintenance dredging and 30 percent in new work projects. Of all material removed in maintenance projects since 1951, more than three-fifths came from Toledo, Cleveland, Buffalo, and Sandusky combined. Most new work dredging quantities during the same period were extracted from the Detroit River, Toledo, and Buffalo.

Maintenance Dredging--

In the past decade, maintenance dredging has accounted for approximately 55 percent of all dredging on the American side of Lake Erie. In terms of volume removed over a longer period, i.e., 1951 to 1972, the Buffalo District C.E. dredged an average of 2.64 million cubic yards of spoil from Lake Erie projects annually in maintenance projects. Absolute amounts for the Buffalo District ranged from a low of 1.98 million cubic yards in 1954 to a high of 3.89 million cubic yards in 1967 (Table 15). In the same period the Detroit District C.E. dredged an average of 1.60 million cubic yards of material annually from Lake Erie projects including the Detroit and Rouge Rivers. Absolute amounts for the Detroit District ranged from a low of 0.87 million cubic yards in 1963 to a high of 3.28 million cubic yards in 1968. Thus, an average of 4.23 million cubic yards of spoil has been removed in maintaining projects in Lake Erie every year from 1951 to 1972. The range was from a low of 3.14 million cubic yards in 1953 to a high of 6.52 million yards in 1967 (Figure 6). A relatively consistent volume of spoil has been dredged from Lake Erie in recent decades. Since 1951, the Buffalo District C.E.

Table 14. HISTORICAL DREDGING IN LAKE ERIE BY HARBOR/WATERWAY AND C.E. DISTRICT, 1951-1972 (47, 50)
(cubic yards)

Harbor/Waterway	Maintenance	New work	Total
Buffalo District			
Ashtabula	2,817,792	2,584,469	5,402,261
Black Rock Channel and Tonawanda Harbor	1,342,475	122,511	1,464,986
Buffalo	9,561,490	6,640,455	16,201,945
Cleveland	19,065,831	2,709,006	21,774,837
Conneaut	1,560,227	1,437,458	2,997,685
Dunkirk	333,320	195,166	528,486
Erie	2,990,890	656,715	3,647,605
Fairport	6,534,780	11,666	6,546,446
Huron	3,236,320	0	3,236,320
Lorain	3,791,160	1,327,271	5,118,431
Rocky River	7,083	0	7,083
Sandusky	7,090,207	1,253,936	8,344,143
Totals	58,331,575	16,938,653	75,270,228
Detroit District			
Bolles	87,371	157,898	245,269
Detroit River	5,396,005	12,273,460	17,669,465
Monroe	4,475,423	0	4,475,423
Port Clinton	57,934	0	57,934
Rouge River	4,493,577	0	4,493,577
Toledo	20,789,930	11,411,931	32,201,861
Totals	35,300,240	23,843,289	59,143,529
Grand totals	93,631,815	40,781,942	134,413,757

Table 15. ANNUAL MAINTENANCE DREDGING IN LAKE ERIE, 1951-1972 (47, 50)
(cubic yards)

Year	Buffalo District	Detroit District	Total Volume
1972	2,112,555	1,366,336	3,478,891
1971	2,321,135	1,080,472	3,401,607
1970	2,478,930	1,804,690	4,283,620
1969	2,996,703	2,396,727	5,393,430
1968	2,869,449	3,278,175	6,147,624
1967	3,892,150	2,636,984	6,529,134
1966	2,784,952	1,693,665	4,478,617
1965	2,141,659	1,636,712	3,778,371
1964	2,739,205	707,539	3,446,744
1963	2,799,863	874,275	3,674,138
1962	2,636,714	943,132	3,579,846
1961	3,053,721	2,126,050	5,179,771
1960	2,911,955	2,586,735	5,498,890
1959	3,097,801	1,648,815	4,746,616
1958	2,942,716	1,675,957	4,618,673
1957	2,880,035	1,437,262	4,317,297
1956	2,178,527	1,129,870	3,308,397
1955	2,195,340	1,424,229	3,619,569
1954	1,980,695	1,596,869	3,577,564
1953	2,082,365	1,062,251	3,144,616
1952	2,938,146	874,808	3,812,954
1951	2,296,959	1,318,687	3,615,646
Totals	58,331,575	35,300,240	93,631,815

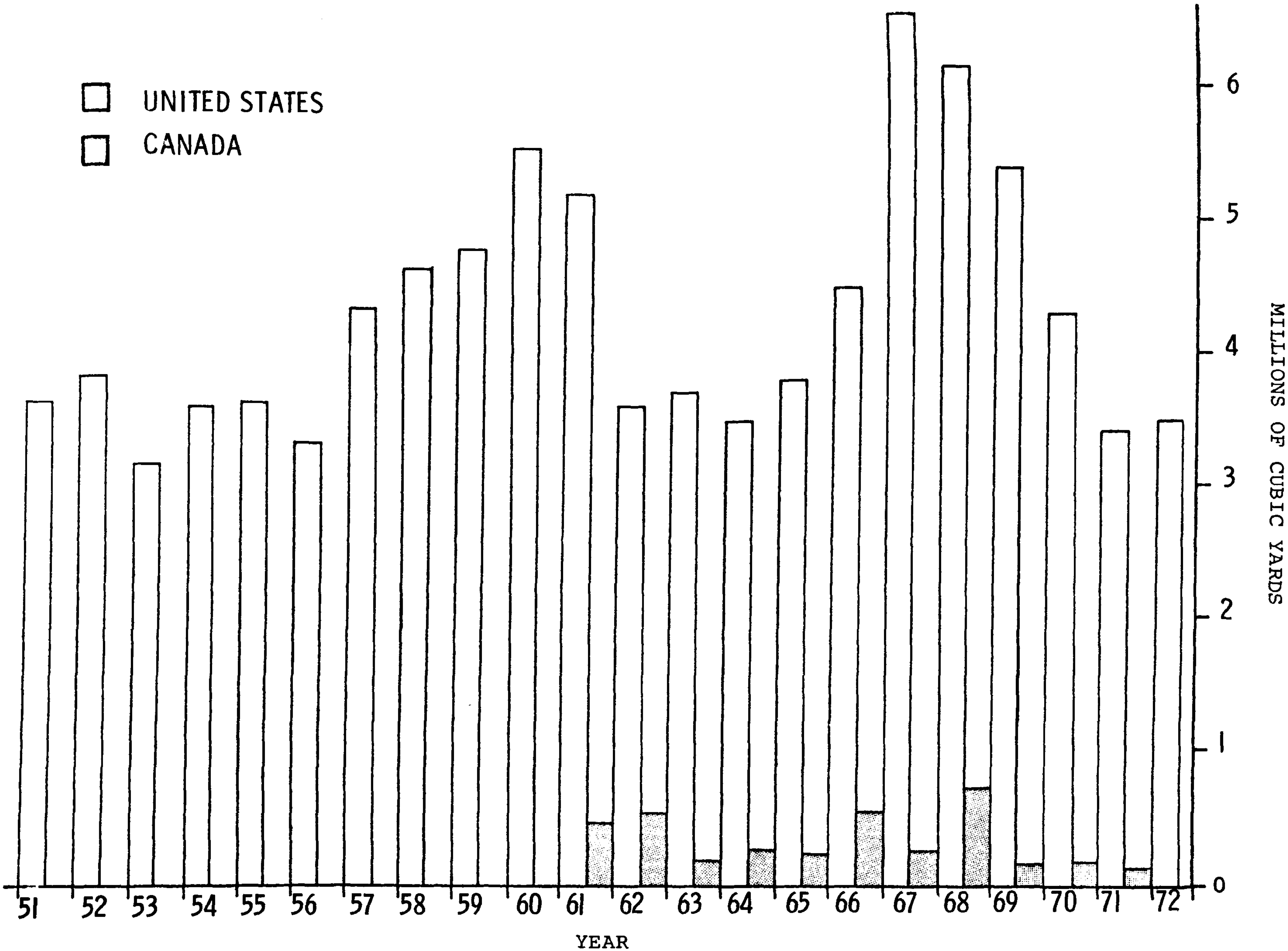


Figure 6. MAINTENANCE DREDGING VOLUMES IN LAKE ERIE, 1951-1972

has been responsible for removing more than 58 million cubic yards of spoil and the Detroit District approximately 35 million cubic yards.

New Work Dredging--

In the past decade, new work has accounted for approximately 35 percent of all dredging activity on the American side of Lake Erie. Over the longer term, i.e., 1951 to 1972, more than 40 million cubic yards of spoil was removed in new work projects. However, unlike average maintenance volumes, new work volume totals display very little regularity from year to year. New work volumes range from a low of no new work in 1971 and 1972 to a high of more than 12 million cubic yards in 1963 (Table 16). During the late 1950's and the early 1960's new work dredging became highly important. In fact, more than 90 percent of the new work dredging in Lake Erie waters since 1951 occurred between 1958 and 1967. For the most part, this was due to the deepening and widening of harbors and waterways to accommodate commerce generated by the St. Lawrence Seaway, which was completed in 1959.

The largest new work project in Lake Erie since 1951 occurred at Toledo. In 1963 almost 7 million cubic yards of spoil were dredged in that project. Of all new work dredging since 1951, 58 percent occurred in Detroit District C.E. projects and 42 percent in Buffalo District projects.

Permit Dredging--

Dredging by non-federal interests may only be undertaken when authorization of the C.E. is obtained through permits. Permit dredging data in Lake Erie has been traced thoroughly from 1963 to the present. Data were gathered from C.E. in Buffalo and Detroit, from the E.P.A. in Chicago, and from New York State Department of Environmental Conservation in Albany. This compilation of permit dredging volume data is as complete as possible, considering certain restrictions such as missing

Table 16. NEW WORK DREDGING IN LAKE ERIE, 1951-1972 (47, 50)
(cubic yards)

Year	Buffalo District	Detroit District	Total
1972	0	0	0
1971	0	0	0
1970	86,836	51,449	138,285
1969	0	46,464	46,464
1968	387,466	0	387,466
1967	1,150,721	79,854	1,230,575
1966	3,186,485	399,467	3,585,952
1965	2,441,336	1,297,268	3,738,604
1964	1,361,080	3,103,642	4,464,722
1963	3,239,048	9,494,166	12,733,214
1962	491,966	2,015,771	2,507,737[a]
1961	294,663	3,499,913	3,794,576
1960	1,167,686	906,416	2,074,102
1959	736,545	1,284,498	2,021,043
1958	0	1,664,381	1,664,381
1957	395,503	0	395,503
1956	720,000	0	720,000
1955	250,000	0	250,000
1954	227,083	0	227,083
1953	193,750	0	193,750
1952	291,958	0	291,958
1951	316,527	0	316,527
Totals	16,938,653	23,843,289	40,781,941

[a]Plus two more jobs of unreported and unknown quantity.

permit files, unreported volumes of spoil removed, and files lacking job completion notices. Compilation of complete and comparable volume data for permit dredging prior to 1963 is actually impossible in Lake Erie projects for such reasons. Therefore, the private dredging volumes presented in this report represent minimum figures.

Approximately 10 percent of all U.S. dredging in Lake Erie is permit dredging. From 1963 to 1972, such projects resulted in the removal of more than 8 million cubic yards of spoil from the lake (Table 17). On the average, approximately 800,000 cubic yards of material are dredged from the lake by permittees each year. The volumes removed ranged from a low of 156,000 cubic yards in 1968 to a high of 2.2 million cubic yards in 1970. No apparent pattern has been established in the past decade. Of all permit dredging, 80 percent of the volume is removed under the jurisdiction of the Detroit District C.E. and 20 percent under the Buffalo District.

Table 17. PRIVATE DREDGING IN LAKE ERIE, 1963-1972 (47, 50)
(cubic yards)

Year	Buffalo District	Detroit District	Total
1972	71,484	409,000	480,484
1971	141,774	393,499	535,273
1970	213,637	2,010,000	2,223,637
1969	130,858	435,067	565,925
1968	106,660	49,800	156,460
1967	160,512	478,860	639,372
1966	163,660	868,010	1,031,670
1965	60,765	624,845	685,610
1964	277,641	795,902	1,073,543
1963	254,190	471,719	725,909
Totals	1,581,181	6,536,702	8,117,883

Canadian Dredging History in Lake Erie

Dredging data for Canadian harbors on Lake Erie have been collected and collated from 1961 to the present (Figure 6). In those 11 years, more than 3.5 million cubic yards of spoil has been removed in maintaining several comparatively small Canadian harbors. Amounts of material removed ranged from a low of about 120,000 cubic yards in 1971 to a high of approximately 710,000 cubic yards in 1968 (Table 18). Essentially no new work dredging has been done on the Canadian side of Lake Erie for more than a decade.

Data on permit dredging are particularly sketchy for Canadian harbors since statistics for Lake Erie were available only from 1969 to 1972. In that period, an approximate total of a one-half million cubic yards of spoil were removed by permittees. Because the sample period is short, no pattern of permit dredging activity for Canadian Lake Erie can be determined.

In terms of volume, the most significant Canadian maintenance dredging projects have historically been at Port Burwell, Port Stanley, Kingsville, and Leamington (Table 19). With the recent phasing out of Port Burwell as a coal port, dredging there has ceased. Port Stanley has become the volume leader with an average of only about 90,000 cubic yards per year.

Projections of Future Dredging Quantities on the United States Side

Maintenance--

Estimations of the quantities of material to be removed from Lake Erie in maintenance dredging in the next decade is possible based on the information available. Three projections will be provided, as follows:

(1) a figure based on C.E. estimates made in 1968 (3,4).

(2) a figure based on relatively recent environmental effects on

Table 18. DREDGING HISTORY IN CANADIAN PROJECTS IN LAKE ERIE, 1961-1972 (47, 50) (cubic yards)

Year	Maintenance	New work	Permit
1972	N.A.	0	5,800
1971	119,789	0	430,000
1970	171,753	0	500
1969	157,233	0	2,000
1968	710,791	0	N.A.
1967	247,831	0	N.A.
1966	535,982	10	N.A.
1965	236,877	0	N.A.
1964	287,226	0	N.A.
1963	199,825	0	N.A.
1962	512,946	0	N.A.
1961	466,026	0	N.A.
Totals	3,619,847	10	438,300

N.A. Data not available.

Table 19. HISTORICAL DREDGING: CANADIAN PROJECTS IN LAKE ERIE, 1961-1970 (48)
(cubic yards)

Project	Total maintenance	Total new work
Kingsville	258,434	0
Pelee Island	15,092	0
Port Dover	32,035	0
Port Maitland	51,692	0
Port Stanley	865,646	0
Amherstburg	6,365	10
Leamington	207,808	0
Port Burwell	1,827,159	0
St. Williams	3,867	0
Wheatley	69,918	0
Rondeau	135,172	0
Windsor	1,023	0
Colchester	11,974	0
Port Bruce	300	0
Port Rowan	13,573	0
Totals	3,500,058	10

dredging in the Great Lakes, and

(3) a median figure projected in this report.

The latter will be based primarily on the past dredging histories in Lake Erie and on developments expected in the near future, i.e., a drop in the present high lake levels, completion of confined disposal sites, and easing of present environmental constraints. Changes in shipping needs in the next decade and the potential of year-round navigation are not expected to affect dredging significantly in Lake Erie.

In 1968 the C.E. projected dredging volumes for most of the major harbors and waterways of Lake Erie (3,4). For a few harbors for which projections were not provided, data on annual average maintenance dredging have been made available by the Buffalo District. Utilizing these data, it is projected that approximately 5.4 million cubic yards of material will be removed annually from American waters of Lake Erie in the next decade (Table 20). This figure is a high estimate compared to other projections in this subsection.

In the past few years, environmental policies have developed which may cause dredging volumes in Lake Erie to decline somewhat in the next decade. It is generally felt by most environmental interests that polluted spoil should be confined. Approximately 95 percent of the material removed from U.S. projects in Lake Erie is classed as polluted by the E.P.A. Confined disposal sites have been in use at high volume such as Buffalo, Cleveland, Toledo, and the Detroit River for some time, but many more sites are necessary. Such sites are in various stages of development, from selection and planning to actual construction. If a sufficient number of confined disposal sites become available, then dredging volumes may continue high in the next decade. However, difficulty is being experienced in some areas in finding and developing suitable sites which are mutually agreeable to all concerned agencies. In some cases, the cost to local interests may be considerable. In others, actual site selection has thus far not been agreeable to all parties.

Table 20. C.E. PROJECTIONS AND ANNUAL MAINTENANCE DREDGING VOLUMES, LAKE ERIE (3, 47, 50, 51) (cubic yards)

Project	Average annual dredging 1960-1968	1969 projection
Ashtabula	104,000	176,000
Black Rock Channel and Tonawanda Harbor	105,776	80,000
Buffalo	464,800	420,000
Cleveland	976,000	976,000
Conneaut	60,000	80,000
Dunkirk	15,448	16,000
Erie	145,600	240,000
Fairport	296,000	320,000
Huron	150,000	160,000
Lorain	150,000	240,000
Rocky River	1,062	12,000[a]
Sandusky	316,000	480,000
Bolles	10,921	20,000[a]
Detroit River	640,000	640,000
Monroe	192,000	192,000
Port Clinton	4,043	8,000[a]
Rouge River	240,000	240,000
Toledo	1,120,000	1,120,000
Total		5,420,000

[a]Reported as average annual dredging by the C.E. in 1970; used as projections for these harbors.

Unless waivers of costs to local groups are obtained, site agreements are reached, and/or the E.P.A. relaxes some of its pollution criteria, maintenance dredging in the future will decline to some extent. As of July, 1974, a waiver was granted to Toledo and additional waivers are pending for Fairport, Conneaut, Cleveland, Lorain, and Ashtabula. However, polluted spoil is being dumped in the open lake in the Buffalo District. Thus, in the interest of the regional and national economy, most major harbors and waterways will probably be dredged at any environmental cost, even if at a reduced scale. But the smaller and more marginal commercial projects and many recreational and harbors of refuge would probably be eliminated entirely. Thus, under these considerations, a lower figure for the C.E. dredging volume in Lake Erie in the next decade is about 35 million cubic yards. This figure represents a decline in dredging volumes of approximately one standard deviation from the norm in the past decade.

Based primarily on the recent dredging history of Lake Erie, a median estimate of the volume of material to be removed in the next decade is possible. The decade of the 1960's, i.e., 1961 to 1970, has been chosen as typical. The St. Lawrence Seaway was completed in 1959, and in the early 1970's higher than average lake levels and E.P.A. pollution criteria have had effects on dredging. In estimating future volumes then, the frequency at which individual projects were dredged during the 1960's has been utilized. Some harbors and waterways are dredged annually while others are maintained less frequently (Table 21).

Between 1961 and 1970 the C.E. dredged 13 to 16 maintenance projects annually: the average per year was 14. During that decade, the volume of material removed each year ranged from 3.4 million cubic yards to 6.5 million cubic yards: the average was 4.6 million cubic yards annually. No significant correlation existed between number of jobs completed per year and volume of spoil removed. Eighteen projects were maintained on Lake Erie between 1961 and 1970. Twelve were dredged a total of at

Table 21. FREQUENCY OF DREDGING BY THE C.E., LAKE ERIE PROJECTS, 1961-1970 (47, 50)

Project	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Ashtabula	x	x	x	x	x	x	x	x	x	x
Black Rock Channel and Tonawanda Harbor	x	x	x	x	x	x	x	x	x	x
Buffalo	x	x	x	x	x	x	x	x	x	x
Cleveland	x	x	x	x	x	x	x	x	x	x
Conneaut	x	x	x	x	x			x	x	x
Dunkirk	x	x	x			x			x	x
Erie	x	x	x	x		x	x	x	x	x
Fairport	x	x	x	x	x	x	x	x	x	x
Huron	x	x	x	x	x	x	x	x	x	x
Lorain	x	x		x	x		x	x	x	x
Rocky River				x	x					
Sandusky	x	x	x	x	x	x	x	x	x	x
Bolles								x		
Detroit River				x	x	x	x	x	x	x
Monroe	x	x	x	x	x	x	x		x	x
Port Clinton				x					x	
Rouge River	x	x	x	x	x	x	x	x	x	x
Toledo	x	x	x		x	x	x	x	x	x
Totals	14	14	13	15	14	13	13	14	16	15

least one million cubic yards of material during that time (Table 22). If the probable fall in lake levels actually occurs in the near future, if pollution criteria are relaxed in consideration of economics in the Great Lakes region, and/or if confined disposal sites planned become available, then dredging in the next decade may be slightly higher than normal. Volumes would be somewhat greater than normal for a few years to allow for the removal of material which has accumulated during the past 3 years, a period of relatively lower than normal dredging activity. A return to average dredging volumes would probably occur within 3 or 4 years. Thus, a median projection of U.S. maintenance dredging in Lake Erie is approximately 4.8 million cubic yards of spoil annually.

Permit--

If permit dredging activity in the past decade can be considered typical of Lake Erie, and if recent decreases in dredging are balanced by greater volumes removed after disposal sites become available in the next few years, then it is estimated that an average of 900,000 cubic yards of material will be removed each year by permittees in the next decade. This projection may be quite low or quite high because permit dredging data, as discussed previously, are not complete. Many small-volume permits may be approved in some years, and the total may be significantly less than the projection. In other years, only a few permits may be approved. However, because the jobs are large, volumes may be considerably greater than the projection posed herein.

Future New Work by the Corps of Engineers in Lake Erie--

Nine projects are in the schedule for new work dredging in Lake Erie at this time. Combined, the total amount of material to be removed is more than 4 million cubic yards (Table 23). However, actual completion of these projects may be considered to be only reasonably certain. In fact, the possibility exists that few of the projects scheduled at present may

Table 22. FREQUENCY OF DREDGING AND VOLUME OF SPOIL REMOVED BY THE C.E. LAKE ERIE, 1961-1970 (47, 50) (cubic yards)

Project	Frequency dredged	Maintenance volume
Ashtabula	10	1,257,691
Black Rock Channel and Tonawanda Harbor	10	834,980
Buffalo	10	4,488,244
Cleveland	10	8,756,299
Conneaut	8	687,035
Dunkirk	6	121,091
Erie	9	1,620,327
Fairport	10	3,026,874
Huron	10	1,519,345
Lorain	8	1,201,993
Rocky River	2	7,083
Sandusky	10	4,397,040
Bolles	1	87,371
Detroit River	7	3,245,073
Monroe	9	1,846,288
Port Clinton	2	59,605
Rouge River	10	2,021,209
Toledo	9	10,837,905
Total		46,015,453

Table 23. FUTURE NEW WORK DREDGING IN LAKE ERIE SCHEDULED BY THE C.E. AS OF 1973 (47, 50) (cubic yards)

Project	Volume
Huron	840,000
Fairport	1,100,000
Lorain	70,000
Sterling State Park	186,000
Cattaraugus Creek	140,000
Kelley's Island	2,400
East Harbor (Ohio)	478,000
Ottawa River	1,281,000
West Harbor (Ohio)	299,000
Total	4,396,400

never develop beyond the planning stage. Future new work dredging is particularly difficult to determine due to economic and environmental factors. Money allocations and environmental impacts must be appraised before any future new work projects are actually accomplished. Projects considered important may be delayed and even cancelled in the future because they lose significance during processes of approval by various governmental agencies and other local interest groups.

One aspect of future dredging may provide a unique situation in Lake Erie. There is a possibility that a new offshore airport complex will be constructed adjacent to Cleveland, in Lake Erie. Such an undertaking would obviously involve development of an offshore land surface. If this project expands beyond planning the stages and construction begins in the next decade, tremendous volumes of material would be needed. At least part of the construction would probably involve great quantities of dredged material from Cleveland Harbor.

Projections of Canadian Dredging Volumes

Maintenance--

The decade 1961 to 1970 may be considered typical of Canadian dredging for purposes of this report for the same reasons considered on the American side. In that decade, a range of 3 to 9 maintenance dredging projects occurred annually in Canadian waters of Lake Erie. The average annual number of projects per year was 6. The total dredged volume ranged from about 160,000 cubic yards to 710,000 cubic yards: the average annual volume removed in that decade was 351,000 cubic yards (Table 24).

In terms of future spoil, projections of maintenance dredging volumes to 1977 were made available by the D.P.W. of Canada. A total of approximately one-half million cubic yards of spoil are anticipated to be dredged in maintaining Canadian harbors on Lake Erie in the next 3 to 4 years. About one-half of the total is expected to be removed from Port Stanley (Table 25).

Obviously, Canadian projections for the near future are lower than the average dredging volumes which occurred during the 1960's. This is due primarily to the loss of Port Burwell volumes, which will be much lower in the future than they were during that decade. Thus, considering Canadian projections, it is anticipated that approximately 150,000 to 200,000 cubic yards of material will be removed from Lake Erie annually in maintenance dredging projects.

Permit--

Permit dredging has fluctuated widely in terms of volumes on the Canadian side of Lake Erie in recent years. In some years very little private dredging activity has occurred. But in others, only a few jobs have resulted in the removal of hundreds of thousands of cubic yards of spoil. Thus to generalize a projection on permit dredging in Canadian

Table 24. CANADIAN DREDGING FREQUENCIES, LAKE ERIE PROJECTS, 1961-1970 (48)

Project	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Kingsville	x	x		x	x	x		x		
Pelee Island		x			x					
Port Dover		x							x	
Port Maitland	x	x								
Port Stanley	x	x	x	x	x	x	x	x	x	x
Amherstburg			x			x				
Leamington		x	x	x	x			x	x	
Port Burwell	x	x	x	x	x	x	x	x		x
St. Williams		x								
Wheatley		x			x	x	x			
Rondeau	x		x		x	x	x	x	x	x
Windsor	x									
Colchester					x					
Port Bruce					x					
Port Rowan								x		
Total projects per year	6	9	5	4	9	6	4	6	4	3

Table 25. FUTURE MAINTENANCE DREDGING IN CANADA 1973-1977, LAKE ERIE (cubic yards) (48)

Project	Volume
Port Burwell	26,400
Rondeau	55,000
Amherstburg	12,000
Cedar Beach	7,000
Colchester	9,200
Kingsville	39,000
Leamington	25,000
Pelee Island	15,000
Port Bruce	4,000
Port Dover	20,000
Port Maitland	10,000
Port Rowan	30,000
Port Stanley	250,000
Wheatley	40,000
Total	542,600

projects, it is postulated that an average of 100,000 cubic yards of material will be removed by permit annually in the next decade.

New Work--

In the decade of the 1960's only one new work job occurred in Canadian waters of Lake Erie, and the volume of material removed was only 10 cubic yards. No capital dredging projects are projected or anticipated by the D.P.W. or the M.O.T. for Lake Erie.

Summary

The total anticipated volume of maintenance and permit dredging in Lake Erie is estimated to be almost 6 million cubic yards per year (Table 26). About 95 percent will occur on the American side and 5 percent on the Canadian side. Since all confined disposal sites planned for the U.S. projects will not be completed until 1977, volumes in the next few years will remain relatively low. However, after disposal sites are prepared, all dredging activities are expected to increase, with volumes being relatively low.. By 1983, the average or normal volumes being removed from Lake Erie should be similar to those which were removed during the decade of the 1960's.

Table 26. ESTIMATES OF FUTURE AVERAGE ANNUAL DREDGING VOLUMES IN LAKE ERIE (cubic yards)

	U.S. projects	Canadian projects
Maintenance	4,800,000	175,000
Permit	900,000	100,000
Annual totals	5,700,000	275,000
Total for Lake Erie	5,975,000	
Future new work	4,400,000	None expected

DREDGING QUANTITIES IN LAKES HURON AND ST. CLAIR

The principal economic function of Lakes Huron and St. Clair is intra-lake navigation and recreation. Based on unpublished C.E. data, Saginaw is the only U.S. harbor on Lake Huron which is unequivocally justified and had over 4,000,000 short tons of commerce in 1972 (5). However, other projects which were similarly justified in 1972 are the connecting waterways of the St. Marys River (80.2 million short tons), the

St. Clair River (105.3 million short tons), and Lake St. Clair (106.4 million short tons). All remaining C.E. projects have benefit/cost ratios between 1.1 to 1 and 8.13 to 1. Many harbors, such as Port Austin and Port Sanilac, have recreational benefits or are harbors of refuge, and are difficult to justify in terms of commerce. Thus, projects of greatest concern to the C.E. and commercial marine interests are Saginaw and the connecting waterways.

Except for southeastern Michigan, the Lake Huron shoreline is not heavily industrialized and most navigation projects do not require channels at Seaway depth. The most significant dredging activities in the past have occurred at the commercial projects of Alpena, Lake St. Clair and the St. Clair River, Cheyboygan, Black River, and the St. Marys River at Sault Ste. Marie (Table 27). Most harbors on the Canadian shore are infrequently dredged, which accounts for the low volume reflected on many tables of the lake. In Ontario, 50 projects are maintained by the D.P.W. Based on the 1973 Canadian Ports and Seaway Directory, 16 of these harbors and waterways have commercial status (6). However, only 3 (Sarnia, St. Clair Cut-off, and Killarney) are maintained to the 27-foot Seaway depth. The distribution of the principal projects in Lake Huron and Lake St. Clair are illustrated on Figure 7.

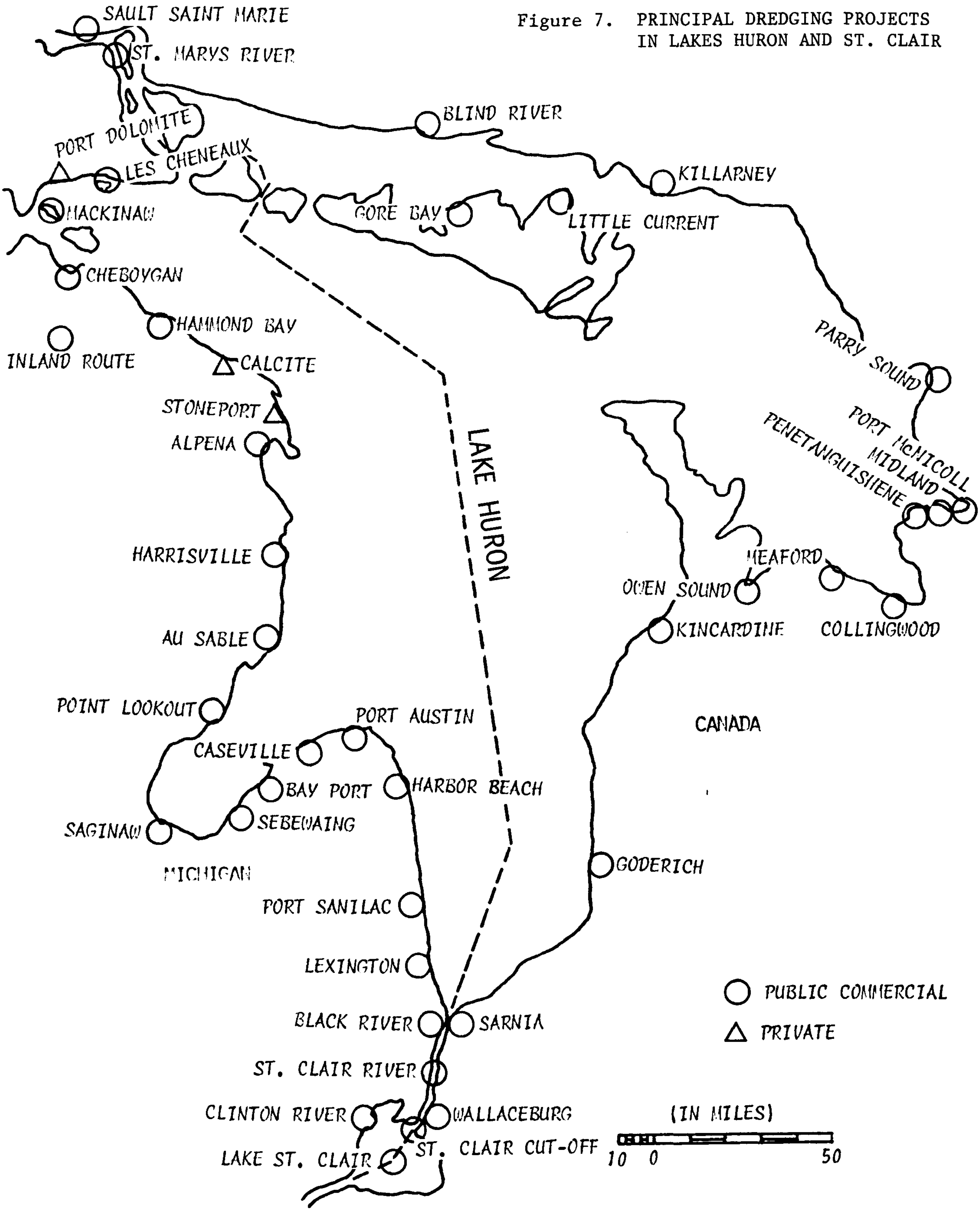
Maintenance and new work dredging data of the C.E. are sufficiently complete and accurate to reconstruct past dredging activities in Lake Huron, principally from the Annual Reports of the Chief of Engineers, U.S. Army on Civil Works. In Canada, the D.P.W. furnished maintenance dredging volumes from 1951-72 and capital dredging data from 1951-72. Private dredging, volumes, which were obtained from the Navigable Waters Protection Act (NWPA) files of the M.O.T., date back to 1960.

Table 27. HISTORICAL DREDGING TOTALS OF C.E. PROJECTS IN LAKE HURON/ST. CLAIR, 1920-1972 (50)
(cubic yards)

Project	Maintenance	New work	Total
Alpena	290,036	259,877	549,913
Au Sable	273,671	25,407	299,078
Bay Port	0	29,089	29,089
Black River	563,348	57,940	621,288
Ch. Lake St. Clair	3,808,457	17,940,248	21,748,705
Clinton River	312,404	127,520	439,924
Caseville	25,889	62,929	88,818
Cheboygan	410,757	173,240	583,997
Hammond Bay	0	142,760	142,760
Harbor Beach	228,249	260,840	489,089
Harrisville	27,625	263,016	290,641
Inland Route	113,055	0[b]	113,055
Les Cheneaux	102,270	66,990	169,260
Mackinaw	0	9,869	9,869
Point Lookout	0	334,872	334,872
Port Sanilac	80,702	0[b]	80,702
Saginaw River	6,999,798[a]	12,938,358[a]	19,938,156
St. Clair River	4,112,237	27,472,621	31,584,858
St. Marys River	5,418,514	32,151,557	37,570,071
Sebewaing	169,120	0[b]	169,120
Totals	22,936,132	92,317,133	115,253,265

[a]1924 volumes are not known.
[b]No new work reported.

Figure 7. PRINCIPAL DREDGING PROJECTS IN LAKES HURON AND ST. CLAIR



Past Dredging Activity in Lake Huron and Lake St. Clair

Annual dredging data from 1930 to the present of the C.E. activities in Lake Huron and Lake St. Clair are illustrated in Table 28. Also included are private dredging quantities from 1960 through 1972 and volumes obtained from the D.P.W. and the M.O.T. Over a 42-year period, the C.E. dredging totaled 115,253,275 cubic yards which averages to approximately 2.7 million cubic yards per year. Annual maintenance dredging during this period was approximately 546, 000 cubic yards. As noted in Figure 8 maintenance dredging follows no predictable pattern and great extremes can occur over short intervals. In 1960, for example, dredging volumes were the lowest since 1930 (31,239 CY) and 8 years later, 1969, was a record high dredging year (1.9 million CY). If dredging totals and averages are determined over 4 decades (Table 29), the great range of maintenance dredging is evident. Furthermore, this table reveals that an increase in maintenance dredging over time, as one may expect with an increase in the number of projects and an increase in economic development, is not evident.

A comparison of Canadian and American data from 1961-70 reveals that in these two lakes, 94 percent of all maintenance, new work, and dredging activities by private interests occurred in Michigan. Most of the maintenance dredging (6 million CY) was at Saginaw and the connecting channels of St. Marys and St. Clair Rivers, and Lake St. Clair. A correlation (-0.52) between lake levels and maintenance dredging may account in part for the increased maintenance dredging during the 1960's. However, the high volumes projects may have also been influenced by the high new work projects between 1959 and 1963 which totaled over 29 million cubic yards and have required maintenance. In Ontario, the general dredging pattern is similar to that in Michigan. In the early 1960's, maintenance dredging by the D.P.W. was the highest in a 21-year period (Table 28). New work dredging quantities from 1961-70 by the C.E. was the highest of any Great Lake (3.4 million CY). The ratio between

Table 28. ANNUAL DREDGING VOLUMES IN LAKE HURON/ST. CLAIR, 1930-1972 (48, 49, 50)
T (cubic yards)

Fiscal year	Maintenance	New work	Private
Michigan			
1972	215,815	197,662	1,250
1971	355,205	305,951	309,000
1970	361,750	559,108	60,293
1969	833,370	5,491,599	109,438
1968	1,903,985	444,057	133,050
1967	407,765	1,159,580	134,260
1966	1,153,184	127,520	696,319
1965	923,356	752,735	536,655
1964	1,156,097	199,572	308,359
1963	128,900	2,297,624	369,125
1962	212,975	6,056,132	264,160
1961	206,379	17,115,099	75,500
1960	31,239	1,502,466	26,025
1959	282,453	2,018,647	
1958	214,751	0	
1957	161,089	2,675	
1956	390,197	0	
1955	245,607	0	
1954	91,910	0	
1953	72,460	0	
1952	107,835	0	
1951	671,919	0	
1950	556,243	0	
1949	277,857	0	
1948	164,855	0	
1947	162,278	0	
1946	107,712	0	
1945	207,487	0	
1944	399,449	0	
1943	408,838	0	
1942	393,442	1,093,204	
1941	354,681	451,762	
1940	1,439,037	556,683	
1939	1,137,374	41,667	
1938	477,981	539,996	
1937	133,801	925,574	
1936	241,860	3,881,839	
1935	358,606	5,276,934	
1934	61,620	8,098,716	
1933	711,160	9,281,574	

Table 28. (continued)

Fiscal year	Maintenance	New work	Private
1934	61,620	8,098,716	
1933	711,160	9,281,574	
1932	201,146	9,431,151	
1931	1,242,867	1,054,414	
1930	413,913	1,466,660	
Totals	19,580,448	80,330,602	3,023,434
Ontario			
1972	109,816	73,550	5,200
1971	23,303	50,500	1,000
1970	0	30,000	7,000
1969	43,911	700	0
1968	37,459	700	0
1967	210,797	40,453	500
1966	192,907	63,885	500
1965	771,681	26,894	10,000
1964	765,132	52,313	
1963	439,548	572	
1962	182,079	2,024	
1961	65,667	0	
1960	97,168	0	
1959	215,870	142	
1958	88,535		
1957	82,907		
1956	24,752		
1955	130,233		
1954	78,213		
1953	159,487		
1952	131,276		
1951	305,855		
Totals	4,156,596	341,733	24,200

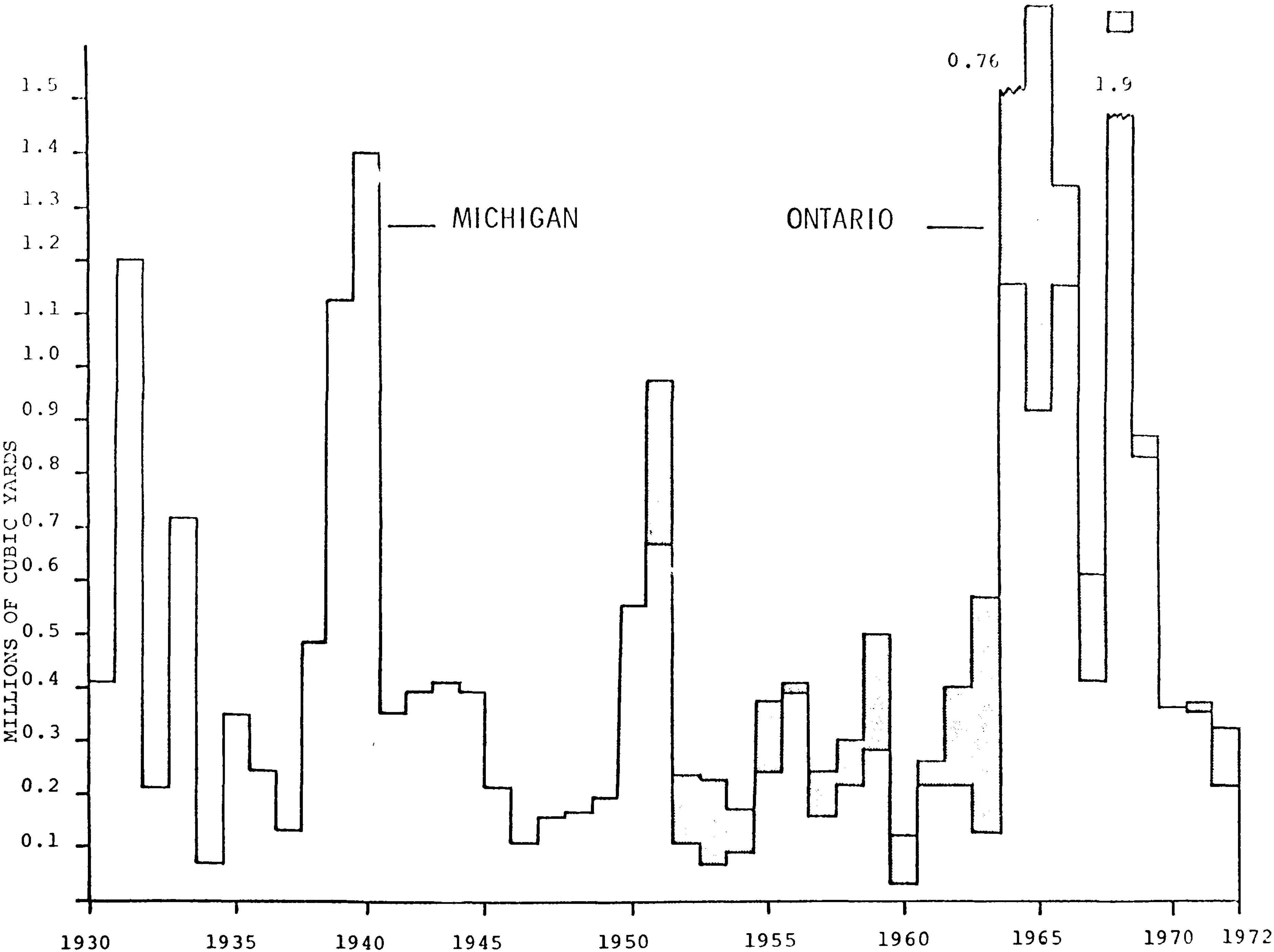


Figure 8. ANNUAL MAINTENANCE DREDGING VOLUMES IN LAKES HURON AND ST. CLAIR, 1930-1972

Table 29. C.E. MAINTENANCE DREDGING BY DECADES IN LAKE HURON/ST. CLAIR, 1930-1970 (50)
(cubic yards)

Years	Total	Average/Year
1960-1969	6,957,250	695,725
1950-1959	2,794,464	279,446
1940-1949	3,915,636	391,564
1930-1939	4,980,328	498,033

maintenance and new work dredging in Michigan from 1961-70 reveals that a year by year comparison (Table 28), with only 2 exceptions, new work dredging exceeds maintenance. As with maintenance dredging, the greatest dredging activity was confined to the connecting channels and Saginaw Harbor. In these 4 projects, approximately 34 million cubic yards of spoil were removed in the 10-year period. Capital dredging in Ontario is difficult to determine because the D.P.W. does not always distinguish it from maintenance dredging. However, as best as could be determined, 217,500 cubic yards of dredgings over the 1961-70 period were removed from 5 projects (i.e., Blind River, Collingwood, Inside Steamer Channel, Midland, and Sault Ste. Marie). Permit dredging in Lake Huron is generally characterized by the excavation of small boat slips associated with recreational marine activity. This is most evident in Lake St. Clair and the lower St. Clair River adjacent to metropolitan Detroit and Windsor. Here projects generally average less than 5,000 cubic yards.

Compared to most other Great Lakes, the private dredging volumes are low and are not necessarily associated with power companies or industry. Only 25 percent of the dredging in Lake Huron is related to industry, which reflects the recreational character of this lake. A similar pattern is evident in Ontario. The total permit dredging in Michigan from 1960 through 1972 is 3,023,434 cubic yards. In Canada, a minimum 24,200 cubic yards of spoil were removed by private interests from 1965 through 1972. As illustrated in Table 28, the average permit dredging volume in Michigan is 232,572 cubic yards annually. Three large private harbors with project depths of 26 feet are located in Michigan. These are Calcite, Port Dolomite, and Stoneport. Of the 3, only Calcite reported dredging activity since 1960. In a 2-year period, 1964 and 1965, 50,500 cubic yards were removed from that harbor. At Saginaw, the major industrialized project on Lake Huron, private dredging averages about 55,000 cubic yards annually.

Present dredging patterns (1972 through 1973) in terms of geographic distribution are similar to those of the past except that volumes have decreased. Table 30 reflects the dredging activities in the past 3 years of harbors in Michigan and Ontario.

Table 30. TOTAL DREDGING VOLUMES IN LAKE HURON/ST. CLAIR, 1971-1973 (48, 50) (cubic yards)

Year	U.S.	Canada	Total
1973	175,589	not available	at least 175,589
1972	414,727	188,566	603,293
1971	970,156	74,803	1,044,959

The average maintenance, new work, and permit dredging in the last decade in Michigan has averaged well over one million cubic yards annually. However, with environmental concerns discussed in Section V and perhaps record high lake levels since 1970, dredging volumes including permit dredging have declined to a total of 175, 589 cubic yards in

1973. In Canada, total dredging volumes in the past 2 years have also decreased.

Future Dredging in Lake Huron and Lake St. Clair--Michigan

Although future dredging is difficult to predict accurately, estimates can be made based on past and present dredging activities. Basically, the volume of spoil to be removed is the sum of projected maintenance dredging, projected new work, and private dredging. How policies, such as PL 91-611, will affect dredging in the next decade cannot be totally or accurately assessed at this point. In the past 2 years maintenance and permit dredging volumes in Michigan have declined, indicating that federal and state policy does play a role in dredging activity. Therefore, a maximum and minimum dredging figure is determined for Lake Huron and Lake St. Clair. Also, based on the historical data, a probable dredging estimate is presented for the next decade.

Future maintenance dredging in Lake Huron and Lake St. Clair is basically related to the projected dredging frequency and volume of spoil removed. Table 31 illustrates the maintenance dredging frequencies of the C.E. projects over the past 13 years. This table reveals that the more commercially significant waterways and harbors, such as Saginaw and the St. Clair River are dredged consistently. Other projects which are economically less important, such as Cheboygan and Alpena are not dredged as often. Most remaining harbors, such as Port Sanilac and Harbor Beach have recreational status and the dredging frequency is low.

In Lake Huron, the dredging period 1961 to 1970 may be selected to obtain a dredging frequency. During the early part of that decade the St. Lawrence Seaway was completed and 27-foot project depths now occur at Saginaw and all Lake Huron and Lake St. Clair connecting channels except Inland Route. Smaller projects, such as Inland Route and Clinton River were actively dredged during the late 1960's and into the 1970's.

Table 31. MAINTENANCE DREDGING FREQUENCIES OF C.E. PROJECTS IN LAKE HURON/ST. CLAIR (50) 1961-1973

Project	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Alpena			x	x	x	x			x	x			
Au Sable	x	x			x	x	x	x	x	x	x	x	x
Bay Port													
Black River													
Ch. of Lake St. Clair			x	x	x	x	x	x	x		x		
Caseville											x		
Cheboygan		x		x		x		x			x		
Clinton River					x	x					x		
Hammond													
Harbor Beach							x	x				x	
Harrisville					x							x	
Inland Route										x	x	x	x
Les Cheneaux								x					
Point Lookout											x	x	
Port Sanilac		x		x	x								
Saginaw	x	x	x	x	x	x		x	x	x	x	x	x
St. Clair R.			x	x	x	x	x	x	x	x	x	x	x
St. Marys R.								x	x	x			x
Sebewaing						x				x			

During most of the 1960's environmental policies such as PL 91-611 and PL 92-500 were not instituted to prohibit dumping or cause dredging to take place in localities where confined sites were available for polluted spoil. Therefore, the decade 1961-70 may be a representative dredging decade since economic stability was reached and environmental policy was less effective in controlling dredging and disposal practices.

As illustrated in Table 31, from 1961 to 1970 the average dredging frequency in Lake Huron and Lake St. Clair was 6 projects per year. The total volume generated during maintenance dredging operations by the C.E. was 7.28 million cubic yards. Therefore in an average year during that decade, 0.73 million yards were removed by an average of 6 projects. Assuming that the status quo is to be maintained in the 1970's and 1980's, an annual projection of about 0.73 million cubic yards may be realistic. However, such a projection does not consider new work projects of the late 1960's and the early 1970's such as at Saginaw and at Sault Ste. Marie. In addition, the more significant environmental policies directly affecting Great Lakes' dredging, such as PL 92-500, were legislated in the 1970's. Thus, a 0.73 million cubic yard projection is somewhat biased since current operational and legislative variables are not considered.

Table 32 represents the dredging the C.E. feels is necessary to maintain harbors and waterways at their project depths over the next decade. Based on this projection, 1.2 million cubic yards are to be removed annually. When compared to Table 28 a record decade is anticipated. Since this projection is almost twice what has been dredged in any of the past 4 decades (1960 to 1969 saw the removal of 6.9 million CY) and most anticipated new work projects are recreational, this projection represents a maximum volume to be removed from Lake Huron/St. Clair in the next decade.

A more accurate estimate of future maintenance dredging is based on projects which have high frequencies and high volumes. Traditionally,

Table 32. C.E. PROJECTED FUTURE MAINTENANCE DREDGING IN LAKE HURON/ST. CLAIR (50) (cubic yards)

Project	C.E. annual projection
Alpena	8,000
Au Sable	30,000
Bay Port	6,000
Black River	3,000
Caseville	12,000
Channels of Lake St. Clair	200,000
Cheboygan	10,000
Clinton River	21,000
Hammond	10,000
Harbor Beach	5,000
Harrisville	12,000
Inland Route	10,000
Les Cheneaux	10,000
Mackinaw City	4,000
Port Austin	4,000
Port Sanilac	7,200
Saginaw	700,000
Sebewaing	20,000
St. Clair River	75,000
St. Marys River	65,000
Total	1,212,200 per year

the most significant projects in Lake Huron are Saginaw and the connecting waterways which reflect high dredging frequencies and high volumes because of their commercial significance. Saginaw, the St. Clair River, Lake St. Clair and Au Sable, based on the last decade, have frequencies of 7 or higher (Table 31). These 4 projects and Sault Ste. Marie account for most of the maintenance dredging which occurs in Lake Huron/ St. Clair. Table 33 reveals that these projects, on a short term basis (1961-70) and on a long time basis (1920-72), have accounted for 86 and 90 percent respectively of all C.E. maintenance dredging in these lakes. Furthermore, the C.E. would like to maintain the same ratio in the future. Based on the C.E. future maintenance dredging (Table 32), 88 percent of the spoil will be removed from these projects. Therefore, it may be concluded that about 88 percent of all C.E. maintenance dredging in the past and future was and will continue to be from the 5 most significant projects. The volume removed from all remaining projects will account for approximately 12 percent of the dredging volume.

Table 33. PAST, PRESENT AND FUTURE MAINTENANCE DREDGING OF MAJOR PROJECTS IN LAKE HURON/ST. CLAIR (50) (cubic yards)

	1920-1972	1961-1970	1973-1983
Au Sable	273,671	97,680	30,000
Ch. Lake St. Clair	3,808,457	1,068,280	200,000
Saginaw	6,999,798	2,947,350	700,000
St. Clair R.	4,112,237	919,150	75,000
Totals	15,194,163(66%)	5,032,460(69%)	1,005,000(83%)
Sault Ste. Marie	5,418,514(24%)	1,219,120(17%)	65,000 (5%)
Percent from above projects	90%	86%	88%

To obtain mean maintenance dredging quantities for the 5 major projects in Lake Huron and Lake St. Clair, the dredging volumes since the last new work were determined. It is felt that at least 5 years of maintenance dredging would be required to obtain a representative average quantity. At Saginaw, for example, the last new work project occurred in 1970, however, the average maintenance dredging volume was determined from 1964 to 1972. The table below (Table 34) represents the average maintenance dredging of the 5 major C.E. projects.

Table 34. ANNUAL MAINTENANCE DREDGING OF MAJOR C.E. PROJECTS, LAKE HURON/ST. CLAIR (cubic yards)

Project	Base period	Volume
Au Sable	1961-1972	20,828
Ch. Lake St. Clair	1964-1972	117,677
Saginaw	1964-1972	334,872
St. Clair R.	1965-1972	108,513
Sault Ste. Marie	1968-1972	243,824
Total		825,714

The total of the projects in Table 34 is 825,714 cubic yards which represents annual maintenance dredging for the next decade. An additional 12 percent, or 99,085 cubic yards is an approximate dredging quantity for the remaining C.E. projects. Therefore, the anticipated maintenance dredging for the C.E. projects in Lake Huron and Lake St. Clair over the next decade, will average 9,247,990 cubic yards, or approximately 925,000 cubic yards annually.

The above technique for obtaining averages may also be applied to individual projects in Michigan since in every case new work is recorded separately from maintenance dredging. In some projects, such as at Alpena, Inland Route, and Port Sanilac, no new work was recorded for 10 to 15 years. In such projects maintenance dredging occurred fairly consistently for several years in the recent past (Table 31). At Alpena, for example, maintenance dredging occurred 6 times from 1963 to 1972. These data were tabulated and a future average calculated. Table 35 is the result of that calculation. The projections by harbor reveal that the 5 principal projects (Au Sable, St. Clair River, Lake St. Clair, Saginaw, and the St. Marys River) represent 85 percent of the total quantity to be removed. This compares favorably with the 86 to 90 percent figure indicated on Table 34. Also, the total annual maintenance dredging volume (967,758 cubic yards) is comparable to the 925,000 cubic yards derived from clustering the 5 principal projects. Although, in some instances, compared with the C.E. projection, differences occur (e.g., Saginaw) based upon maintenance dredging histories over the past few years the projection reflects modern harbor conditions in Lakes Huron and St. Clair.

With the recent introduction and enforcement of environmental constraints (PL 91-611) maintenance dredging activities in the past few years have decreased. This pattern is reflected in all the Great Lakes including Lake Huron and Lake St. Clair. Corps of Engineers dredging activity in FY 1972 and FY 1973 was 379,314 and 165,549 cubic yards respectively. These figures include new work as well as maintenance dredging. Assuming that: (1) 10-year disposed sites in areas of polluted sediments are not constructed; (2) E.P.A. upholds the present pollution criteria and that local interests at Saginaw cannot meet the cost of a containment area as specified in PL 91-611 Sec. 123 (C) (2) or the request for a waiver is not recommended by the E.P.A.; and (3) no economic stress occurs, the average maintenance dredging volume will remain at about 250,000 cubic yards per year. Thus, the figure of 250,000 cubic yards represents a minimum annual average for Lake Huron based principally on events over the last 3 or 4 years.

Table 35. FUTURE ESTIMATED MAINTENANCE DREDGING BY HARBOR OF C.E. PROJECTS (50) (cubic yards)

Project	Base period	Average annual maintenance dredging	C.E. projection
Alpena	1963-1972	9,768	8,000
Au Sable	1961-1972	20,828	30,000
Bay Port	--	0	6,000
Black River	--	0	3,000
Caseville	1965-1972	3,236	12,000
Channels of Lake St. Clair	1964-1972	117,677	200,000
Cheboygan	1962-1972	11,614	10,000
Clinton River	1968-1972	7,602	21,000
Hammond Bay	--	0	10,000
Harbor Beach	1967-1972	32,083	5,000
Harrisville	1965-1972	3,453	12,000
Inland Route	1968-1972	22,611	10,000
Les Cheneaux	1968-1972	20,545	10,000
Mackinaw	--	0	4,000
Point Lookout	--	0	0
Port Austin	--	0	4,000
Port Sanilac	1962-1972	6,973	7,200
Saginaw	1964-1972	334,871	700,000
St. Clair River	1965-1972	108,513	75,000
St. Marys River	1968-1972	243,824	65,000
Sebewaing	1966-1972	24,160	20,000
Totals		967,758	1,212,200

Several factors suggest that more than the minimum yardage will be removed from Lake Huron. Of the 4 principal harbors and waterways, Sault Ste. Marie, Saginaw, Lake St. Clair and the St. Clair River, sediment pollution is identified as a problem at only 2 projects (Saginaw and Lake St. Clair). Confined disposal sites are planned for Saginaw and Lake St. Clair and are to be completed in June, 1977 and June 1975 respectively. Saginaw has requested the E.P.A. to recommend a waiver (PL 91-611) which, if recommended and granted, will alleviate 25 percent of the construction costs to Saginaw of a confined disposal site. Also, constructive criticism of the E.P.A. pollution criteria for dredged material is being evaluated and may be modified in the near future. Lake levels in the next decade, which are of some significance, will probably drop from their record highs of the early 1970's requiring more maintenance dredging to alleviate the problems of economic stress to industrial and shipping firms.

Future Permit Dredging in Michigan

Permit dredging over the next decade is difficult to predict. This is especially the case in Lake Huron where some 25 percent of the private dredging is from industrial areas such as Saginaw. Such private dredging is dictated by the same policy as C.E. maintenance dredging. If the spoil is polluted it must be confined. Since a confined site is scheduled for Saginaw, it may be expected that permit dredging volumes in that area will be low until the site is constructed. Permit dredging (Table 28) in 1972 was at a record low (1,250 CY) suggesting again that environmental policies (Section V), and perhaps high lake levels influence private dredging volumes. The C.E., however, suggests that 200,000 cubic yards of permit dredging will occur annually in Lake Huron and Lake St. Clair. Based on a 10-year period (1961-70), 268,000 cubic yards were removed annually. Since the C.E. does not anticipate expanding any commercial harbors in the next decade and no significant private expansion is expected, permit dredging will remain between 200,000 and 268,000 cubic yards or about 235,000 yards annually.

Scheduled New Work Dredging in Lake Huron and Lake St. Clair

Table 36 illustrates new work or capital dredging in Lake Huron and Lake St. Clair over the next decade. New work must be justified and it normally takes several years before a project is authorized and completed. Quite possibly some projects may be curtailed or delayed because of environmental, economic, and/or feasibility factors. A capital dredging project at Sault Ste. Marie, Ontario was proposed in the

Table 36. FUTURE NEW WORK IN LAKE HURON/ST. CLAIR, 1973-1983 (48, 50) (cubic yards)

Project	Volume	Date of completion
Sault Ste. Marie		
a) Angle Courses	893,500	1976
b) Point Iroquois	3,995,000	1973
c) Ontario	1,150,000	1975
De Tour	4,000	1979
Black River, Alcona Co.	110,000	1980
Forestville	73,400	1979
Middle Island Harbor	40,000	1983
Grindstone City	75,000	1979
Lexington	4,700	1976
Black River, Port Huron	140,000	1974
Middle Channel St. Clair River, Michigan	60,000	1976
Lake St. Clair, Ontario	60,000	1974
Total	6,605,000	

late 1950's and is yet to be initiated in the field. Therefore, the new work dredging, which totals 6,605,600 cubic yards, represents a maximum anticipated value over the next decade.

With few exceptions such as at Sault Ste. Marie, most new work does not involve expansion of established commercial projects. These new projects are to accommodate shallow watercraft (8-12 feet) and are designed for recreational use. Future economic and industrial expansion of American and Canadian harbors on Lake Huron is not anticipated by the C.E. or the Ministry of Transport (M.O.T.). Therefore, expansion to 27-foot channels is not expected over the next decade. The new work dredging data suggest, that an economic plateau in terms of project depths will occur, and that dredging in Lake Huron will level off with the completion of the high volume projects at Sault Ste. Marie in 1975 and 1976.

Future Dredging in Lake Huron and Lake St. Clair, Ontario

As in the U.S., most of the 50 Canadian projects dredged by the D.P.W. are recreational and are not dredged frequently or with any consistency. However, based on a 10-year average, approximately 27 percent of all Lake Huron maintenance dredging occurs in Canada. If the 924,799 future annual average is maintained in the U.S. projects in Lake Huron/St. Clair, it may be expected that 250,000 cubic yards will be removed during maintenance dredging activities from Ontario ports in Lake Huron/St. Clair. The annual average maintenance dredging in the past 22 years (1951-1972) was 188,934 (Table 28). However, based on future plans both figures appear to be low. The D.P.W.-scheduled maintenance dredging activity on Table 37 includes the period from 1973 through 1977. According to these data, an average of 317,575 cubic yards will be removed by 1977 which is a substantial increase over the past 2 decades. Although future new work is presented in Table 36, some new work may be incorporated in Table 37 since capital dredging is often difficult to

Table 37. FUTURE DREDGING IN CANADIAN PROJECTS IN LAKE HURON/ST. CLAIR, 1973-1977 (48, 49)
(cubic yards)

Project	Volume
Belle River	26,000
Byng Inlet	48,874
Cedar Beach	7,000
Collingwood	70,000
Goderich	70,000
Grand Bend	40,000
Kincardine	15,000
Midland	5,000
Oliphant	10,000
Pike Creek	16,000
St. Clair Cut-off	1,200,000
Sault Ste. Marie	12,500 (1973) and 13,500 (1976)
Sarnia	26,000
Sydenham	28,000
Total	1,587,874

separate from Canadian maintenance dredging. This being the case, 317,575 cubic yards represents a maximum annual figure.

Permit dredging in Lake Huron and Lake St. Clair is presented in Table 28. Permit dredging, administered by the M.O.T., averages about 2,000 cubic yards annually. Most projects on Lake Huron are for small private boat slips which may require the removal of 300 to 500 CY per project. The M.O.T. expects private dredging to level off to 8 to 10 projects on Lake Superior and Lake Huron over the next few years. The future permit dredging under the NWPA is anticipated to remain at about 2,000 cubic yards per year.

In summary, future maintenance dredging on the Ontario shore of Lake Huron and Lake St. Clair will probably range between 250,000 to 318,000 cubic yards per year. Most D.P.W. personnel believe that all scheduled dredging will occur. Thus, the latter figure is probably more accurate based in part on the following: (1) dredging projects are dispersed, the volumes are generally small, and few disposal problems occurred thus far; (2) although some projects exceed the M.O.E. pollution parameters, few harbors have been sampled and open-lake disposal is occurring; (3) by 1977, 1.2 million cubic yards will have been dredged from the economically important St. Clair Cut-off channel. Although the sediment exceeds the M.O.E. pollution criteria, confined facilities are currently being tested at Mitchell Bay in Lake St. Clair; it appears that the D.P.W. and the M.O.T. (as in Toronto Harbor) are anticipating a confined disposal program for polluted spoil in the future; (4) lake levels will probably drop in the next few years and commercial projects particularly at Collingwood, Midland, and St. Clair Cut-off will have to be maintained if economic stress is to be avoided.

Summary

Future maintenance and permit dredging in Lake Huron and Lake St. Clair is estimated to be approximately 1.5 million yards per year (Table 38). Since most of the confined disposal sites will not completed until 1976 or 1977, it can be expected that maintenance and private dredging volumes will remain low for the next 2 to 3 years. By the end of the decade, confined disposal sites are to be available for polluted dredgings and with anticipated lower lake levels, maintenance and permit dredging activity will increase.

In addition to the above, the following trends are anticipated in Lake Huron and Lake St. Clair:

Table 38. FUTURE DREDGING ESTIMATES IN LAKE HURON/ST. CLAIR
(cubic yards)

	Michigan		Ontario
Maintenance	925,000		318,000
Permit	235,000		2,000
Annual totals	1,160,000		320,000
Total for Lake Huron		1,480,000 annually	
New work	5,395,600		1,210,000

1. Maintenance dredging will increase. The C.E. projects 1.2 million cubic yards of annual maintenance dredging in the next decade. Our projection (0.9 million cubic yards) is about 25 percent or 300,000 cubic yards lower than the C.E. projection.
2. Scheduled new work dredging will remain high (0.6 million cubic yards annually). With the completion of new work projects at Sault Ste. Marie in 1976, most new work will occur at recreational or shallow draft harbors.
3. High maintenance dredging will remain at the St. Clair River, Lake St. Clair, Sault Ste. Marie, and Saginaw. These projects will account for approximately 88 percent of future maintenance dredging.

DREDGING QUANTITIES IN LAKE MICHIGAN

For the benefit of commercial navigation, recreation, and fishing in Lake Michigan, 6 private harbors and 42 public harbors and waterways must be dredged (Figure 9). Although private recreational harbors have not been mapped in Figure 9, quantities dredged from these harbors have been incorporated into the private dredging data. Private commercial harbors are few in number and require relatively little dredging. Of

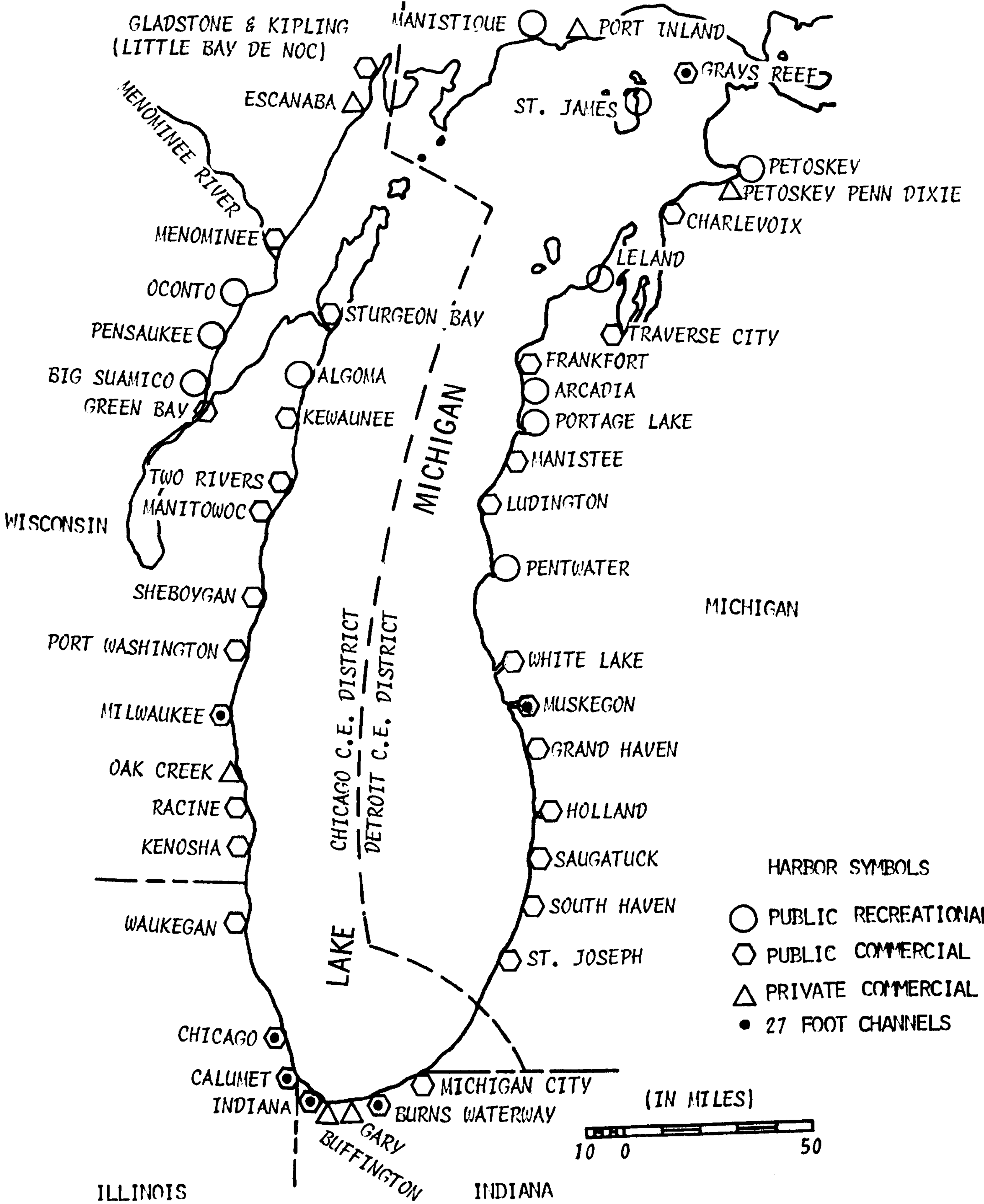


Figure 9. PRIVATE COMMERCIAL AND PUBLIC HARBORS AND C.E. DISTRICTS IN LAKE MICHIGAN

the public commercial and recreational harbors and waterways, which are maintained by the C.E., 22 are located in the Chicago District and 20 are part of the Detroit District.

The economic status and commerce of the private and public harbors are presented by C.E. district in Table 39. Public harbors and waterways which can accommodate vessels with Seaway drafts of 27 feet include Burns Waterway, Calumet, Chicago, Grays Reef, Indiana, Milwaukee, and Muskegon. In the Chicago District, those commercial harbors which are declining in commerce are Kenosha, Michigan City, Racine, Sheboygan, and Two Rivers. In the Detroit District, harbors which are declining in commercial importance include Charlevoix, Manistique, Pentwater, Saugatuck, South Haven, and White Lake.

Dredging operations by private interests probably were initiated soon after white settlement of the territories, but records of dredging quantities are available only to 1957. Many of the public harbors, such as Holland Harbor which was constructed in 1852, have long been in existence. Though the removal of sediments from public harbors began after the mid-1800's, records maintained by the C.E. are available only from 1918.

Private Dredging Quantities

Available data regarding volumes of spoil dredged by private interests in the Chicago and Detroit Districts are presented in Table 40. Because of the low priority of Section 10 permit records, these data are incomplete and available only from 1957. In the past, especially in northern Wisconsin and upper Michigan, private interests, such as operators of marinas, frequently dredged boat slips and other facilities without applying for a Section 10 permit. In addition, the C.E. lacks the manpower to field check permittees to ensure compliance with the permit, including the yardage actually dredged. Private dredging is considered to be reported in place measure.

Table 39. ECONOMIC STATUS AND 1972 COMMERCE OF HARBORS BY C.E. DISTRICT, LAKE MICHIGAN (5)

Public Harbors	Economic status	Tons of commerce
Chicago District		
Algoma	Recreational/Fishing	826
Big Suamico	Recreational/Fishing	0
Burns Waterway[a]	Commercial	4,759,827
Calumet H. & R.[a]	Commercial	25,431,158
Chicago H. & R.[a]	Commercial	4,516,892
Gladstone-Kipling	Commercial	292,031
Green Bay	Commercial	2,823,604
Indiana[a]	Commercial	17,610,662
Kenosha	Commercial	103,648
Kewaunee	Commercial	1,205,791
Manitowoc	Commercial	1,818,313
Menominee	Commercial	152,568
Michigan City	Commercial/Recreational	371
Milwaukee[a]	Commercial	5,373,630
Oconto	Recreational/Fishing	1,041
Pensaukee	Recreational/Fishing	2,943
Port Washington	Commercial/Recreational	717,312
Racine	Commercial/Recreational	100,192
Sheboygan	Commercial/Recreational	221,128
Sturgeon Bay/Ship Canal	Commercial	216,650
Two Rivers	Commercial	99,447
Waukegan	Commercial	436,710
Total		65,884,744
Private harbors		
Buffington	Commercial	1,731,519
Escanaba	Commercial	10,954,237
Gary	Commercial	8,751,620
Oak Creek	Commercial	920,766
District total		88,242,886

Table 39. (continued)

Public harbors	Economic status	Tons of commerce
Detroit District		
Arcadia	Recreational	0
Charlevoix	Commercial/Recreational	185,523
Frankfurt	Commercial	1,353,101
Grand Haven	Commercial	2,977,109
Grays Reef[a]	Commercial (Passageway)	6,080,391
Holland	Commercial/Recreational	261,738
Leland	Recreational	1,134
Ludington	Commercial	3,368,015
Manistee	Commercial/Recreational	522,741
Manistique	Recreational/Fishing	135
Muskegon[a]	Commercial	2,835,823
Pentwater	Recreational/Fishing	0
Petoskey	Recreational	0
Portage Lake	Recreational	0
Saugatuck	Commercial/Recreational	212
South Haven	Commercial	45,915
St. James (Beaver Island)	Recreational	2,559
St. Joseph	Commercial	475,139
Traverse City	Commercial/Recreational	446,244
White Lake	Commercial/Recreational	3,615
Total		18,559,394
Private harbors		
Petoskey Penn Dixie	Commercial	473,074
Port Inland	Commercial	4,199,020
Total		4,672,094
District total		23,231,488
Totals for lake		111,474,374

[a]Harbors with project depths of 27 feet.

Table 40. PRIVATE DREDGING VOLUMES IN LAKE MICHIGAN BY C.E. DISTRICT, 1957-1973 (51, 52)
(cubic yards)

Fiscal year	Chicago District	Detroit District	Total
1973	193,425	80,000	273,425
1972	336,278	762,505	1,098,783
1971	400,727	72,000	472,727
1970	602,700	29,560	632,260
1969	160,237	41,000	201,237
1968	787,087	57,288	844,375
1967	468,245	842,500	1,310,745
1966	399,982	31,450	431,432
1965	1,053,598	41,000	1,094,598
1964	390,971	24,800	415,771
1963	279,677	0	279,677
1962	437,039	50,200	487,239
1961	1,567,196	8,345	1,575,541
1960	1,047,411	a	1,047,411
1959	1,050,156	a	1,050,156
1958	1,149,827	a	1,149,827
1957	969,982	a	969,982
Totals	11,294,538	2,040,648	13,335,186

[a] Data not available.

Based on the period 1957 through 1973, private dredging in Lake Michigan averaged 784,420 cubic yards annually; this quantity is approximately 18 percent of the total average annual dredging volume. Private dredging operations include the excavation and maintenance of private harbors and marinas as well as private boat slips and berthing facilities in public harbors. However, most of the spoil is derived from private docking facilities in public harbors, and not from private harbors. Volumes derived from dredging for bulkhead construction and fill operations were not considered herein to constitute private dredging. In addition, inland dredging, i.e., dredging upstream from a rivermouth harbor, was not included in the private dredging volumes.

Large volumes, i.e., over 100,000 cubic yards per permit, were frequently dredged by Inland Steel, U.S. Steel, and Youngstown Sheet and Tube from Indiana and Calumet Harbors. Municipalities and power companies, e.g., Commonwealth Edison, occasionally generate moderately large dredging projects. Conversely, smaller industries and firms, such as yacht clubs, make numerous permit applications, but these projects usually involve less than 25,000 cubic yards of spoil per permit.

In most instances the sediment removed by private interests was dumped on the permittee's property. During its review of Section 10 permit applications, the E.P.A. generally recommends that spoil be confined and not returned to the waters of the Great Lakes or rivers, nor disposed on nearshore environments where it may be washed or leached into the lakes or rivers. A few large industries and municipalities have requested permission to dump spoil in federal disposal sites. At present the C.E. must allow some capacity in their confined disposal sites for such requests.

The C.E. does not dredge private navigational facilities. In the Chicago District, 3 large industries were recently assessed, pro rata, the cost of dredging by the C.E. for causing sedimentation in federal harbors. Sloughing of sediment from privately-maintained channels into

Table 41. ANNUAL MAINTENANCE AND NEW WORK DREDGING VOLUMES IN PUBLIC HARBORS OF LAKE MICHIGAN BY C.E. DISTRICT, 1918-1973 (50, 52) (cubic yards)

Fiscal year	Chicago District		Detroit District		Totals
	Maintenance	New work	Maintenance	New work	
1973	811,274	624,296	597,360	0	2,032,930
1972	545,018	1,410,831	391,552	44,378	2,391,779
1971	217,621	908,056	461,161	15,650	1,602,488
1970	495,926	1,631,174	799,890	4,524	2,931,514
1969	695,696	1,089,236	594,515	145,701	2,525,148
1968	956,687	1,865,902	613,856	61,300	3,497,745
1967	669,262	2,197,681	702,797	16,524	3,586,264
1966	319,693	6,187,987	667,606	10,571	7,185,857
1965	1,387,892	3,257,264	618,952	190,837	5,454,945
1964	1,344,556	1,698,138	800,215	387,412	4,230,321
1963	1,195,469	958,784	436,261	72,211	2,662,725
1962	876,049	458,764	535,996	0	1,870,809
1961	810,417	94,103	226,756	263,325	1,394,601
1960	742,389	64,581	597,183	0	1,404,153
1959	909,232	0	322,048	0	1,231,280
1958	658,950	87,791	459,770	47,610	1,254,121
1957	1,117,768	491,654	377,273	256,148	2,242,843
1956	618,085	91,643	365,309	0	1,075,037
1955	411,044	45,133	370,839	0	827,016
1954	279,379	0	400,509	0	679,888
1953	556,525	0	287,084	0	843,609
1952	296,630	0	320,206	0	616,836
1951	618,396	0	595,548	0	1,213,944
1950	892,748	0	553,092	245,772	1,691,612
1949	493,557	0	642,085	208,909	1,344,551
1948	939,100	0	549,827	0	1,488,927
1947	257,096	191,184	333,118	0	781,398
1946	578,888	5,238	257,218	0	841,344

Table 41. (continued)

Fiscal year	Chicago District Maintenance	Chicago District New work	Detroit District Maintenance	Detroit District New work	Totals
1945	784,955	0	376,412	0	1,161,367
1944	1,009,934	152,360	362,951	0	1,525,245
1943	1,051,572	318,153	436,976	0	1,806,701
1942	582,444	347,400	433,912	0	1,363,756
1941	593,480	468,854	396,607	0	1,458,941
1940	675,885	523,716	550,216	189,154	1,938,971
1939	862,944	1,836,835	523,709	671,072	3,894,560
1938	428,347	343,079	540,722	54,136	1,366,284
1937	900,210	3,817,223	517,811	16,137	5,251,381
1936	648,157	4,114,580	491,037	0	5,253,774
1935	920,479	2,623,095	578,589	0	4,122,163
1934	589,964	328,448	589,307	0	1,507,719
1933	889,403	319,542	473,431	282,727	1,965,103
1932	374,907	1,037,174	520,757	156,320	2,089,158
1931	1,499,869	379,111	256,889	350,213	2,486,082
1930	914,778	233,214	499,284	0	1,647,276
1929	343,903	335,837	228,847	0	908,587
1928	623,858	0	305,393	0	929,251
1927	907,814	411,300	0	0	1,319,114
1926	495,986	0	0	0	495,986
1925	418,326	366,957	0	0	785,283
1924	388,279	185,120	0	0	573,399
1923	396,709	0	0	0	396,709
1922	471,070	0	0	0	471,070
1921	329,809	0	0	0	329,809
1920	166,142	201,019	147,555	0	514,716
1919	268,422	0	153,400	17,046	438,868
1918	165,267	88,610	124,997	117,514	496,388
Totals	37,398,260	41,791,067	22,386,828	3,825,191	105,401,346

public channels maintained by the C.E. slightly reduces the quantity of private dredging in the public harbors. In several harbors, especially in Calumet, Chicago and Indiana Harbors, both public and private dredging volumes are decreasing due to reduced industrial sedimentation and sewage deposits. The federal project limit in Calumet Harbor was recently extended inland, resulting in a reduction of some private dredging.

Public Dredging Quantities

Since 1918, 105 million cubic yards of sediment have been dredged from the public harbors and waterways of Lake Michigan (Table 41). Of the total quantity dredged, 57 percent, or 60 million cubic yards, was derived from maintenance dredging operations, whereas the remainder involved new work dredging. When the dredging quantities are compared by district, the larger volumes in the Chicago District are obvious. In the Detroit District, maintenance dredging quantities are moderate. Relatively little new work dredging has been done. Historical dredging records in Chicago for years prior to 1935 are incomplete. In the Detroit District records, there is a hiatus from 1920 through 1927.

The period 1935 through 1973 may be selected as a base for the calculation of long-term dredging averages or means. In the Chicago District the long-term mean for annual maintenance and new work dredging volumes are 721,900 and 971,900 cubic yards, respectively. In the Detroit District the average annual maintenance is 489,400 cubic yards, while new work dredging quantities average 74,400 cubic yards. With regard to all of Lake Michigan, the mean annual maintenance dredging quantity is 1,211,300 cubic yards and the mean new work dredging volume is 1,046,300 cubic yards. Even though the project depths in most harbors have increased over the years, the historical maintenance dredging does not exhibit a steady upward trend.

The volume of annual maintenance dredging in the Chicago District has been more variable than that of the Detroit District. Years with above average maintenance dredging are characterized by the coincidence of 2 or more very large dredging projects within the same fiscal year. Much of the dredged spoil from the Chicago District is derived from industrial sediments and municipal sewage as well as from littoral and fluvial (stream) transport processes. In the Detroit District, the source of harbor sediments is primarily the result of littoral drift which apparently is fairly constant from year to year.

Shoaling within the harbors, lake levels below mean low datum, and availability of federal funds appear to be positively correlated with the scheduling of maintenance dredging projects. Based on the period 1935-1973, an annual average of 22 harbors underwent maintenance dredging in Lake Michigan. In the Chicago District, fewer harbors than usual were scheduled for maintenance dredging during the period 1970 through 1973 as the open-lake disposal of dredged spoil was being re-evaluated. During the low lake level years of 1963 to 1965, the C.E. maintained harbors at maximum project depths to avoid groundings. The Korean War effort in the early 1950's was accompanied by a reduction in the funding of federal projects. During this period, the C.E. dredged fewer projects, and very few projects were contracted to private dredgers.

Unlike maintenance dredging, most of the new work dredging was performed in 3 time periods. First, stimulated by shipping needs of the lumber industry as well as by demands for ferry and excursion boats, a number of public harbors were constructed in the late 1800's. The second period, the 1930's, was characterized by the deepening and widening of many harbors. During this time harbor depths commonly ranged from 18 to 25 feet. Finally, the period with the largest volume of new work dredging was the 1960's and early 1970's when many industrial harbors were deepened to meet the 27-foot draft requirement of the St. Lawrence Seaway system. New work was carried out in Burns Waterway, Calumet Harbor and River, Chicago Harbor and River, Green Bay, Indiana, and Milwaukee Harbors. Between these 3 periods, as in the 1920's as well as in the 1940's and 1950's, few new work projects were scheduled.

As indicated by Table 42, the total quantity of spoil dredged varies tremendously from harbor to harbor. In general, public harbors with heavy industries and 27-foot project depths have the largest dredging requirements. Conversely, small quantities are extracted from recreational harbors wherein project depths usually range from 12 to 14 feet. In this study, Chicago Harbor and River are separated into 2 areas. No dredging quantities were indicated in the Corps of Engineers' records for Arcadia, Petoskey, St. James, and Traverse City Harbors.

The maintenance/new work ratio (M/NW) may be employed to identify those harbors which have undergone little expansion or those which are costly to maintain because of high maintenance dredging requirements. It is obtained by dividing the total new work dredging quantity into the total maintenance dredging volume for each harbor. The M/NW ratio for all public harbors of Lake Michigan is 1.3, whereas the Chicago District averages 0.9 and the Detroit District mean is 5.9 (Table 42). In general, harbors in the Detroit District exhibit relatively high maintenance dredging requirements and little harbor expansion or deepening has occurred in that area.

Present Dredging Quantities

The quantity of sediment currently being dredged in Lake Michigan is based on a 10-year average from the period 1961 through 1970. The years 1971 through 1973 were not included in the average because maintenance dredging volumes were below normal, especially in the Chicago District, due to the temporary ban on open-lake disposal of dredged spoil.

Table 43 shows the average annual private, maintenance, and new work dredging quantities by C.E. district. The average annual private

Table 42. TOTAL MAINTENANCE AND NEW WORK DREDGING VOLUMES BY HARBOR IN LAKE MICHIGAN BY C.E. DISTRICT, 1918-1973 (50, 52) (cubic yards)

Public harbors	Maintenance	New work	Totals	M/NW ratio
Chicago District				
Algoma	200,210	0	200,210	-
Big Suamico	64,525	46,905	111,430	1.4
Burns Waterway	0	4,282,503	4,282,530	-
Calumet H. & R.	7,241,529	14,113,323	21,354,852	0.5
Chicago Harbor	299,192	302,687	601,879	1.0
Chicago River	2,616,419	0	2,616,419	-
Gladstone-Kipling	0	238,782	238,782	-
Green Bay	5,361,078	9,918,981	15,280,057	0.5
Indiana	5,286,346	3,708,074	8,994,420	1.4
Kenosha	977,292	305,723	1,283,015	3.2
Kewaunee	1,514,248	419,429	1,933,677	3.6
Manitowoc	1,311,635	501,802	1,813,437	2.6
Menominee	1,197,664	246,421	1,444,085	4.9
Michigan City	1,247,349	302,673	1,550,022	4.1
Milwaukee	1,376,628	4,399,995	5,776,623	0.3
Oconto	189,818	0	189,818	-
Pensaukee	43,548	82,795	126,343	0.5
Port Washington	402,561	288,836	691,397	1.4
Racine	1,185,448	174,755	1,360,203	6.8
Sheboygan	1,636,601	810,860	2,447,461	2.0
Sturgeon Bay/ Ship Canal	2,071,014	1,393,348	3,464,362	1.5
Two Rivers	2,176,515	149,460	2,325,975	14.6
Waukegan	1,099,636	40,274	1,139,910	27.3
District totals	37,499,254	41,727,626	79,226,880	

Table 42. (continued)

Public harbors	Maintenance	New work	Totals	M/NW ratio
Detroit District				
Arcadia	0	0	0	-
Charlevoix	230,165	4,505	234,670	51.1
Frankfurt	680,400	379,529	1,059,929	1.8
Grand Haven	7,101,322	989,464	8,090,786	7.2
Grays Reef	306,060	0	306,060	-
Holland	2,131,571	841,492	2,973,063	2.5
Leland	68,884	33,744	102,628	2.0
Ludington	954,219	93,510	1,047,729	10.0
Manistee	1,551,017	386,293	1,937,310	4.0
Manistique	399,839	255,967	625,806	1.8
Muskegon	1,408,822	572,925	1,981,747	2.5
Pentwater	912,020	0	912,020	-
Petoskey	0	0	0	-
Portage Lake	196,374	0	196,374	-
Saugatuck	1,255,141	0	1,255,141	-
South Haven	1,812,306	52,025	1,864,331	34.8
St. James	0	0	0	-
St. Joseph	2,487,957	234,484	2,731,441	10.2
Traverse City	0	0	0	-
White Lake	936,494	0	936,494	-
District totals	22,432,591	3,822,938	26,255,529	
Totals for lake	59,931,845	45,550,564	105,482,409	

Table 43. AVERAGE ANNUAL PRIVATE, MAINTENANCE, AND NEW WORK DREDGING IN LAKE MICHIGAN BY C.E. DISTRICT, 1961-1970 (50, 52)
(cubic yards)

	Chicago District	Detroit District	Total	Percent of grand total
Private	636,200	114,600	750,800	18
Maintenance	878,800	602,600	1,481,400	35
New work	1,878,500	115,200	1,993,700	47
Totals	3,393,500	832,400	4,225,900	100

dredging volume, 18 percent of the grand total, is relatively large due to the high permit dredging during the early 1960's in Calumet, Chicago, and Indiana Harbors. However, the C.E. reported that Section 10 permit dredging accounts for only 10 percent of the total annual volume in the Great Lakes (1).

During the base period (1961-1970), maintenance dredging has averaged 1.5 million cubic yards, whereas new work dredging has average 2.0 million cubic yards. Approximately 60 percent of the maintenance and 94 percent of the new work dredging took place in the Chicago District. The average new work dredging volume was relatively high, reflecting the construction of Burns Waterway Harbor and the deepening and/or expansion of Calumet, Chicago, Green Bay, Indiana, Kenosha, and Milwaukee Harbors.

In Table 44, the average annual private, maintenance, and new work dredging quantities are listed by harbor for each C.E. district. Although the private dredging data are not complete, the table does indicate those harbors with high permit dredging. Dredging quantities from private recreational harbors, such as Wilmette Harbor, Illinois, and quantities removed by power generating companies, for example Consumer's Power in the Detroit District, are included in the 'Miscellaneous sites' data.

Table 44. AVERAGE ANNUAL PRIVATE, MAINTENANCE, AND NEW WORK DREDGING IN LAKE MICHIGAN BY HARBOR 1961-1970 (50, 52)
(cubic yards)

Chicago District	Private	Maintenance	New work	Totals
Public harbor				
Algoma	0	830	0	830
Big Suamico	0	2,130	0	2,130
Burns Waterway	0	0	428,250	428,250
Calumet H. & R.	187,880	198,680	737,280	1,123,840
Chicago Harbor	97,910	830	29,640	128,380
Chicago River	10,800	68,590	0	79,390
Gladstone-Kipling	0	0	23,880	23,880
Green Bay	620	117,150	140,220	257,990
Indiana	221,930	137,180	78,570	437,680
Kenosha	1,180	15,360	23,870	40,410
Kewaunee	1,350	39,590	13,250	54,190
Manitowoc	1,200	35,950	0	37,150
Menominee	490	8,910	1,860	11,260
Michigan City	0	40,930	2,260	43,190
Milwaukee	34,830	41,800	394,830	471,460
Oconto	0	3,530	0	3,530
Pensaukee	0	2,030	0	2,030
Port Washington	5,400	7,720	0	13,120
Racine	0	17,510	0	17,510
Sheboygan	0	33,090	0	33,090
Sturgeon Bay/ Ship Canal	3,410	42,230	0	45,640
Two Rivers	0	43,490	1,070	44,560
Waukegan	6,810	21,280	3,480	51,970
Totals	573,810	878,810	1,878,460	3,351,480
Private harbor				
Buffington	0	-	-	0
Escanaba	0	-	-	0
Gary	11,000	-	-	11,000
Oak Creek	5,000	-	-	5,000
Miscellaneous sites	46,400	-	-	46,400
Totals	62,400			62,400
District totals	636,210	878,810	1,878,460	3,413,880

Table 44. (continued)

Detroit District	Private	Maintenance	New work	Totals
Public harbors				
Arcadia	6,300	0	0	6,300
Charlevoix	0	6,410	0	6,410
Frankfurt	0	18,690	15,020	33,710
Grand Haven	4,860	146,390	0	151,250
Grays Reef	0	30,610	0	30,610
Holland	0	74,560	0	74,560
Leland	0	570	3,370	3,940
Ludington	5,550	24,210	0	29,760
Manistee	0	27,450	21,880	49,330
Manistique	0	9,950	21,130	31,080
Muskegon	2,140	38,820	48,630	89,590
Pentwater	0	37,420	0	37,420
Petoskey	0	0	0	0
Portage Lake	0	8,920	0	8,920
Saugatuck	0	48,220	0	48,220
South Haven	0	46,320	5,200	51,520
St. James	620	0	0	620
St. Joseph	0	59,450	0	59,450
Traverse City	0	0	0	0
White Lake	0	24,580	0	24,580
Totals	19,470	602,570	115,230	737,270
Private harbors				
Petoskey Penn Dixie	0	-	-	0
Port Inland	0	-	-	0
Miscellaneous sites	95,080	-	-	95,080
Totals	95,080			95,080
District totals	114,550	602,570	115,230	832,350
Totals for lake	750,760	1,481,380	1,993,690	4,225,830

Harbors with over 100,000 cubic yards of average annual maintenance dredging include Calumet, Grand Haven, Green Bay, and Indiana. The average annual maintenance dredging quantities listed in this study are 19 percent lower than averages calculated by the C.E. Part of this difference is accounted for in the conversion of all dredging volume data in this report to place measure. The remainder may be explained by a safety margin allowed for by the C.E. in their data.

Average annual new work dredging quantities are not useful statistics except to indicate the quantity of new work that took place during the base period. Moreover, future new work dredging quantities cannot be predicted on the basis of previous new work dredging.

Future Dredging Quantities

Future private and maintenance dredging quantities have been projected by harbor in each Corps of Engineers' district as indicated in Table 45. Future annual private dredging volumes are based on averages of the 1963 through 1973 dredging records for each harbor. In the Chicago District, only Calumet and Indiana Harbors should require relatively high average annual private dredging, while moderate permit dredging will probably take place in Manitowoc, Milwaukee, and Racine Harbors. In the Detroit District, little permit dredging, except for miscellaneous areas, is anticipated. Miscellaneous permit dredging sites include private recreational harbors and coastal areas where municipalities, power generating companies, and others may have dredging performed.

Future average annual maintenance dredging projections were determined by averaging the maintenance dredging quantities of the past several years, then modified by consideration of special circumstances. For example, in Indiana Harbor the project depth was extended to 27 feet in 1963, therefore the projection of future average annual maintenance dredging was based on the period 1964 to the present. Some harbors, such as Sheboygan, did not undergo new work dredging during the past

Table 45. FUTURE AVERAGE ANNUAL PRIVATE AND MAINTENANCE DREDGING VOLUMES IN LAKE MICHIGAN BY C.E. DISTRICT (1, 50, 52) (cubic yards)

Chicago District	Private dredging	Maintenance dredging	Base period for maintenance	C.E. maintenance dredging
Public harbor				
Algoma	0	1,400	1945-1964	3,000
Big Suamico	0	2,700	1959-1966	5,000
Burns Waterway	0	30,000	By C.E.	30,000
Calumet H. & R.	193,800	113,800	1967-1973	200,000
Chicago Harbor	400	6,900	1951-1961	59,000
Chicago River	5,100	77,500	1958-1967	49,000
Gladstone-Kipling	0	3,000	By C.E.	3,000
Green Bay	7,000	156,100	1967-1973	137,000
Indiana	187,500	97,200	1964-1973	151,000
Kenosha	0	20,000	1966-1970	29,000
Kewaunee	2,800	38,000	1965-1970	28,000
Manitowoc	8,200	36,900	1963-1970	35,000
Menominee	500	7,900	1956-1966	15,000
Michigan City	0	36,100	1964-1973	48,000
Milwaukee	19,600	53,200	1965-1969	70,000
New Buffalo[a]	600	10,000	By C.E.	10,000
Oconto	0	2,200	1949-1964	3,000
Pensaukee	0	1,400	1952-1966	2,100
Port Washington	5,400	5,900	1962-1972	15,000
Racine	12,100	21,900	1961-1968	30,000
Sheboygan	0	33,100	1961-1970	23,000
Sturgeon Bay/Ship Canal	6,800	42,200	1961-1970	50,000
Two Rivers	0	40,100	1964-1973	51,000
Waukegan	6,800	25,000	1961-1969	32,000
Washington Island[a]	1,300	0	-	0
Totals	447,900	862,500		1,078,100
Private harbor				
Buffington	1,500			
Escanaba	0			
Gary	3,500			
Oak Creek	5,000			
Miscellaneous sites	76,200			
Total	86,200			
District totals	534,100	862,500		1,078,100

Table 45. (continued)

Detroit District	Private dredging	Maintenance dredging	Base period for maintenance	C.E. maintenance dredging
Public harbors				
Arcadia	6,300	0	-	None required
Charlevoix	0	6,100	1963-1972	30,000
Frankfurt	0	23,100	1963-1973	32,000
Grand Haven	5,000	130,800	1964-1973	100,000
Grays Reef	0	21,900	1960-1973	16,000
Holland	0	73,700	1964-1973	105,000
Leland	0	12,600	1969-1973	15,000
Ludington	7,000	31,600	1966-1973	55,000
Manistee	0	34,800	1965-1973	55,000
Manistique	0	11,900	1965-1972	40,000
Muskegon	1,300	49,200	1966-1973	105,000
Pentwater	0	42,500	1964-1973	70,0000
Petoskey	0	0	-	None required
Portage Lake	0	16,000	1963-1973	40,000
Saugatuck	0	50,300	1964-1973	55,000
South Haven	0	40,000	1964-1973	74,000
St. James	1,000	1,500	By C.E.	1,500
St. Joseph	0	54,900	1964-1973	80,000
Traverse City	0	1,500	By C.E.	1,500
White Lake	0	26,500	1964-1973	60,000
Totals	20,600	628,900		935,000
Private harbors				
Petoskey Penn Dixie	0			
Port Inland	0			
Miscellaneous sites	180,000			
Total	180,000			
District totals	200,600	628,900		935,000
Totals for lake	734,700	1,491,400		2,013,100

[a]New harbor to be constructed.

decade. Their projection was based on a 10-year period beginning with the year of the last maintenance dredging project. Since some of the smaller harbors, for example, Oconto Harbor, were not dredged for several years, the base period for the projection had to be extended back beyond the past decade. Projected volumes for Green Bay, Ludington and Milwaukee include an additional 10 percent because of new work projects scheduled for these harbors.

Since no historical maintenance dredging quantities were indicated in the C.E. records for Burns Waterway, Gladstone-Kipling, New Buffalo, St. James, and Traverse City, projections made by the C.E. were accepted for these harbors. Some shoaling is projected to occur in New Buffalo Harbor even though it has not yet been expanded into a new public recreational harbor. Shoaling problems in Burns Waterway are not expected to develop for another 3 to 4 years.

Although a correlation factor between annual maintenance dredging volumes and mean annual lake levels of Lake Michigan was determined to be -0.58, this relationship was not built into the projection because lake levels are unpredictable (see Section VI). When lake levels are low, to prevent groundings, the C.E. stringently maintains the commercial harbors at project depths plus 1 to 2 feet of subgrade. Because dredging is performed with regard to the mean low-water datum, during high lake levels maintenance dredging in some harbors may be temporarily postponed, even though some shoaling has occurred.

The future average annual maintenance dredging volume for Lake Michigan has been projected to be 1,491,400 cubic yards place measure, or nearly equal to the average of the 1961 through 1970 period (Table 43). Compared to the long-term average (1935-1973), which was calculated to be 1,211,300 cubic yards, future maintenance dredging quantities should increase by 280,000 cubic yards annually. Thus, a small future annual increase is projected. Several new harbors, for example Burns Waterway, will require maintenance dredging. A few harbors, such as Green Bay and

Milwaukee, may have slightly larger dredging requirements due to new work projects. This increase should be partially offset by a reduction of dredging in some industrialized harbors, such as Indiana and Calumet Harbors, where man-made sedimentation is decreasing.

Drawing on their experience with individual harbors, the C.E. has estimated future average annual maintenance dredging volume in Lake Michigan to be 2,013,100 cubic yards (Table 45). These projected quantities represent maximum dredging volumes, which would be dredged provided that no funding limitations, disposal site availability, or other constraints are imposed. Compared to the Corps of Engineers' projection, future average annual maintenance dredging volume calculated in this study is 525,100 cubic yards less or 26 percent lower. However, a Chi-square analysis revealed no significant difference, at the .01 level, between the two projections.

In the Chicago District, with the exception of Calumet, Indiana, Menominee, and Port Washington Harbors, there is only general correspondence between the two projections. Because dredging volumes are small in Menominee and Port Washington, differences between the two projections are insignificant. Big Suamico Harbor may not undergo maintenance dredging in the future as this project is no longer economically justified. Due to the effect of pollution elimination systems on industrial and municipal sedimentation (Public Law 92-500), harbors such as Calumet, Chicago, and Indiana will probably exhibit slightly lower maintenance dredging requirements than that projected by the C.E. As much as 75 percent of the spoil volume dredged from Calumet Harbor and River may be comprised of industrial wastes.

With regard to the Detroit District, less correspondence exists between the projection of this study and that of the C.E. for future average annual maintenance dredging. Specifically, large differences are noted for Charlevoix, Manistique, Portage Lake and White Lake, with moderate disparities for Ludington, Muskegon and South Haven Harbors. Conversion of the dredging volumes from bin measure to place measure probably accounts for some of the difference. At Muskegon Harbor the breakwater is relatively new; thus, sediments from littoral transport may not accumulate in the outer harbor for a couple of years. Therefore, future annual maintenance dredging at Muskegon may exceed the average of the past decade.

Conversely, recent dredging histories of Charlevoix, Manistique, and Portage Lake do not substantiate the Corps of Engineers' projection for these harbors. Moreover, due to a long-term decline in commerce and increasing recreational activities, some small harbors such as Pentwater, Portage Lake, Saugatuck and White Lake may, in the future, be dredged only to a depth of 12 to 14 feet instead of being maintained at their present project depth of 18 to 24 feet.

New work dredging projects currently planned by the C.E. for Lake Michigan are listed in Table 46. Because all 9 of these federal projects may not receive final authorization and funding, the list should be regarded as a maximum new work projection. Construction of the New Buffalo Harbor was scheduled to begin September, 1973 with completion in 1974-75. No data were collected regarding construction of new private harbors, however there is a trend away from private harbors.

All of the new public harbors scheduled for construction will be recreational harbors and as such should generate small volumes of additional future maintenance dredging. New work projects in Green Bay, Ludington and Milwaukee harbors are expected to cause a small increase in annual maintenance dredging. Usually, this increase in maintenance dredging occurs during the first few years following channel deepening or widening as the walls of these new channels slough in due to vessel traffic and effect of bow thrusters.

<u>Summary</u>

In summary, a historical total of 118.7 million cubic yards have been

Table 46. FUTURE NEW WORK DREDGING PROJECTS IN PUBLIC HARBORS OF LAKE MICHIGAN BY C.E. DISTRICT (50, 52)
(cubic yards)

Project	Volume to be dredged	Completion date of project
Chicago District		
Cedar River[a]	50,600	1976
Green Bay	603,000	1976-77
Illinois Beach State Park[a]	100,000	1976-77
Milwaukee	1,535,000	1977
New Buffalo[a]	67,000	1974-75
Northport[a]	1,310,000	1977-79
Port Washington	20,000	1975-76
Total	3,685,600	
Detroit District		
Cross Village[a]	42,200	1979
Ludington	695,000	1977
Total	737,200	
Total for lake	4,422,800	

[a]New public harbor to be constructed.

dredged from private and public harbors of Lake Michigan. During the past decade (1961-1970), an annual average of 3,042,000 cubic yards were removed from these harbors. Private dredging volumes accounted for 18 percent of this average total, while maintenance and new work dredging amounted to 35 and 47 percent, respectively. The largest quantities of spoil are derived from Calumet, Chicago Harbor and River, Grand Haven, Green Bay, and Indiana Harbors. Excluding Grand Haven, these public commercial harbors with high maintenance dredging requirements are characterized by 27-foot seaway channels and are part of industrial-urban complexes.

For the next decade, the future average annual dredging volume in Lake Michigan has been estimated to be 2,963,200 cubic yards. Private dredging volumes will probably continue to be quite high, i.e., about 735,000 cubic yards, which is 25 percent of the total annual quantity. The projected volume of average annual maintenance dredging is 1.5 million cubic yards, a quantity similar to that of the 1961-1970 period. Should the water level of Lake Michigan drop suddenly during the next decade, the annual maintenance dredging volume may slightly exceed this projection. Conversely, if confined disposal sites are not available for those public harbors which are considered polluted, maintenance dredging may have to be postponed in some harbors until acceptable methods of disposal are found. Future new work dredging volumes are expected to average 737,100 cubic yards annually, a relatively low figure when compared to the 1961-1970 period or to the long-term average (1935-1973). Six of the 9 new work projects scheduled by the C.E. concern the construction of new recreational harbors while only 3 projects involve deepening of existing commercial harbors.

DREDGING QUANTITIES IN LAKE SUPERIOR

Dredging activity in Lake Superior dates from the early 1900's. In the early days harbor improvement projects were largely expediency projects, assigned to those harbors where shoaling restricted the free movement of ships. Few detailed records were kept and dredge spoils were dumped in the open lake. The Canadian harbors were primarily opened and developed to serve the lumbering industry and later the paper industry. As the steel industry placed more and more demand upon shipping, ship drafts increased requiring deeper harbors and waterways. Ship lengths and beams increased, which required more adequate berthing space as well as enlarged turning basin and anchorage facilities. Parallel developments of harbor facilities can be traced in the ports of the "copper country." As copper mining declined and the lumbering industry closed down, the harbors of Lake Superior have consolidated activities. Some of the smaller ports have been relegated to recreational use and some still maintain a small fishing trade (Figure 10).

Changes in principal use and trade patterns of the upper Great Lakes dictated alterations in the dredging requirements and frequencies. During the earlier years of Lake Superior's waterborne trade and harbor maintenance, the C.E. operated from an office in Duluth, Minnesota. In 1955, the Duluth office was closed and moved to a consolidated operation in the St. Paul District at St. Paul. In preparation for the consolidation of activities in St. Paul some of the old records of the Duluth office were destroyed. Therefore, historic dredging records, in particular the permit files, are generally not available prior to 1955. The history of dredging activity can be gleaned with increasing detail and accuracy primarily from the annual reports of the C.E. Early reports cited only the total expenditures of the district without regard to activity. During the 1930's the annual reports began to itemize expenditures for certain activities, however, dredging if listed was commonly shown only as a lump dollar sum. During the 1940's, dredge activities began to be reported in cubic yards and in the middle 1950 period a distinction was being made between maintenance and new work dredging volumes. Annual reports of the C.E. Districts have never recorded the volume of permit dredging, inasmuch as these activities are privately

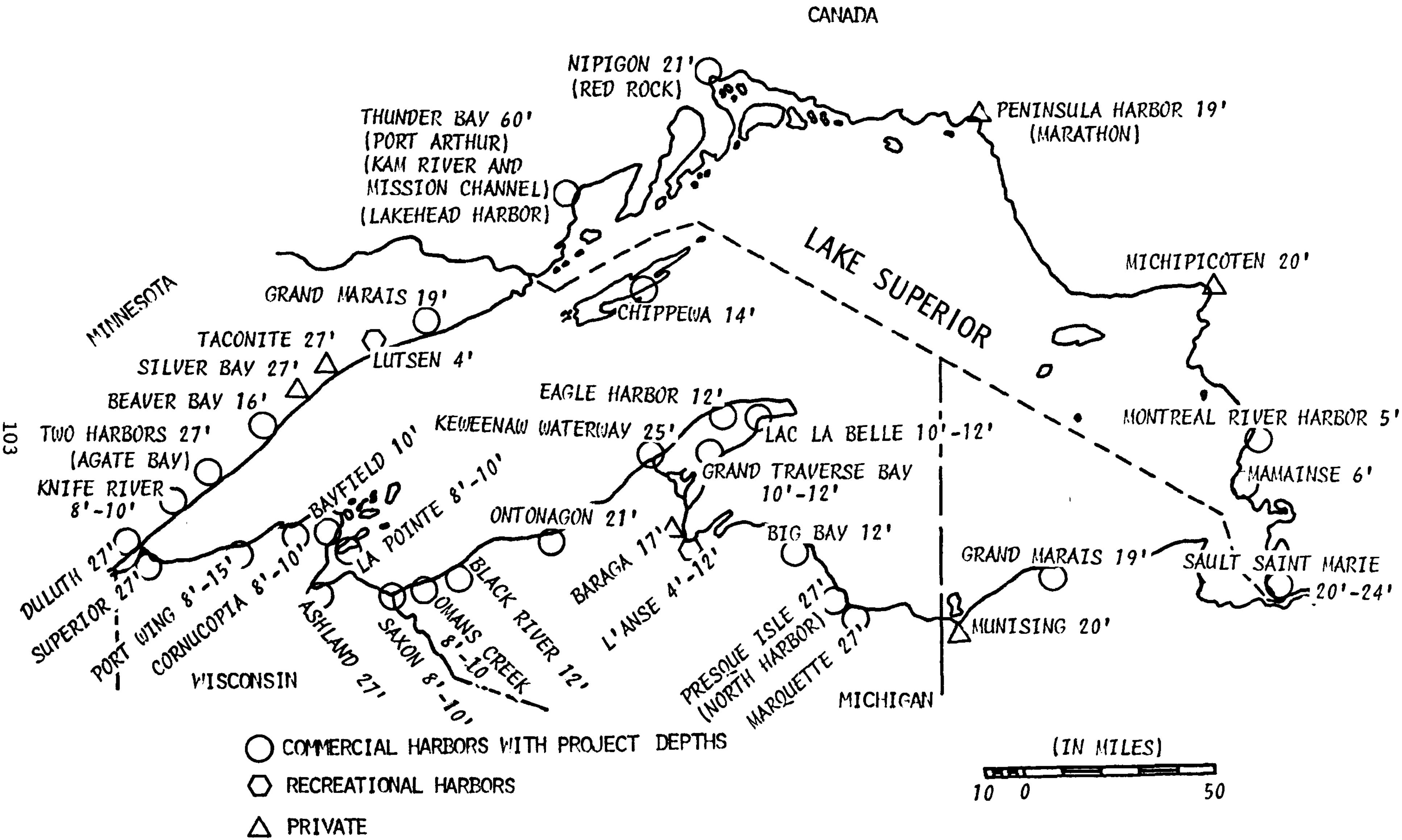


Figure 10. CLASSIFICATION AND PROJECT DEPTHS OF HARBORS IN LAKE SUPERIOR

funded and are not the fiscal responsibility of the C.E. Inasmuch as private dredging in the navigable waters of the Great Lakes requires the approval of the C.E., applications to dredge are filed in the C.E. office after approval. These are available for scrutiny, however all types of permit work in navigable waters are filed together in accession number order by year. In general, current policy of the St. Paul District indicates that the permit files may be destroyed 2 years after date of application. Although the files of the St. Paul District are reasonably intact since 1955, space limitations may dictate their destruction at any time.

Dredging problems in Lake Superior are somewhat unique to the other Great Lakes. Bottom gradients are generally steep within the nearshore area and commonly bedrock based or composed of unsorted glacial till. Dredging is almost universally limited to dipper or clam shell work for boulder and bedrock removal. For this reason of bottom configuration, longshore drift or littoral current transfer is of little consequence to harbor maintenance.

The major dredging problem in the Lake Superior harbors is tied directly to ice-shove and ice rafting during winter storms. Bottom profiles show submarine benching of sands caused by storms of different intensity. Soundings made by the C.E. show that the development of benches at various depths are directly caused by the winter storms. This is particularly true of the "long fetch harbors" exposed to the prevailing NW winter storms. The sheltered harbors show virtually no effect. These can be roughly summarized as:

<u>LONG FETCH--NW</u>

- Port Wing
- Cornucopia
- Saxon
- Black River
- Ontonagon
- West Keweenaw Entry
- Eagle
- Marquette
- Munising
- Grand Marais, Michigan
- All Whitefish Bay (Sault entry)

<u>Protected of Lee Harbors</u>

- All north shore harbors
- Duluth--Superior
- Bayfield
- LaPointe
- Ashland
- Lac La Belle
- Grand Traverse
- Chippewa

Occasional NE storms in winter are very severe and, with a frequency of one in 10 years, very easily upset ALL THE PLANNING OF TEN YEARS for harbor maintenance. No dredging frequency can even be attempted in most exposed harbors because they are at the mercy of the storms. Those harbors most susceptible to NE severe storms are those opening to the NE, such as: L'Anse, Marquette, Grand Marais (Michigan), Duluth-Superior, Big Bay and Bayfield.

Dredging frequency is directly related to:

1. Storm azimuth
2. Wind velocity
3. Thickness of ice
   Low mean winter temperatures
4. Bottom gradient
5. Nature of bottom sediments vs. azimuth
6. Nature of harbor basement
7. Stream mouth harbor vs. "pocket harbor"
8. Stream flow regimen in harbor
9. Storm frequency by azimuth

Alternatively, an off-azimuth storm of high intensity may clean-out 10 years of sediment accumulation in a period of a few hours in a summer storm and completely negate all dredging plans. Bayfield and North Coast Harbors are good examples of the effects of freak SE storms of high intensity.

The C.E. finds that seiche patterns in the harbors are more critical in sediment control and in shipping hazards than stream flows and normal winds. Most of the larger harbors have seiche reporting services for the pilots and use seiche-lights at the entries and breakwaters. They show by colored lights the state of the 'tide' and current velocities. Harbor pilot advisories notify skippers and pilots of dangerous ebb and flow conditions. Normal seiches on the long fetch coastline combined with wide barometric differences over Lake Superior cause more sediment transfer than any other factors except severe storms.

A Reach Map of Lake Superior (7), shows the Reaches of the shorelines set into categories determined by fetch, storm frequencies and littoral current direction. Each category essentially presents a similar set of conditions for all harbors within the Reach. In Lake Superior the Reaches are numbered in the 9000 series. All other lakes have been likewise subdivided with appropriate Reach numbers. Using that map in conjunction with the Fetch Chart of wind directions (Table 11-28) (7) for the 9000 series Reaches, it is possible to determine the wind azimuths which provide the significant sediment transfer effects. Deep Water Wave Forecasting Curves (Fig. 11-39) (7) give a concept of wave intensity--height values possible at harbors within each Reach. These observations combined with a wind rose analysis at stations around the Great Lakes demonstrates the effect of prevailing and storm winds on harbor maintenance problems. Charts #54 and 55 from the Canadian Climatological Studies report (8) illustrate the frequency, direction and intensity of winds as they may be correlated with the fetch data. January and April are used here to illustrate winds which most effect the movement of ice. January represents the early ice forming period when shore ice is most mobile and has local effect. April wind rose charts show the period of average ice decay when the shore effect is expected to be the greatest. The predominance of westerlies in winter and an increase in easterlies in spring is a notable feature.

United States Maintenance Dredging History

Based upon dredging records since 1937, a total of 30 U.S. harbors have been dredged at least once. During the 36 years of record, an average of 4.1 harbors are dredged each year for maintenance. In the representative sample period of 10 years (1961-1970), maintenance dredging was performed on an average of 4.8 harbors per year. The number of projects per year ranged from 2 to 6 during the 36-year period, and from 3 to 6 during the 10-year sample period. Peak maintenance years appeared in 1939, 1945, 1948, 1951, 1961, 1966 and 1970-1972 (Table 47).

Table 47. HISTORICAL ANNUAL MAINTENANCE AND NEW WORK DREDGING IN LAKE SUPERIOR, 1937-1972 (48, 49, 53)
(cubic yards)

Fiscal year	Maintenance	No. harbors	New work	No. harbors	Private
1972	97,830	5	290,548	8	63,500
1971	132,280	4	142,035	9	7,850
1970	304,115	4	20,575	3	6,000
1969	250,684	5	5,985	2	76,000
1968	196,077	3	40,000	1	1,165,610
1967	152,860	4	275,661	2	63,000
1966	164,688	6	12,675	1	0
1965	168,649	5	417,080	1	22,800
1964	77,085	5	1,902,164	3	780,000
1963	69,794	5	3,208,387	6	0
1962	228,745	5	292,919	4	0
1961	144,190	5	129,520	3	200,000
1960	115,456	4	289,121	5	40,000
1959	225,507	4	50,300	1	0
1958	180,184	4	85,571	5	0
1957	423,774	3	32,850	1	0
1956	250,664	5	555,058	2	0
1955	326,345	3	480,932	1	0
1954	248,314	2	0	0	0
1953	335,498	4	32,732	1	0
1952	319,738	4	18,774	2	0
1951	450,916	5	87,281	3	0
1950	238,155	4	150,022	2	0
1949	246,924	4	14,214	1	0
1948	285,646	6	52,182	1	0
1947	285,112	5	0	0	0
1946	278,919	3	0	0	0
1945	452,602	5	0	0	0
1944	68,920	2	0	0	0
1943	111,073	3	0	0	0
1942	12,935	1	0	0	0
1941	328,556	3	33,585	1	0
1940	396,372	3	1,898,825	2	0
1939	7,658,554	6	5,236,617	8	420,795
1938	0	0	29,910	1	0
1937	1,931,122	1	285,977	1	0
Prior	92,237	2	53,676,746	4	0
Totals	17,250,520		69,749,246		2,842,555

U.S. grand total:	89,842,321
Canadian grand total:	3,888,718
Total for lake:	93,731,039

Maintenance dredging in Lake Superior by the C.E. throughout the historic period of dredging records (1937-1972) totals 17,250,520 CY. This represents 19.1 percent of all U.S. dredging during the period and 18.3 percent of the total dredging in Lake Superior (Canada included) in all categories.

During the 10-year sample period (1961-1970) maintenance dredging within U.S. harbors in Lake Superior totaled 1,594,742 CY. This represents 15 percent of the total (10,611,464 CY) in all categories. On the basis of the 10-year representative sample, annual maintenance dredging may be projected to be approximately 160,000 CY annually for the next 10 years. It is recognized that dredging volumes have decreased materially in the last 10 to 15 year period, as explained elsewhere in this report. Therefore, an analysis of annual maintenance dredging volumes of Lake Superior from 1940 to the present may provide a viable average annual figure. The starting year 1940 is selected in order to eliminate the unusually high volume year of 1939, in which 7,658,554 CY were removed from U.S. harbors. Average annual dredging volume in the 33-year period is 238,268 CY.

A reasonable prediction for the next 10 years would then range from 160,000 to 238,000 CY or approximately 200,000 CY annually. This figure of course does not consider the constraints of pollution abatement, disposal site problems, commerce patterns and lake levels.

United States New Work--

During the 36-year record period an average of 2.3 harbors were committed to new work development, whereas in the 10-year sample period an average of 2.5 harbors were expanded or deepened. New work frequencies range from 0 to 9 harbors per year over the historical sequence and from 0 to 6 during the 10-year sample period. Years showing no new work included the World War II period of 1942 to 1944, and 1946, 1947, 1954, and 1966. Peak years of new work activity occurred in 1939, 1962 and 1963, and in 1971 and 1972 (Table 47).

New work dredging during the historic period (1937-1972), by the C.E. totals 69,749,246 CY. This represents 74 percent of all historic U.S. dredging. This figure, however, includes a "prior years" total of 53,676,746 CY, representing the early years of development of the Lake Superior projects. The largest individual "new work year" was 1939, when 5,236,617 CY were dredged. Eliminating the "prior years" total, new work dredging since 1937 is indicated as 16,072,500 CY or an average annual rate of 446,458 CY for 36 years.

The representative 10-year total of new work is 6,304,966 CY, which is an annual average rate of 630,496 CY. This figure, however, includes 2 very high volume years. In 1963 and 1964, approximately 5.1 million cubic yards were extracted in development work. A more realistic mean value can be determined for this 10-year period by adding the 8 other years, dividing by 8, to yield 149,301 CY/year. Averages during this test period of 10 years are of little significance, inasmuch as the low volume of 5,985 CY (1969), for example, averages in with 3,209,387 CY (1963). The most realistic predictions can probably be made by comparing long term averages over 36 years of record with this erratic activity period of 10 years. The 36-year average of approximately 446,000 CY is close to a mean value between the adjusted 10 years (150,000 CY) and the unadjusted same average (630,000 CY). The mean of these 2 values is 390,000 CY.

A 10-year prediction for average annual new work should range between 390,000 CY and 446,000 CY, depending upon plans and budget appropriations for new facilities. An average of these 2 values is 418,000 CY per year. Such a figure is strictly a statistical average of long term performance. No new work is scheduled for Lake Superior at this time. A potential project in Duluth-Superior Harbor has been publicized to develop 225 acres on St. Louis Bay as a coal loading facility, costing

$25,000,000 (9). Plans call for the filling of existing slips west of the Burlington Northern grain elevators. Although no comment has been made regarding the source of fill material, it is presumed that some will be dredge spoil. As of February 1974, no application for a Section 10 permit had been filed with the E.P.A. in Chicago or the C.E. in St. Paul.

United States Permit Work--

The paucity of records on permit dredging limits interpretation of patterns of activity during the 36-year term. More complete records for the later part of the 10-year sample, suggest that at least one permit is issued per year with 1968 showing the issuance of 4 permits. These were granted for Baraga, Duluth-Superior, Keweenaw Waterway, and Presque Isle. In 1972, private interests received permits to dredge in Duluth-Superior, Oman's Creek, Presque Isle and Two Harbors. Volumetric averages and totals have been determined using those years of record available in the C.E. St. Paul District files.

During the historic period of 1937 to the present, private operators moved a minimum of 2,842,555 CY. Considerably more than this may have been dredged. From 1940 to 1960, no private dredging is recorded, which appears to be an unlikely operational fact. The 2.8 million cubic yards of record is 3 percent of the total volume of dredge spoils handled during the historic period.

The 10-year sample period (1961-1970) probably reveals a more complete record of activity, volume and frequency for projection purposes. The volume of spoil moved by private interests between 1961 and 1970 totaled 2,313,410 CY or 22 percent of the dredging in this period (10,375,263 CY) (Table 47).

An annual average projection for the next 10 years, amounting to 231,000 CY appears to be unrealistic, inasmuch as this figure includes a 1.6 million CY year averaged with 3 years of no activity. A selected-year grouping may be more representative of this 10-year sample. Elimination of the 1968 high volume year (1.16 million CY) and the "no activity" years of 1962, 1963 and 1966, an average of the remaining 6 years volumes indicates 191,300 CY annually. It is recognized that no individual year will probably ever meet this volume, but that over a 10-year period variations in demand and activity may well call for this magnitude of spoil removal.

The validity of this projection may be enhanced during the next 10 years by demands upon higher rates of coal consumption in the current energy crisis. It seems plausible that port cities, which only a few years ago switched from coal to natural gas and fuel oil for electric power generation and general heating, may have to revert to coal. Harbor facilities, which were downgraded and allowed to shoal to recreational boating depths and fishing boat drafts, etc. may have to be reopened to project depths for the larger coal freighters. Docking facilities, including "alongside" draft depth, are usually the responsibility of the dock owner and/or the other private interests who use it. Examples of downgraded harbors in Lake Superior include Ashland, Bayfield, Big Bay, Black River, Cornucopia, Eagle Harbor, Grand Traverse, Knife River, Lac La Belle, and Saxon. Most of these harbors are now open to boats of 1 to 6 foot drafts.

Canadian Maintenance Dredging History

Canadian harbors represent a relatively small percent of the dredging activity in Lake Superior. Within the 13-year period of record examined, 5 of the 9 Canadian harbors have been serviced by maintenance dredging. These are, Kam River, Mission Channel, Montreal River, Nipigon, and Port Arthur (Thunder Bay). It should be noted that, "In 1970, the cities of Fort William and Port Arthur were amalgamated into one new city called the city of Thunder Bay. The harbor of the city of Thunder Bay is officially known as the Lakehead Harbour, and is administered by the

Lakehead Harbour Commission" (10). Dredging areas in the Thunder Bay area are historically listed under Kam River, Mission Channel, Port Arthur, Fort William and Lakehead. In this study, activity is consolidated under the heading of Thunder Bay. During the record period, Kam River has been dredged almost annually, Mission Channel has been maintained 8 out of the 13 years, Montreal River's last 2 years of maintenance occurred in 1960 and 1961. Nipigon (Red Rock) has been dredged for maintenance purposes 4 out of the last 13 years and Thunder Bay has been worked 9 years.

During the sample decade, maintenance dredging has been performed from one to 4 projects per year. The years 1961, 1965 and 1966 were peak activity years, showing 4 projects annually. Thunder Bay was the only harbor serviced in 1969.

Five Canadian harbors are maintained with some regularity. Historic records indicate that 3,827,872 CY have been removed during maintenance work, representing 98 percent of all historic Canadian dredging. Virtually all of the significant volume of maintenance dredging has taken place in the Thunder Bay area. Nipigon Harbor is dredged occasionally to relieve minor shoaling problems.

On a 10-year average basis, only 86,000 CY are moved per year.

Canadian New Work--

Most Canadian harbors were first opened during the logging days and have required very little new work or capital dredging since the initial development. New work was performed in 2 of the 9 harbors during the record period. These were Michipicoten and Mission Channel which were dredged in 1971 and 1962-1963 respectively.

Canadian historic records indicate new work volumetric data for Michipicoten and Mission Channel. Their total of 59,551 CY represents 1.5 percent of historic dredging in the Canadian ports. This figure is

Table 48. DREDGING QUANTITIES IN LAKE SUPERIOR PROJECTS[a]
(1000's cubic yards)

Project of more than 30,000 CY/yr.	Annual total volume
Ashland, Wisconsin	60
Duluth-Superior, Minnesota-Wisconsin	796
Keweenaw Waterway, Michigan	30
Little Lake, Michigan	32
Marquette, Michigan	34
Ontonagon, Michigan	46
Kam River, Ontario	129
Mission Channel, Ontario	70
Port Arthur, Ontario	116

[a]Includes maintenance, private, and new work.

Table 49. CANADIAN DREDGING IN LAKE SUPERIOR: HISTORIC TOTALS BY HARBOR, TEN-YEAR TOTALS, AND AVERAGE VOLUME PREDICTIONS (48, 54)
(annual cubic yardage)

Harbor	Historic 1951-1970 per D.P.W.	Totals this study	Total from 1961-1970	Annual projection	Pollution %	Pollution Class	Vol./Yr.	Disposal area
Kam River[a]	6,290,900	1,640,541	1,294,747	220,000[b] 129,747[c]	100	P	129,747	LF
Maimainse	4,040	--	--	--	0	U	--	--
Michipicoten	--	6,500	--	1,400[b]	0	U	--	R
Mission Channel	(see Kam R.)	1,016,278	697,540	69,754[c]	--	U	--	OL
Montreal R.	--	3,000	1,500	130[c]	--	U	0	OL
Nipigon (Red Rock)	34,360	34,353	12,783	1,000[b] 1,278[c]	100	P	1,278	LF
Peninsula	--	0	0	0	0	U	0	--
Port Arthur	3,660,680	1,188,068	1,163,538	80,000[b] 116,353[c]	0	U	0	OL LF
Port Arthur-Keefer Term.	357,000	--	--	d	--	P	--	LFD
Sault Ste. Marie	108,200	0	0	6,800[c]	0	U	--	OL
Nipigon R.	56,560	--	--	--	--	U	--	OC

Table 49. (continued)

Annual volume projections:	302,400[b] 323,789[c]	Polluted: 130,752
If Leigh Harbor capital project is completed, the total D.P.W. projection is:	587,400	

[a]Includes Mission Channel.

[b]Department of Public Works (D.P.W.).

[c]In this study.

[d]Future work to be included with Port Arthur data.

[e]See Leigh Harbor

R river; OL open lake; LF landfill; OC overcast; LFD diked.

undoubtedly not representative of Canadian activity in harbor development and therefore cannot be used for projections.

Canadian Private Dredging--

Although there is considerably less government surveillance of private dredging in Canada than in the United States, Canadian records reveal that only Mission Channel has been dredged by private interests. Private operators have performed work in 1965-1967 and in 1970, removing 1295 CY. Three harbors, i.e., Mamainse, Peninsula and Sault Ste. Marie show no record of dredging for navigational purposes. However, an estimate of 1000 CY per year would cover usual minimal activity.

Private interests have dredged commercial sand and gravel at the rate of about 42,000 CY per year from the St. Marys River entrance channel. Approximately 100,000 CY of sand and gravel have been dredged in the last 10 years from the Algoma Steel approach channels. In any event, the impact of private operations in Canada cannot be considered significant to dredge volume totals or disposal problems. With the figures available it appears that private work is less than 0.5 percent of the Canadian volume.

Summary

Tables 47 and 49 present details of U.S. and Canadian dredging activity in Lake Superior. However, the principal dredging activity is summarized in Table 48 below.

SUMMARY OF FUTURE DREDGING VOLUMES IN THE
IN THE GREAT LAKES

An average of 15.56 million CY of sediment will be dredged annually from the harbors and connecting channels of the Great Lakes during the next decade. Approximately 78 percent of this total will be removed from the American harbors and waterways. Of the future annual volume to be removed from United States' dredging projects, 64 percent involves maintenance dredging, 19 percent consists of new work, and 17 percent involves private dredging. In Canada, these percentages are 31, 54, and 15, respectively. Estimates of future dredging volumes are summarized by lake as follows:

1. With regard to maintenance dredging, an annual average of 8.85 million CY of spoil will be dredged from public harbors and connecting channels by the C.E. and the D.P.W. combined (Table 50). About 88 percent of this volume will be dredged from American projects and 12 percent from Canadian projects. As in the past, Lake Erie will be the center of the maintenance dredging activity. About 56 percent of the total volume will be removed from projects on this lake, including the Detroit River. Compared to the past decade, future maintenance dredging in the Great Lakes is expected to exhibit little change.

2. It is projected that private interests will dredge an average of 2.59 million CY annually during the next decade. Approximately 80 percent of this quantity will be removed in dredging American projects, while 20 percent will involve Canadian projects. Nearly 40 percent is anticipated from Lake Erie, while 27 percent will be derived from Lake Michigan. The number of private dredging permits is expected to increase in the future, and the quantity dredged from Canadian harbors may increase to about 0.5 million CY.

3. An annual average of 4.1 million CY of new work dredging is anticipated during the next 10 years. If all scheduled new work projects are completed, then much of this new work will be accomplished in Lake

Table 50. FUTURE AVERAGE ANNUAL DREDGING VOLUMES IN THE GREAT LAKES
(cubic yards)

	United States	Canada	Total
Huron/St. Clair			
Maintenance	925,000	318,000	1,243,000
Private	235,000	2,000	237,000
New work	539,500	242,000	781,500
Michigan			
Maintenance	1,491,400	--	1,491,400
Private	734,700	--	734,700
New work	737,100	--	737,100
Erie			
Maintenance	4,800,000	175,000	4,975,000
Private	900,000	100,000	1,000,000
New work	550,000	0	550,000
Ontario			
Maintenance	360,000	500,000	860,000
Private	30,000	400,000	430,000
New work	7,625	1,620,000	1,627,625
Superior			
Maintenance	200,000	86,000	286,000
Private	191,000	1,000	192,000
New work	418,000	0	418,000
Totals			
Maintenance	7,776,400	1,079,000	8,855,400
Private	2,090,700	503,000	2,593,700
New work	2,252,225	1,862,000	4,114,225
	12,119,325	3,444,000	15,563,325

Ontario. New work scheduled for Toronto Harbor comprises 40 percent of all scheduled new work dredging. As compared to the 1961-1970 period, when an annual average of 9.79 million CY of dredging was performed, future new work dredging will decline sharply. Moreover, most of the projects scheduled involve the construction of new recreational harbors, or the deepening and/or expansion of existing commercial harbors.

4. The 5 harbors and connecting channels with the largest maintenance dredging requirements, in descending order, are: Toledo, Cleveland, Detroit River, Buffalo, and Saginaw. These commercial waterways are characterized by industrial-urban complexes and have 27-foot Seaway channels.

5. If water levels in the Great Lakes drop considerably during the next few years, annual maintenance dredging volumes may somewhat exceed our projections. Conversely, if disposal sites are not available for those public projects which are classified as polluted, maintenance dredging may have to be temporarily postponed until acceptable methods of disposal are found.

SECTION IV

POLLUTION OF SPOIL DREDGED FROM THE GREAT LAKES

INTRODUCTION

In recent years national and provincial policies have been enacted which determine the quality of spoil which can be disposed in the open waters of the Great Lakes. In many dredging projects, particularly in heavily industrialized harbors, these policies may determine the scheduling of future maintenance dredging and the disposal method of the dredged spoil. These policies, which include pollution criteria, apply to federal dredging agencies as well as to private contractors.

In the United States, the eligibility of dredged spoil for open-lake disposal in the waters of the Great Lakes is basically determined by the Criteria for Determining Acceptability of Dredged Spoil Disposal to the Nation's Waters (11). These criteria were developed by the E.P.A. Region V, Chicago, for the Great Lakes and have since been applied nationally. Since 1967, nearly all the federal harbors and waterways maintained by the C.E. have been sampled by the E.P.A. Although private harbors and private channels are not routinely sampled, the pollution criteria are applicable. Surface grab samples of bottom sediments are usually taken throughout the dredging area of each harbor with a Peterson dredge sampler. In Canada, the M.O.E. has developed Water Quality Guidelines for the Review of Proposed Dredging and Spoil Operations (12). The Canadian guidelines are similar to the E.P.A. criteria (Table 51). Sampling by the M.O.E. compares to that of the E.P.A., except that

Table 51. POLLUTION CRITERIA OF HARBOR/WATERWAY SEDIMENTS (54, 55)
(percent)

Parameter	Canadian guidelines	E.P.A. criteria
	(Maximum allowable concentration, % dry weight basis)	
Volatile solids	6.0	6.0
Chemical oxygen demand	5.0	5.0
Total Kjeldahl nitrogen	0.2	0.1
Oil and grease	0.15	0.15
Mercury	0.00003	0.0001
Zinc	0.005	0.005
Lead	0.005	0.005

frequently more samples are taken and occasionally short sediment cores are analyzed.

Both sets of pollution criteria comprise seven mandatory parameters. In Canada, sediments having concentrations of pollutants lower than the acceptable limits may still be deemed unsuitable for open-lake disposal on the basis of one or more of the following tests:

Total phosphorus

Settleability measured in Jackson Turbidity Units

Sulfides

Trace metals including cadmium, copper, chromium, arsenic and nickel

Pesticides

Bioassay for toxicity

In the United States the following additional tests are recommended where appropriate and pertinent:

Total phosphorus

Total organic carbon

Immediate oxygen demand

Settleability

Sulfides

Trace metals including cadmium, copper, chromium, arsenic and nickel

Although sediment quality is a primary determinant of the eligibility of dredged spoil for open-lake disposal, other factors may influence the selection of a disposal method in Canada and the United States including:

Volume of dredged material

Existing and potential quality and the use of the water in the disposal area

Other lake conditions at the disposal site such as depth and currents

Time of the year disposal

Method of disposal

Physical, chemical, and biological characteristics of the dredged spoil

Duration of disposal operations

In Section III, projections of future annual maintenance dredging volumes were presented. In this section, where data are available, the public harbors in the United States are classified as unpolluted, partially polluted, and polluted. The classification was based on the distribution of polluted bottom samples, as analyzed by the E.P.A., taken from each of the dredging projects. A dredging project is considered polluted if the analyses reveal that at least one pollution parameter exceeds the acceptable limits in all of the samples taken. In some harbors, only a portion of the total dredging area was deemed polluted by the bottom sediment analyses. Such harbors are considered partially polluted. In Canada, projects have not been formally classified in this manner. However, for the purpose of arriving at an overview of the polluted and unpolluted volumes of maintenance dredgings, harbors which exceed the M.O.E. pollution criteria are considered polluted, while those that do not exceed the criteria are classified as unpolluted.

Sampling by the E.P.A. and the M.O.E. is continually occurring, usually prior to maintenance dredging. Several high volume and economically significant projects such as Sandusky, Toledo, Duluth, Milwaukee, and Lake St. Clair have been sampled since the completion of this report. As the analyses were not available before February, 1973, the data presented in this section are through mid-1973.

QUANTITY OF POLLUTED DREDGED SPOIL IN LAKE ONTARIO

Projects in Lake Ontario exhibit a high correlation between industrial/commercial port activities and sediment pollution. Of the 5 U.S. harbors which were sampled by the E.P.A., only Rochester and Oswego are classed as entirely polluted. These are the major ports of commercial activity on the lake. One other American harbor, Great Sodus, is classed as partially polluted. Wilson and Little Sodus, both small and with no commercial traffic, are classed as unpolluted. Of the 6 Canadian harbors on Lake Ontario which were sampled by the M.O.E., all exceed the maximum allowable concentration of some pollutant in at least a few samples (Figure 11). For the purposes of this report, these harbors are classed as polluted. Thus, of 11 sampled harbors in Lake Ontario, American and Canadian combined, 9 are at least partially polluted.

A total of 27 sediment samples have been taken from American dredging projects in Lake Ontario. The average number of samples analyzed per harbor is 5 (Table 52). The range in number of samples is from 4 at harbors such as Wilson and Little Sodus to 5 at Rochester and Great Sodus and 9 at Oswego. All samples were taken from 1968 to 1971. The most commonly occurring pollutants in American dredging projects are phosphorus, oil and grease, Kjeldahl nitrogen, and volatile solids. All of these, particularly phosphorus, were excessive in most samples tested.

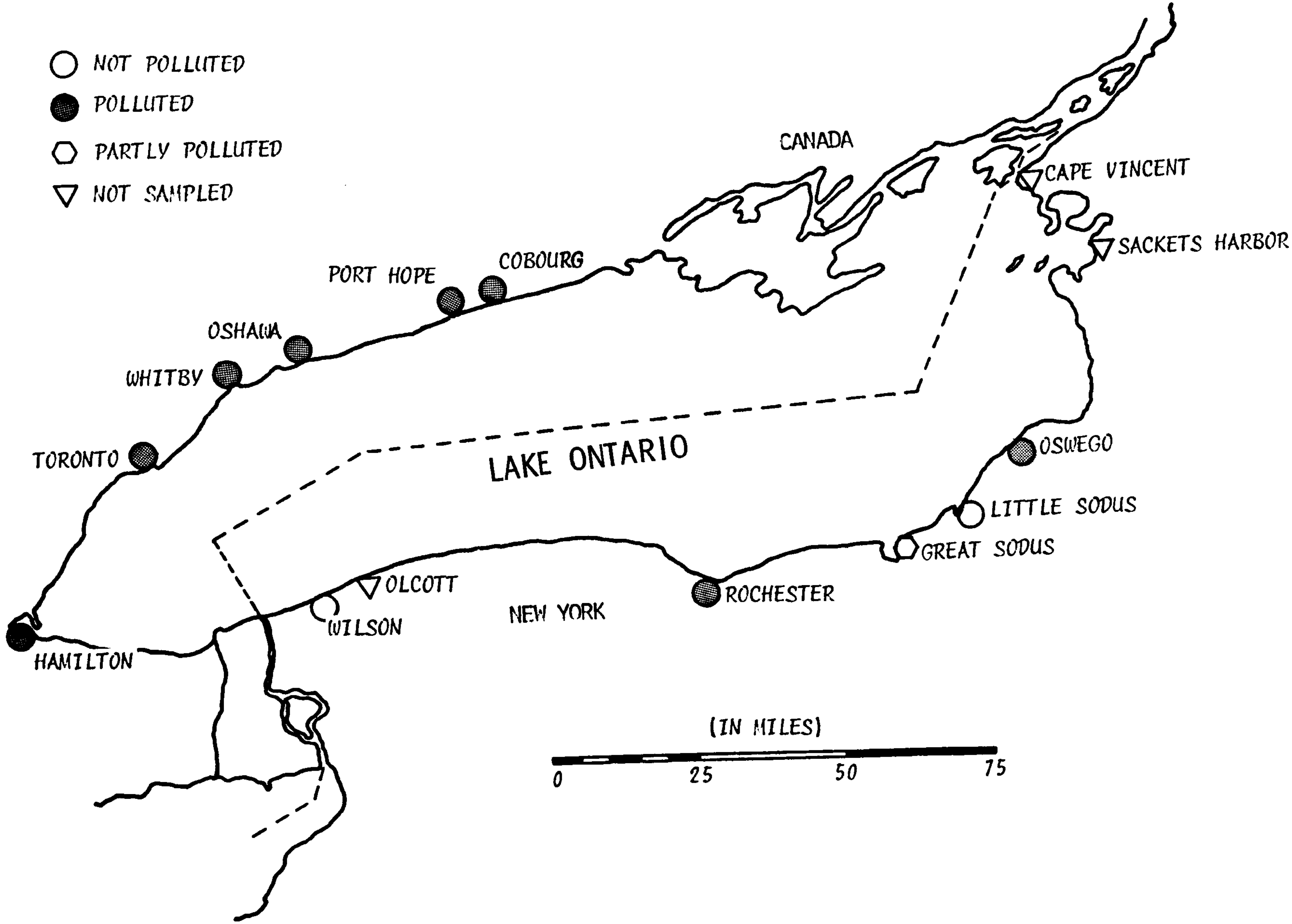


Figure 11. POLLUTION STATUS OF HARBORS IN LAKE ONTARIO

Table 52. SAMPLING OF PROJECTS ON LAKE ONTARIO (54, 55)

Harbor	Year sampled	No. of samples	Number exceeded								
			P	sol.	COD	Kjel. N	Oil & grease	Fe	Hg	Pb	Zn
U.S. samples											
Great Sodus	1968	5	5	3	0	nt	nt	nt	nt	nt	nt
Little Sodus	1969	4	4	1	2	2	1	nt	nt	nt	nt
Oswego	1969	9	9	4	4	5	6	nt	nt	nt	nt
Rochester	1969	5	5	0	0	1	5	0	nt	nt	nt
Wilson	1970	4	2	2	3	3	0	0	nt	nt	nt
Olcott	No data										
Totals		27	25	10	9	11	12	0	-	-	-
Canadian samples											
Cobourg	'71,'72	8	7	1	3	6	3	nt	nt	nt	5
Hamilton	'70,'72	24	19	14	24	21	17	nt	4	9	11
Oshawa	'70,'72	34	17	5	6	15	16	nt	nt	1	19
Port Hope	1972	4	4	0	4	4	1	nt	nt	1	1
Toronto	'72,'73	181	90	2	65	90	20	nt	2	49	50
Whitby	1971	11	nt	10	11	nt	nt	nt	nt	nt	11
Totals		262	137	32	113	136	57	--	6	60	97

nt Not tested.

A total of 262 samples have been analyzed for Canadian harbors on Lake Ontario. Canadian samples average about 44 per harbor; but this average is skewed by 181 samples taken from Toronto Harbor. The range is from 4 at Port Hope and 8 at Cobourg to 34 at Oshawa and 181 at Toronto. All samples were taken during the years 1970 to 1973. Phosphorus, Kjeldahl nitrogen, zinc, and chemical oxygen demand are the most commonly surpassed pollution parameters in Canadian waters of Lake Ontario. Apparently, zinc tests are considered more important by the M.O.E. than by the E.P.A. Of the 6 Canadian harbors samples, all were tested for zinc. Zinc tests were not made at any of the 5 American harbors sampled.

Future Quantity of Polluted Spoil

U.S. Projects--

Since most spoil dredged by permit is presently being confined and since most new work dredging involves unpolluted material, the projections of future polluted spoil in this report involve only maintenance dredging over the next decade. From 1961 to 1970, an average of approximately 363,000 cubic yards of spoil were removed from U.S. projects annually in maintenance dredging. Of this volume, about 334,000 cubic yards (92 percent) involved polluted spoil (Table 53). The volume of polluted spoil was calculated on the basis of the E.P.A. classification of harbors and detailed analysis of their sediment sample maps.

Maintenance dredging in the next decade should result in the removal of approximately the same total volume of spoil that was removed during the 1960's. Most of the material to be dredged in the future will be polluted spoil from Rochester and Oswego, the major commercial harbors in Lake Ontario (Figure 12). Thus, it is projected that unless unlimited open-lake disposal is permitted to resume as a result of severe economic stress or relaxation of pollution standards, confinement of more than 90 percent of the material to be dredged in the next decade will be necessary. This means that 3.3 million cubic yards of dredged spoil will

Table 53. VOLUME OF POLLUTED DREDGED SPOIL, C.E. PROJECTS IN LAKE ONTARIO, 1961-1970 (cubic yards)

Project	Year E.P.A. sampled	Pollution class	Average annual maintenance dredging	Percent polluted	Volume of polluted spoil
Great Sodus	68	P/U	23,763	50	11,882
Little Sodus	69	U	15,075	0	0
Oswego	69	P	54,683	100	54,683
Rochester	69	P	267,029	100	267,029
Wilson	70	U	948	0	0
Olcott	no data	-	2,116	--	--
Totals			363,614		333,594

have to be confined in diked sites in the Lake Ontario region during the next 10 years.

As of July, 1974, the only Lake Ontario projects in the C.E.'s confined disposal program were at Rochester and Oswego. At Rochester, a site has been selected, and construction is planned for 1976. Oswego had no site agreement as of July, 1974, but construction is scheduled for 1975. Thus, for most dredging in the lake, confined disposal facilities are expected to be available by 1977. Volumes of material removed in the past few years have been slightly lower than the average removed during the 1960's; they should increase in the latter 1970's and remain higher than average into the early 1980's.

Canadian Projects--

From 1961 to 1970 an average of approximately 536,000 cubic yards of spoil were removed from Canadian waters of Lake Ontario every year in

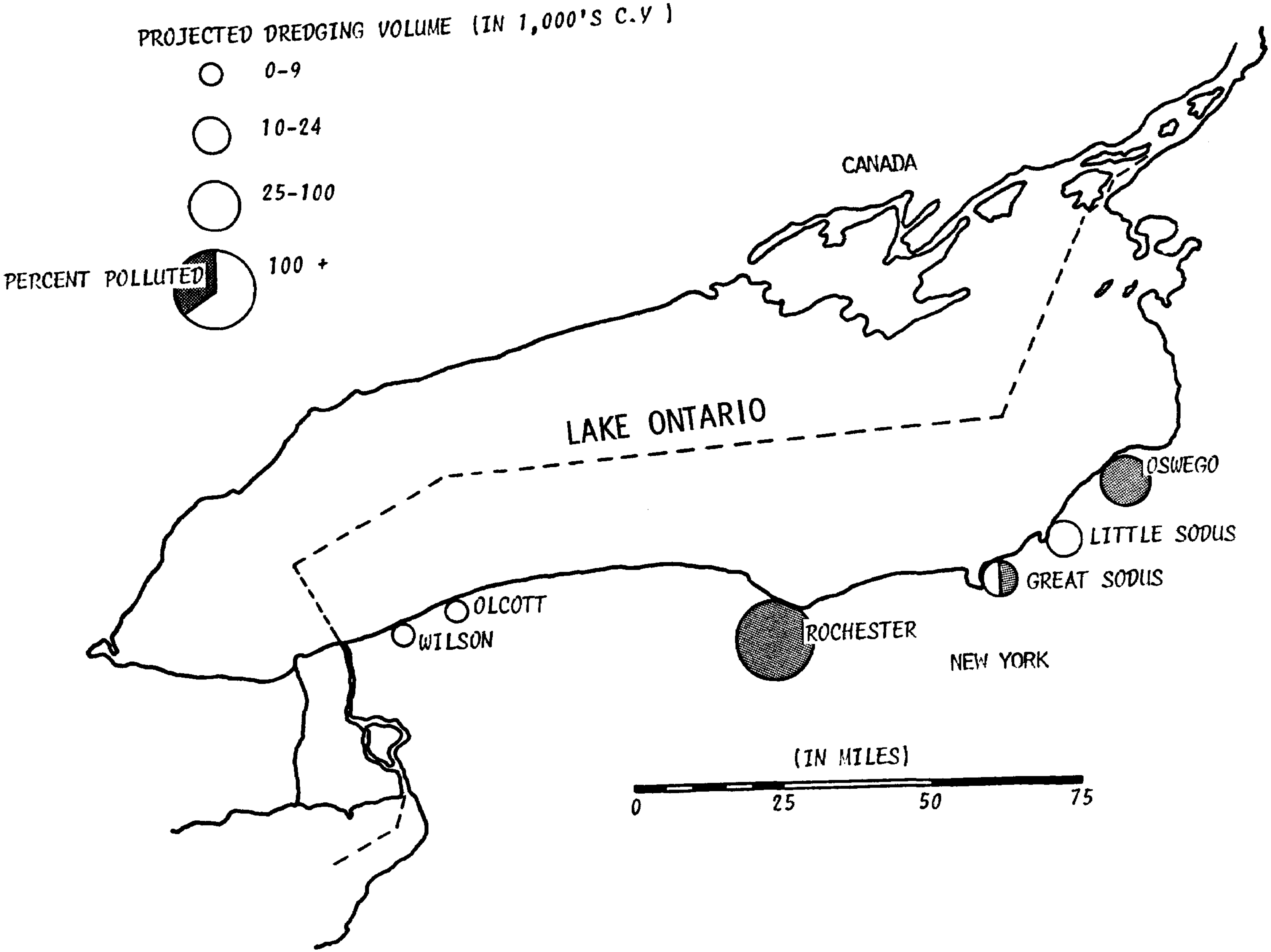


Figure 12. PROJECTED ANNUAL POLLUTED AND UNPOLLUTED MAINTENANCE DREDGING VOLUMES IN LAKE ONTARIO

maintenance dredging projects. However, maintenance dredging volumes are anticipated to decline slightly in the next decade. Projections made available by the D.P.W. indicate that only approximately 435,000 cubic yards of spoil are expected to be dredged in maintaining harbors on Lake Ontario by 1977. About 97 percent of this volume is to be removed from Toronto, Whitby, Oshawa, and Cobourg Harbors, all of which have been sampled by the M.O.E. (Table 52). All harbors had some samples which exceeded at least some pollution parameters and, for the purposes of this report, are considered polluted. Assuming that the Canadian projects which have not been sampled are not polluted, then approximately 420,000 cubic yards of polluted spoil will be dredged by 1977 from Canadian harbors. This represents about 97 percent of the total volume of material scheduled for dredging in Canadian waters of the lake in the near future.

Four of the 5 harbors scheduled for maintenance dredging in the near future have been sampled to date. Four other harbors (Hamilton, Port Hope, Port Credit, and Cataraqui) are dredged at least occasionally. Thus, the percentage of polluted spoil to be removed in the future is, at best, a rough estimate. More accuracy in estimating future polluted volumes in Canada will only be possible when all projects are sampled and more test results become available.

<u>Summary</u>

1. Of a total of 11 sampled American and Canadian harbors in Lake Ontario, 9 are polluted or partially polluted.

2. Most commonly occurring pollutants in U.S. projects are phosphorus, oil and grease, Kjeldahl nitrogen, and volatile solids. Phosphorus, Kjeldahl nitrogen, zinc, and chemical oxygen demand are the most commonly surpassed pollution parameters in Canadian waters.

3. Approximately 92 percent of the spoil dredged from American projects during the 1960's was polluted.

4. Approximately 3.3 million cubic yards of polluted spoil dredged from U.S. projects in Lake Ontario are anticipated during the next decade.

5. Major maintenance dredging projects, i.e., Rochester, Toronto, Hamilton, Oswego and Oshawa, have high volumes of polluted spoil.

6. Two Lake Ontario projects, Rochester and Oswego, are in the C.E. diked disposal program; confined facilities are expected to be available at both by 1977.

7. Approximately 435,000 cubic yards of material are scheduled to be removed from Canadian projects on Lake Ontario by 1977. An estimated 97 percent of this material will be polluted.

8. Because many Canadian harbors have not been sampled, future polluted spoil volumes cannot be accurately determined.

QUANTITY OF POLLUTED DREDGED SPOIL IN LAKE ERIE

According to present operational guidelines drafted by the United States Environmental Protection Agency and the Ontario Ministry of Environment, sediment dredged from Lake Erie is highly polluted. Every harbor or waterway sampled by either agency is at least partially polluted, i.e., some samples in a harbor exceed established pollution criteria. In some cases, such as Bolles, Huron, Fairport, and Ashtabula, samples from inner portions of harbors are classed as polluted whereas those taken from outer portions (usually outside breakwaters) are not. Of 21 U.S. harbors sampled, 15 are classified as entirely polluted and 6 as partially polluted. In Canada, of the 5 harbors sampled, all exceed the maximum allowable concentration of some pollutant in at least a few samples (Figure 13). Thus, all harbors and waterways sampled in Lake Erie exceed pollution criteria established for both United States and Canadian projects.

As of late 1973, a total of 165 samples have been taken from U.S. projects in Lake Erie. The average number of samples analyzed per

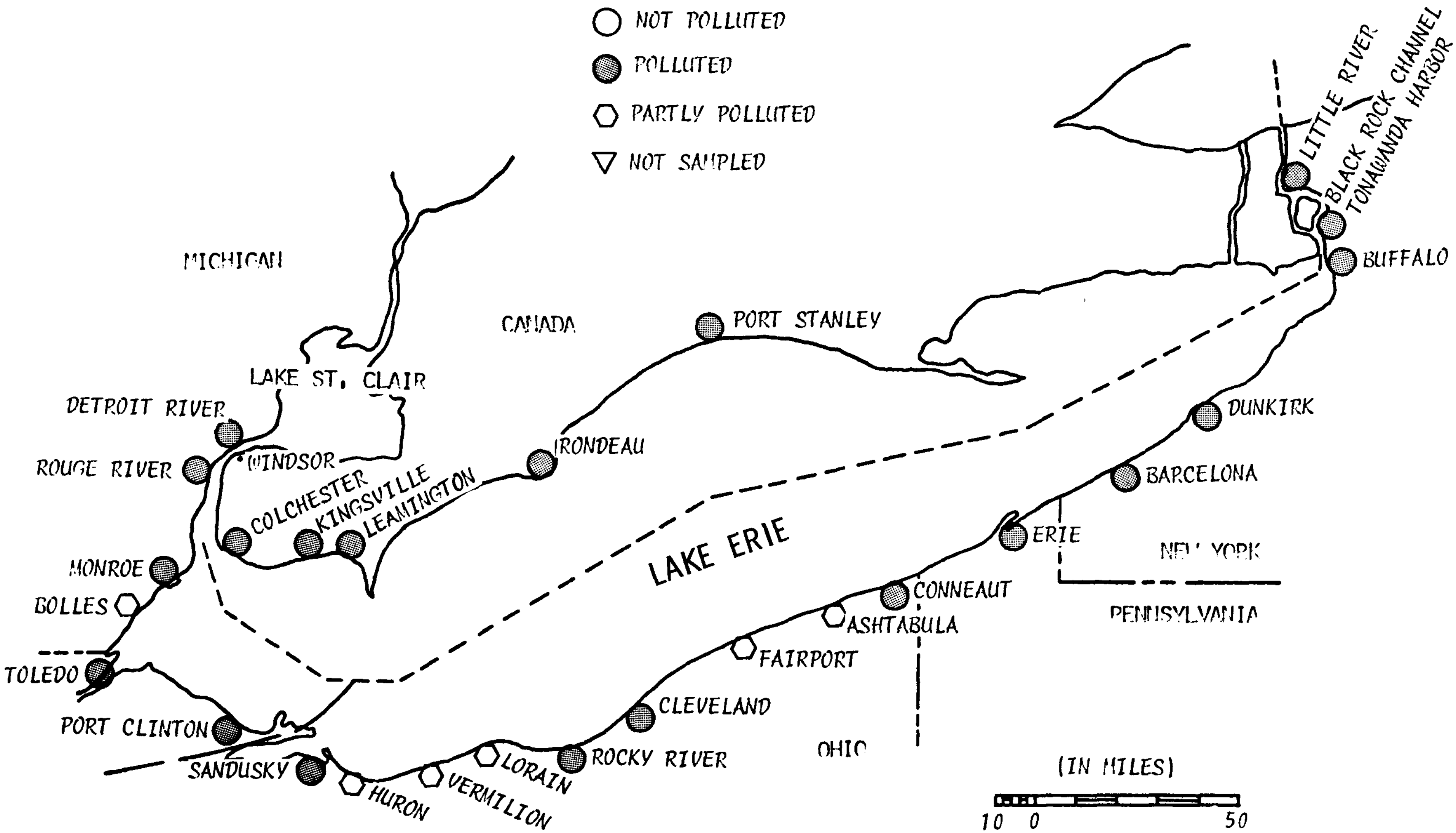


Figure 13. POLLUTION STATUS OF HARBORS IN LAKE ERIE

harbor is 8 (Table 54). The range in number of samples is from 3 at small harbors such as Rocky River, Barcelona, and Dunkirk to 17 at Buffalo and 26 from the Rouge River. All sampling was done prior to 1972. Some sampling has occurred since then, but testing has not been completed. The most commonly occurring pollutants in U.S. projects are phosphorus, oil and grease, Kjeldahl nitrogen, and volatile solids. All of these were excessive in almost every sample tested.

A total of 48 samples have been analyzed for Canadian harbors on Lake Erie. Canadian samples average about 10 per harbor. The range is from 3 at Colchester and Rondeau to 21 at Port Stanley. Phosphorus, Kjeldahl nitrogen, zinc, and COD are the most commonly surpassed pollution parameters in the Canadian projects. Apparently, testing for zinc has been considered more important by the M.O.E. than by the E.P.A. Of the 5 Canadian harbors sampled, 3 were tested for zinc. Of the 21 American harbors and waterways sampled, zinc tests were made at Cleveland and Fairport. In both projects zinc surpassed the E.P.A. criteria.

Future Quantity of Polluted Spoil

United States Projects--

Basically polluted dredged spoil is a problem associated with maintenance work. Most spoil dredged by permit is presently being confined and most new work dredging involves unpolluted material. Therefore, the projection of future polluted spoil in this report involves maintenance dredging over the next decade. From 1961 to 1970, an average of approximately 4.6 million cubic yards of spoil were removed from the American waters of Lake Erie every year in maintenance dredging projects. Of this volume, approximately 4.4 million cubic yards, about 95 percent of the total involved polluted material (Table 55). The volume of polluted spoil was calculated on the basis of the E.P.A. latest pollution classification of harbors and detailed analysis of their sediment sample maps.

Table 54. SAMPLING OF PROJECTS ON LAKE ERIE (54, 55)
(number of samples exceeded)

Harbor	Date of samples	No. of samples	Number exceeded: P	Vol. sol.	COD	Kjel. N	Oil & grease	Fe	Hg	Pb	Zn
U.S. samples											
Detroit R.	70	15	12	10	5	10	10	7	15	nt	nt
Rouge River	67	26	23	25	nt	21	24	10	nt	nt	nt
Monroe	69	3	2	3	3	2	2	1	nt	nt	nt
Bolles	72	5	3	1	1	1	1	nt	nt	nt	nt
Toledo	68	11	11	11	11	11	9	11	nt	nt	nt
Port Clinton	68	4	4	4	4	4	4	4	nt	nt	nt
Sandusky	68	7	7	7	7	7	7	7	nt	nt	nt
Huron	68	5	4	5	5	5	5	5	nt	nt	nt
Vermilion	68	4	4	4	4	4	4	4	nt	nt	nt
Lorain	68	7	7	7	7	7	7	7	nt	nt	nt
Rocky River	70	3	3	3	3	3	3	3	nt	nt	nt
Cleveland	72	15	15	15	15	15	15	nt	15	15	15
Fairport	72	6	6	6	6	5	5	nt	0	6	6
Ashtabula	68	7	7	1	0	6	3	5	nt	nt	nt
Conneaut	68	10	10	10	10	10	10	10	nt	nt	nt
Erie	68	6	6	6	6	6	6	6	nt	nt	nt
Barcelona	70	3	2	1	1	2	3	2	nt	nt	nt
Dunkirk	68	3	3	3	3	3	3	3	nt	nt	nt
Buffalo H&R	67	17	17	17	17	17	17	17	nt	nt	nt
Black Rk. Ch.	67	8	8	8	8	8	8	8	nt	nt	nt
Little River	No data, but classed polluted by E.P.A.										
Tonawanda Hbr.	No data, but classed polluted by E.P.A.										
Totals		165	154	147	116	147	146	110	30	21	21
Canadian samples											
Port Stanley	70,71	21	21	0	13	21	nt	nt	0	nt	19
Rondeau	71	3	3	2	nt	3	nt	nt	nt	nt	nt
Leamington	70	6	6	0	6	6	nt	nt	0	nt	4
Kingsville	70,72	15	15	0	12	11	1	nt	10	nt	12
Colchester	71	3	nt	2	3	3	nt	nt	nt	nt	nt
Totals		48	45	4	34	44	1	nt	10	nt	35

[a] nt Not tested

Table 55. VOLUME OF POLLUTED DREDGED SPOIL: C.E. PROJECTS IN LAKE ERIE, 1961-1970 (cubic yards)

Project	Year E.P.A. sampled	Pollution class	Ave. annual maintenance dredging	Percent polluted	Volume of polluted spoil
Detroit District					
Bolles	1972	P/U	8,737	75	6,553
Detroit River	1970	P	324,507	100	324,507
Monroe	1969	P	184,629	100	184,629
Port Clinton	1968	P	5,961	100	5,961
Rouge River	1967	P	202,121	100	202,121
Toledo	1973	P	1,083,791	100	1,083,791
District totals			1,809,746		1,807,562
Buffalo District[a]					
Ashtabula	1968	P/U	125,769	75	94,327
Black Rk. Ch./ Tonawanda Hbr.	1967	P	83,498	100	83,498
Buffalo	1967	P	448,824	100	448,824
Cleveland	1972	P	875,629	100	875,629
Conneaut	1968	P	68,704	100	68,704
Dunkirk	1968	P	12,109	100	12,109
Erie	1968	P	162,033	100	162,033
Fairport	1972	P/U	302,687	80	242,150
Huron	1973	P/U	151,935	75	151,935
Lorain	1968	P/U	120,199	80	96,159
Rocky River	1970	P	708	100	708
Sandusky	1973	P	439,704	100	439,704
District totals			2,791,799		2,637,796
Totals for Lake Erie			4,601,545		4,445,358

[a]Vermilion, Barcelona, and Little River are rarely dredged.

As determined in Section III, maintenance dredging in the next decade should result in the removal of approximately the same total volume of spoil that was removed during the 1960's. Most of the material to be dredged in the future will be polluted spoil from the large commercial harbors in Lake Erie (Figure 14). Thus, it is projected that unless unlimited open-lake disposal is permitted to resume as a result of severe economic stress or relaxation of pollution standards, confinement of more than 90 percent of the material to be dredged in the next decade will be necessary. This means that 40 to 45 million cubic yards of dredged spoil will have to be confined during the next 10 years.

As of July, 1974, 19 projects were in the diked disposal program for Lake Erie. They were at various degrees of completion, from planning to actual construction. For most dredging projects in the lake, confined disposal facilities are expected to be available by 1977 (Table 56). Thus, confined disposal should occur by that time. Volumes of material removed in the past few years have been slightly lower than the average removed during the 1960's. However, they should increase in the latter 1970's and remain higher than average into the early 1980's.

Canadian Projects--

From 1961 to 1970, an average of approximately 351,000 cubic yards of spoil were removed from Canadian projects in Lake Erie annually in maintenance dredging projects. But due to the loss of Port Burwell's volumes with a change in status as previously discussed, maintenance dredging in the next decade is expected to decline and average between 150,000 and 200,000 cubic yards annaully.

Projections made available by the D.P.W. indicate that about 542,000 cubic yards of spoil are expected to be dredged from public harbors on Lake Erie by 1977. About 70 percent of this volume is to be removed from Port Stanley, Rondeau, Leamington, Kingsville, and Colchester, harbors which have been sampled by the M.O.E. (Table 54). These

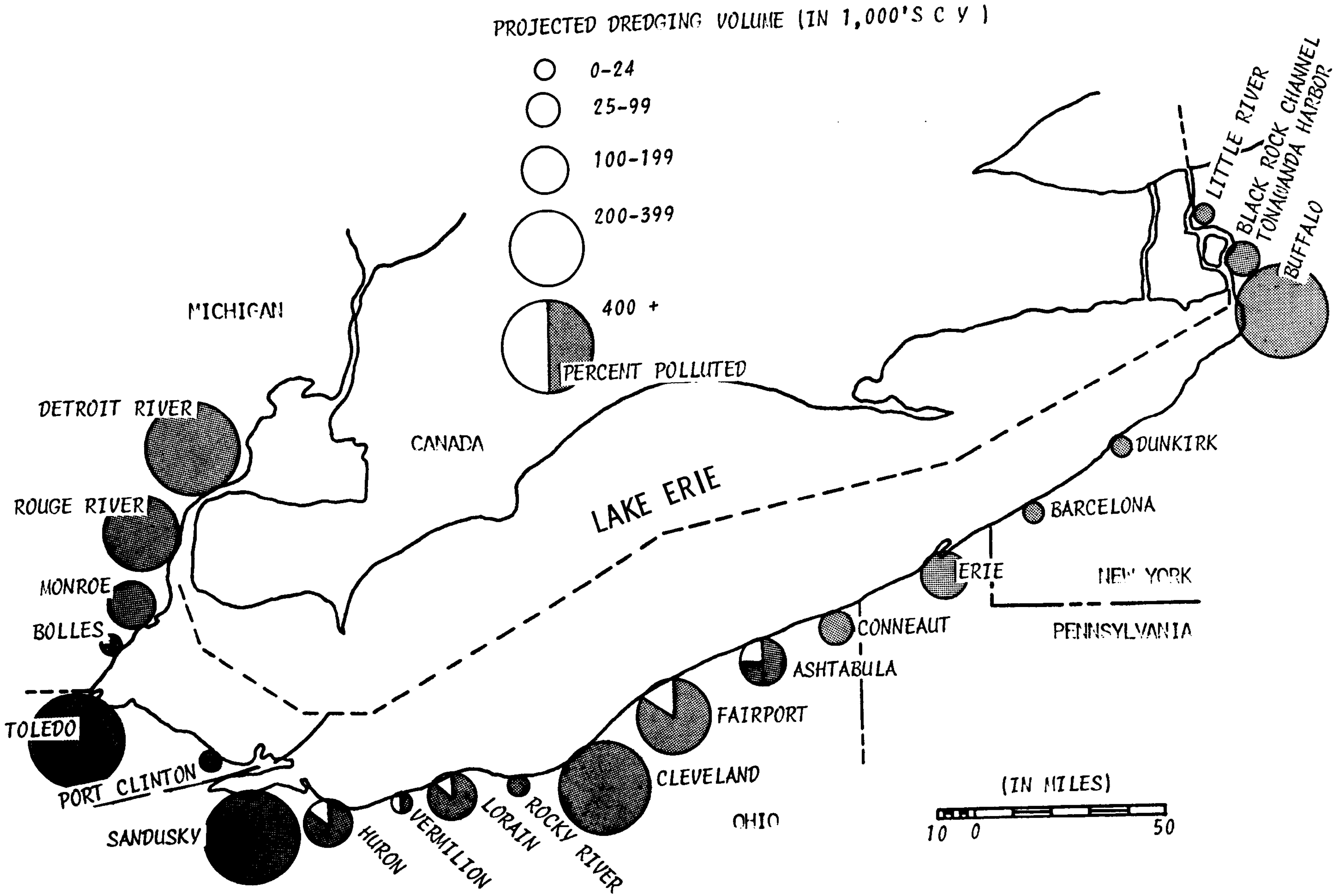


Figure 14. PROJECTED ANNUAL POLLUTED AND UNPOLLUTED MAINTENANCE DREDGING VOLUMES IN LAKE ERIE

Table 56. 1974 STATUS OF LAKE ERIE DIKED DISPOSAL PROGRAM (52)

Project	On program	Site being used now	Site selected	Construction date
Rouge River	x	x	x	1975
Detroit River	x	x	x	1975
Toledo	x	x	x	1974
Port Clinton	x	-	-	--
Monroe	x	x	-	--
Bolles	x	-	x	1974
Ashtabula	x	-	x	1976
Buffalo	x	x	x	1974
Black Rock/Tonawanda	x	x	x	1974
Cleveland	x	x	x	1974-75
Conneaut	x	-	x	1974
Erie	x	-	x	1975
Fairport	x	-	x	1975
Huron	x	-	x	1974
Lorain	x	-	x	1975
Sandusky	x	-	x	1975
Dunkirk	x	-	-	1975
Vermilion	x	-	-	1975
Little River	x	-	-	1975
Rocky River	x	-	-	1975

harbors yielded some samples which exceeded at least some pollution parameters and, for the purpose of this report, are considered polluted. Assuming that the Canadian projects which have not been sampled are not polluted, then approximately 380,000 cubic yards of polluted spoil will be dredged by 1977. This represents about 70 percent of the total volume of material scheduled for dredging in Canadian waters of the lake in the near future.

Only 5 of the 14 harbors scheduled for maintenance dredging in the future have been sampled to date by the M.O.E. Thus, the percentage of polluted spoil to be removed in the future, as projected above, is only an estimate. More accuracy in estimating future polluted volumes on the Canadian side of Lake Erie will only be possible when all projects are sampled and more test results completed.

<u>Summary</u>

1. Of the 21 sampled American harbors on Lake Erie, 15 are entirely polluted and 6 are partially polluted. All 5 Canadian harbors sampled exceeded the maximum allowable concentration of at least one pollutant.

2. Most commonly occurring pollutants in U.S. harbors are phosphorus, oil and grease, Kjeldahl nitrogen, and volatile solids. Phosphorus, Kjeldahl nitrogen, zinc, and COD are the most commonly surpassed parameters in Canadian projects.

3. Approximately 95 percent of the spoil dredged from American projects in Lake Erie during the 1960's was polluted.

4. Forty to 45 million cubic yards of polluted dredged spoil from American projects are anticipated during the next decade.

5. Major maintenance dredging projects, i.e., Toledo, Cleveland, Sandusky, Buffalo, and the Detroit River, have high volumes of polluted spoil.

6. A few large dredging projects, such as Fairport, Ashtabula, Lorain,

and Huron (with 100,000 to 300,000 cubic yards of material removed annually) are classified as partially polluted.

7. Twenty Lake Erie projects are in the C.E. diked disposal program. Confined facilities for these projects are expected to be available by 1977.

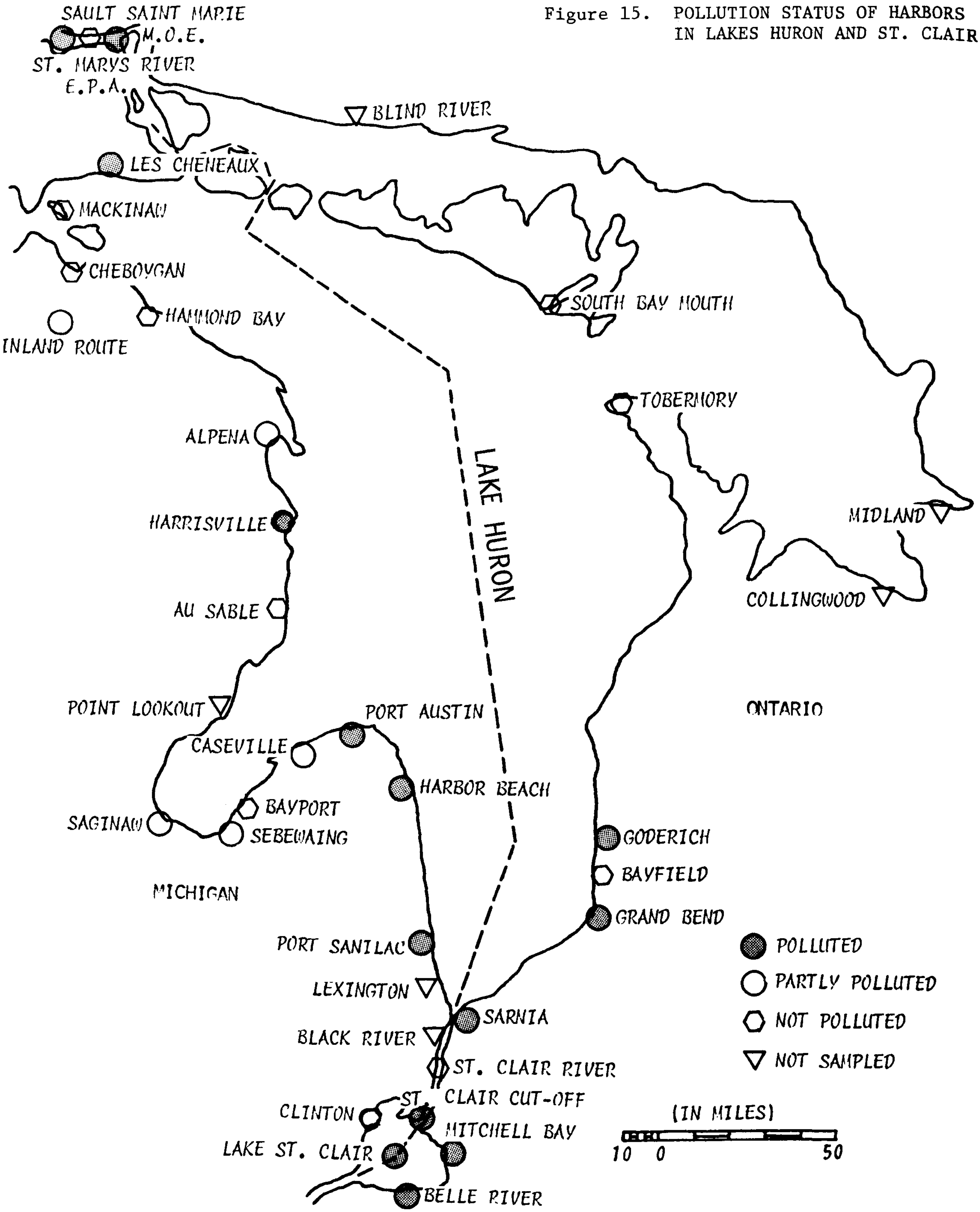
8. About one-half million cubic yards of material are scheduled to be removed from Canadian projects on Lake Erie by 1977. An estimated 70 percent of this material will be polluted.

9. Most Canadian harbors on Lake Erie have not been sampled by the M.O.E. Only when they are sampled are accurate estimates of future polluted spoil volumes possible.

QUANTITY OF POLLUTED DREDGED SPOIL IN LAKE HURON AND LAKE ST. CLAIR

In Lake Huron and Lake St. Clair a project design cannot always be associated with polluted or unpolluted dredged spoil. Generally, where long approach channels serve river harbors such as Saginaw, the channel sediments are unpolluted whereas the river sediments are polluted. Polluted spoil, however, is not entirely confined to such harbors. Many lakefront harbors, deriving their sediments from the nearshore environment, such as Harrisville and Harbor Beach, have polluted sediments. Figure 15 reveals that in Lake Huron only 10 out of the 30 harbors and waterways sampled do not exceed the principal E.P.A. or the M.O.E. criteria. As mentioned in the introduction of this section, sampling by the M.O.E. is confined to few localities. However, D.P.W. projects have been sampled more thoroughly than C.E. projects. Waterways such as the St. Clair River present significant problems. According to the E.P.A., the St. Clair River sediments are not polluted whereas samples retrieved by the M.O.E. at Sarnia and the St. Clair Cut-off exceed their criteria. Similar problems arise at Sault Ste. Marie. In many instances,

Figure 15. POLLUTION STATUS OF HARBORS IN LAKES HURON AND ST. CLAIR



therefore, it is not possible to classify a harbor or waterway in Lake Huron as completely polluted or unpolluted. There are areas of a dredging project which may be unpolluted whereas other areas are polluted. In Lake Huron, harbors such as Alpena, Caseville, and Sebewaing are therefore categorized as partially polluted (P/U).

In many sediment samples, several parameters have been exceeded and are noted in Table 57. Of the 7 mandatory parameters tabulated for the C.E. projects, COD is the most commonly occurring pollutant followed by volatile solids, and oil and grease. In the D.P.W. projects, Kjeldahl nitrogen and COD are the most common pollution parameters which exceed the M.O.E. criteria. Both environmental agencies confirm the high occurrence of mercury in Lake St. Clair. In Michigan, most C.E. projects have been sampled since 1967 whereas in Ontario only 10 projects have been assessed through 1973. Therefore, based on the number of projects sampled, a more accurate estimate of future polluted dredging volumes may be determined for the C.E. dredging projects.

Projects where sediments were classified as polluted and unpolluted by the E.P.A. were mapped on the Project Maps of the C.E. and the ratio of polluted sediment volume to the unpolluted sediment volume determined. When possible this ratio was confirmed by the C.E. Detroit District. Table 58 represents, by project, future annual maintenance dredging that the C.E. feels necessary to maintain all projects in Lake Huron and Lake St. Clair at project depth and the percent of polluted sediment within each project. Based on these data, 874,650 of the 1.2 million cubic yards or 72 percent of the spoil would not be suitable for open-lake disposal. Table 59 represents a decade (1961-70) of C.E. maintenance dredging in the 2 lakes by project. During the 1960's, 728,776 cubic yards were removed annually from C.E. projects. Assuming that the sediment quality did not change in the past decade, 426,186 cubic yards or 58 percent of these dredgings would have exceeded E.P.A.'s criteria. Therefore, if the C.E. were to meet their projection in the next decade,

Table 57. SAMPLING OF PROJECTS ON LAKE HURON/ST. CLAIR (54, 55)

Harbor	Year sampled	No. of samples	Number exceeded: Vol. sol.	COD	Kjel. N	Oil & grease	Hg	Pb	Zn
Michigan									
Alpena									
Inner	1972	5	0	2	0	0	nt	nt	nt
Outer	1972	3	1	1	1	1	nt	nt	nt
Au Sable	1967	3	0	nt	0	0	nt	nt	nt
Bay Port	1972	9	0	0	0	0	nt	nt	nt
Caseville	1972	4	1	2	2	1	nt	nt	nt
Cheboygan	1967	3	0	nt	nt	0	nt	nt	nt
Clinton R.	1970	4	3	3	3	3	0	nt	nt
Hammond Bay	1970	2	0	0	nt	0	0	nt	nt
Harbor Beach	1972	5	4	5	5	0	nt	nt	nt
Harrisville	1970	4	0	1	nt	0	0	nt	nt
Inland Route	1970	5	3	4	nt	3	0	nt	nt
L. St. Clair	1970	8	1	3	3	0	6	nt	nt
Les Cheneaux	1970	3	3	2	nt	0	0	nt	nt
Lexington	Not sampled								
Mackinaw City	1970	2	0	0	nt	0	nt	nt	nt
Point Lookout	Not sampled								
Port Austin	1972	2	0	2	nt	0	nt	nt	nt
Port Sanilac	1972	7	0	3	5	0	nt	nt	nt
Saginaw									
Inner	1972	10	8	8	2	9	nt	nt	nt
Outer	1972	5	2	4	4	4	nt	nt	nt
Sebewaing	1972	4	3	4	4	3	nt	nt	nt
Straits of Mackinaw	1970	4	0	0	nt	0	0	nt	nt
St. Clair R.	1970	7	0	0	0	0	1	nt	nt
St. Marys R.	1972	15	0	0	0	0	nt	nt	nt
Totals		114	29	44	29	24	7	-	-
Ontario									
Bayfield	1973	Visual inspection							
Grand Bend	1973	3	Organics, COD, Zn exceed M.O.E. criteria						
Goderich	1973	1	0	0	0	nt	nt	1	0
Mitchell Bay	1971	2	0	nt	0	nt	2	0	0
Ruscom R.	1971	8	3	nt	2	nt	nt	nt	nt
St. Clair R.	1972	38	0	30	37	0	29	0	2
Sarnia	1971	7	1	6	1	7	nt	nt	nt
South Bay M.	1972	None exceed M.O.E. criteria							
Tobermory	1972	1	0	0	0	nt	nt	nt	nt
Sault Ste. Marie									
N. of Locks	1971	8	2	0	nt	3	nt	nt	nt
Pt. aux Pins	1972	27	4	0	4	4	nt	0	2
Totals		97	10	36	44	14	31	1	4

[a]nt Not tested

Table 58. C.E. PROJECTED MAINTENANCE DREDGING AND POLLUTED VOLUMES, LAKE HURON/ST. CLAIR (50) (cubic yards)

Project	C.E. projection	Percent polluted	Ann. ave. polluted spoil	class	10-year site completed
Alpena	8,000	90	7,200	P/U	June, 1976
Au Sable[a]	30,000	0	0	U	--
Bay Port	6,000	0	0	U	June, 1976
Black River[a]	3,000	Not sampled			--
Caseville	12,000	40	4,800	P/U	October, 1976
Ch. Lake St. Clair	200,000	100	200,000	P	June, 1975
Cheboygan[a]	10,000	0	0	U	--
Clinton River	21,000	85	17,850	P/U	June, 1976
Hammond[a]	10,000	0	0	U	--
Harbor Beach	5,000	100	5,000	P	December, 1976
Harrisville[a]	12,000	100	12,000	P	--
Inland Route	10,000	50	5,000	P/U	December, 1976
Les Cheneaux	10,000	100	10,000	P	December, 1976
Mackinaw City[a]	4,000	0	0	U	--
Port Austin[a]	4,000	100	4,000	P	--
Port Sanilac	7,200	100	7,200	P	June, 1976
Saginaw	700,000	85	595,000	P	June, 1976
Sebewaing	20,000	33	6,600	P/U	October, 1976
St. Clair R.[a]	75,000	0	0	U	--
St. Marys R.[a]	65,000	0	0	P/U	--
Totals	1,212,200		874,650 (72%)		

[a]Not on the 10-year confined disposal program (PL 91-611).

Table 59. VOLUME OF POLLUTED DREDGED SPOIL: C.E. PROJECTS IN LAKE HURON/ST. CLAIR, 1961-1970
(cubic yards)

Project	Year sampled	Average annual maintenance dredging	Percent polluted	Polluted volume
Alpena	1972	9,768	90	8,791
Au Sable	1967	20,775	0	0
Bay Port	1972	0	0	0
Caseville	1972	0	30	0
Black River	Not sampled	0	0	0
Channels of Lake St. Clair	1970	106,828	100	106,828
Cheboygan	1967	9,123	0	0
Clinton River	1970	15,350	85	13,050
Hammond Bay	1970	0	0	0
Harbor Beach	1972	22,825	100	22,825
Harrisville	1970	600	100	600
Inland Route	1970	90	50	45
Les Cheneaux	1970	10,273	100	10,273
Lexington	Not sampled	0	0	0
Mackinaw	1970	0	0	0
Point Lookout	Not sampled	0	0	0
Port Sanilac	1972	7,670	100	7,670
Saginaw	1972	294,735	85	250,524
St. Clair River	1970	91,915	0	0
St. Marys River	1972	121,912	0	0
Sebewaing	1972	16,912	33	5,580
Totals		728,776		426,186 (58%)

Port Austin, sampled in 1972, is 100 percent polluted. However, it has not been dredged in two decades, and no confined disposal site is planned.

a 14 percent increase of polluted dredged spoil over the 1961-1970 decade may be anticipated.

As mentioned in the previous section, the C.E. projection of future maintenance dredging represents a maximum projected figure. Based on dredging frequencies in the recent past, projects such as Port Austin, although classified as polluted, have not been dredged in several years. Thus, the percent of polluted dredged spoil associated with the C.E. dredging projection (Table 58) may indeed be high.

Table 60 illustrates new work and maintenance dredging totals of the C.E. in 1972 and 1973. If it is assumed that dredgings disposed on land are polluted and dredgings disposed in open water are not polluted, it may be concluded that in 1972 about 43 percent of the dredging volume is not suitable for open-lake disposal. In 1973, approximately 53 percent of the spoil did not qualify for open-lake disposal. Based on actual field data over the past 2 years less than one half of the spoils removed from C.E. projects were polluted.

Perhaps the greatest concern of polluted dredged spoil is in projects which have the highest maintenance dredging volumes. Approximately 88

Table 60. DISPOSAL OF SPOIL IN LAKE HURON/ST. CLAIR PROJECTS, 1972 AND 1973 (50) (cubic yards)

Project	1972		1973	
	On land	Open lake	On land	Open lake
Au Sable	0	41,625	0	7,420
Harrisville	0	25,950	0	0
Inland Route	76,259	0	0	0
Saginaw	86,994	0	87,943	21,263
St. Clair R.	0	26,337	0	8,800
St. Marys R.	0	122,099	0	40,123
Totals	163,253(43%)	216,011(57%)	87,943(53%)	77,606(47%)

percent of the past and future dredging has and will occur in Au Sable, Lake St. Clair, Saginaw, the St. Clair River, and the St. Marys River (Table 33). Assuming that past and future sediment quality is representative of the present sediment quality, 57 percent of the dredgings from these harbors will be polluted (Table 61).

Table 61. ESTIMATED POLLUTED DREDGED SPOIL IN MAJOR C.E. PROJECTS IN LAKE HURON/ST. CLAIR (cubic yards)

Project	Annual maintenance dredging--1961-1970	Percent polluted	Polluted volume
Au Sable	9,768	0	0
Saginaw	294,735	85	250,524
Lake St. Clair	106,828	100	106,828
St. Clair River	91,915	0	0
St. Marys River	121,912	0	0
Totals	625,158		357,352 (57%)

Based on a harbor by harbor projection determined in Section III, the percent of polluted sediment to be dredged may be estimated (Figure 16). As noted in Table 62, the greatest volume of polluted dredged spoil will be derived from Saginaw and Lake St. Clair. Other areas where relatively high volumes of polluted sediments occur are Inland Route, Harbor Beach, Les Cheneaux, Alpena, and Sebewaing. Of the above mentioned projects, Saginaw faces the most serious problem in terms of confined disposal. Dow Chemical Company withdrew their site offer and the Michigan Department of Natural Resources is opposed to filling bottom land near the shoreline (13). The C.E. has estimated that there is a backlog of 2.5 million cubic yards of sediment which is increasing at a rate of approximately 600,000 cubic yards annually. The channel depth has been reduced from between 4 to 7 feet above project depth. To our knowledge an Environmental Impact Statement has not been prepared for this project.

Figure 16. PROJECTED ANNUAL POLLUTED AND UNPOLLUTED MAINTENANCE DREDGING VOLUMES IN LAKES HURON AND ST. CLAIR

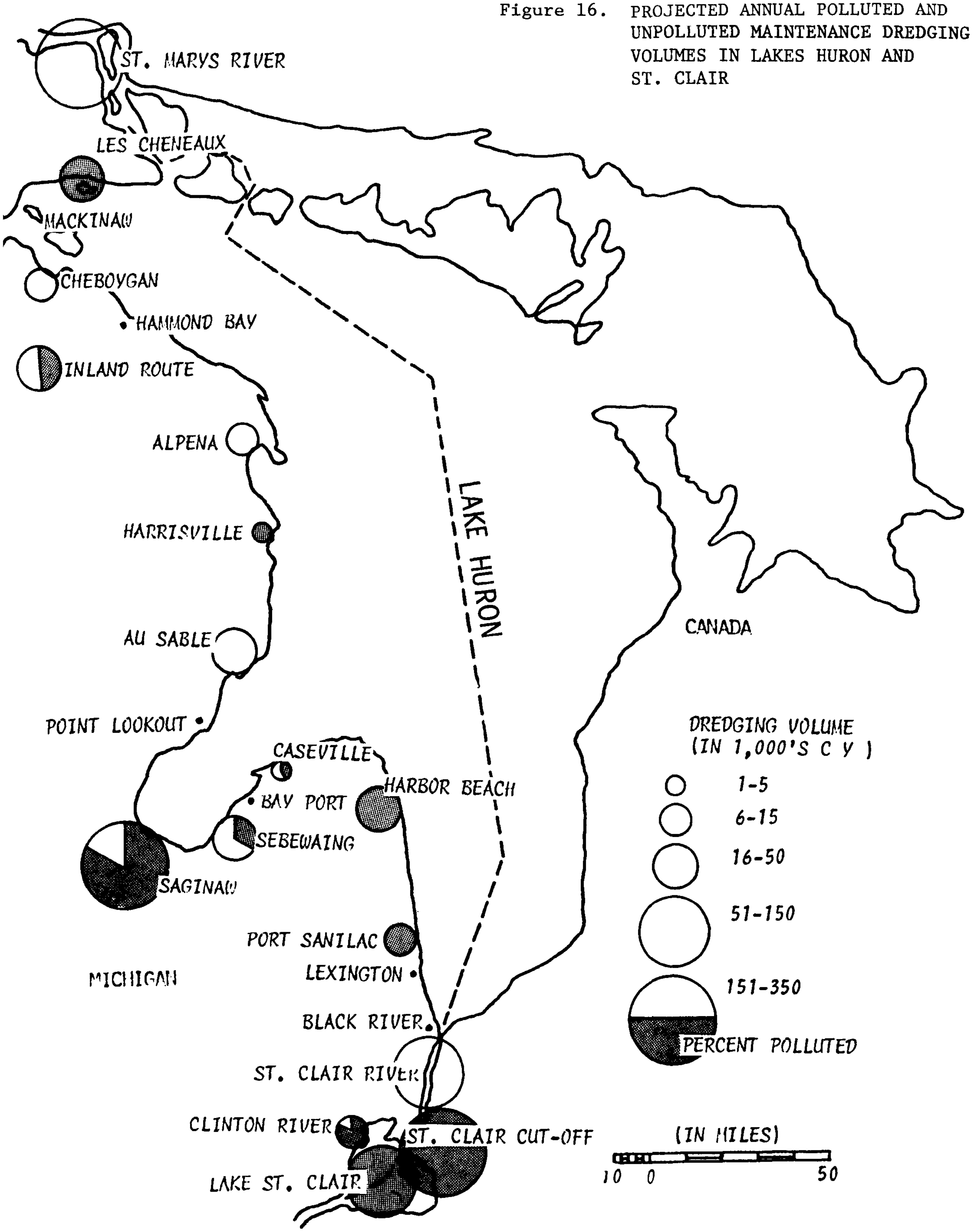


Table 62. ESTIMATED VOLUME OF FUTURE POLLUTED DREDGED SPOIL IN LAKE HURON/ST. CLAIR (cubic yards)

Project	Maintenance dredging	Percent polluted	Polluted volume
Alpena	9,768	90	8,791
Au Sable	20,828	0	0
Bay Port	0	0	0
Black River	0	0	0
Caseville	3,236	40	1,294
Ch. Lake St. Clair	177,677	100	177,677
Cheboygan	11,614	0	0
Clinton R.	7,602	85	6,462
Hammond Bay	0	0	0
Harbor Beach	32,083	100	32,083
Harrisville	3,453	100	3,453
Inland Route	22,611	50	11,306
Les Cheneaux	20,545	100	20,545
Lexington	-	Not sampled	-
Mackinaw	0	0	0
Point Lookout	0	100	0
Port Sanilac	6,973	100	6,973
Saginaw	334,871	85	284,640
St. Clair R.	108,513	0	0
St. Marys R.	243,824	0	0
Sebewaing	24,160	33	8,053
Totals	967,758		501,277 (52%)

The confined disposal site for dredgings from Lake St. Clair is firm and a final Environmental Impact Statement has been prepared in April 1974. No foreseeable problems, other than the property purchase for the confined site on the St. Clair delta, are anticipated there at this time.

It may be expected that, based on an annual maintenance dredging projection of 967,768 cubic yards in Lake Huron and Lake St. Clair, 52 percent of the volume will not meet the sediment quality criteria of the E.P.A. Future annual maintenance dredging is anticipated to increase by 200,000 cubic yards over the 1961-1970 decade, however the volume of polluted spoil will increase by 85,000 cubic yards. If no sediment abatement programs are initiated and the E.P.A. upholds its present sediment quality criteria, it may be expected that between 45 and 72 percent of future maintenance dredging will not qualify for open-lake disposal. However, based on a projection of the principal projects (Table 61) and individual projects (Table 62) it appears that approximately 55 percent of the spoil to be removed in the future will be polluted. In most projects confined disposal facilities under PL 91-611 are to be constructed in the next 2 to 3 years (Table 58), suggesting that polluted sediments will be confined in the prepared sites by 1977 and dredging activity and hence volumes will increase at that time.

In Ontario, investigations by the M.O.E. are not as complete in terms of the number of harbors sampled as in Michigan. However, of the 14 sampled projects in Lake Huron, 7 exceed the recommended criteria of the M.O.E. (Figure 15). Although the M.O.E. as yet does not classify navigation projects as polluted and unpolluted, in this lake, it is assumed that if the criteria are exceeded the project is polluted. Between 1961 and 1970 maintenance dredging averaged 278,000 cubic yards annually. Assuming that the D.P.W. projects sampled exceeded the M.O.E. criteria, then as now, and the remaining projects did not exceed the criteria, approximately 135,000 cubic yards or 49 percent of the dredgings were polluted. Table 63 represents the future maintenance dredging in Lake

Table 63. FUTURE DREDGING BY D.P.W. IN LAKE HURON/ST. CLAIR AND PROJECTED VOLUME OF POLLUTED SPOIL (48, 54) 1973-1977 (cubic yards)

Project	Total volume	Sediment quality
Belle River	26,000	n.s.[a]
Byng Inlet	48,874	n.s.
Cedar Beach	7,000	n.s.
Collingwood	70,000	n.s.
Goderich	70,000	Polluted
Grand Bend	40,000	Polluted
Kincardine	15,000	n.s.
Midland	5,000	n.s.
Oliphant	10,000	n.s.
Pike Creek	16,000	n.s.
St. Clair Cut-off	1,200,000	Polluted
Sault Ste. Marie	26,000	Polluted
Sarnia	26,000	Polluted
Sydenham	28,000	n.s.
Total	1,587,874 of which 1,362,000 (85%) exceed M.O.E. criteria	

[a]n.s. not sampled.

Huron and the sediment quality of sampled areas. If the projects which are not sampled do not exceed the M.O.E. criteria, it may be concluded that 85 percent of the dredgings in Canadian projects are polluted. Approximately 1.2 million cubic yards of polluted sediment is located at Sault Ste. Marie and in the St. Clair Waterway. The D.P.W. is presently constructing and testing a diked disposal area at Mitchell Bay in Lake St. Clair. It is therefore anticipated that a confined site will be prepared to receive dredgings from the St. Clair Cut-off in the near future.

As can be seen from the data above, an unbiased estimate of polluted dredged spoil cannot be determined for Canadian projects in Lake Huron/ St. Clair. If the M.O.E. criteria are exceeded, confinement of spoil does not necessarily follow. At Sault Ste. Marie open-lake disposal has recently occurred at Gros Cap. Very few of the approximately 50 projects in Ontario have been sampled. Only when all the projects are sampled can accurate assessments of polluted volumes be made. However, based on available data, thus far, it appears that the percent polluted spoil in Ontario is comparable to that of Michigan.

Summary

Based on data in this section and Section III the following have been determined:

1. Of the 30 sampled harbors in Lake Huron, 10 are not polluted.

2. Pollution parameters most often exceeded in C.E. dredging projects are COD, volatile solids, and Kjeldahl nitrogen. In D.P.W. projects, Kjeldahl nitrogen and COD are the most commonly exceeded parameters.

3. Polluted sediments are not exclusively limited to river harbors. Harbors on the lake front (e.g., Harrisville, Port Sanilac) are also polluted.

4. Polluted dredged spoil in C.E. projects in 1972 and 1973 was 42 and 53 percent respectively.

5. The quantity of polluted dredged spoil in the last decade is approximately the same as the volume to be dredged in the future (57% vs. 52%).

6. If the C.E. were to dredge 1.2 million cubic yards annually, as they have projected, 72 percent of the dredgings would be polluted.

7. Based on an annual projection of 0.9 million cubic yards, approximately 52 percent of the spoil would be polluted.

8. Although future annual maintenance dredging is anticipated to increase by about 200,000 cubic yards over the past decade, the quantity of polluted sediments will increase by only 85,000 cubic yards.

9. High maintenance dredging projects, such as the St. Clair River, Au Sable and St. Marys River, are not necessarily equated with high volumes of polluted spoil.

10. The largest volume of polluted spoil (90%) in the next decade will be dredged from Lake St. Clair and from Saginaw.

11. Saginaw, where dredging of polluted spoil has been delayed, faces the most serious problem in terms of confined disposal. A site for Lake St. Clair's polluted spoil is firm at this time. Confined sites for all polluted projects under PL 91-611, with the exception of Port Austin, are also firm.

12. Based on available data, 85 percent of the future dredging volumes in Ontario will be polluted. Most of this quantity (1.2 million cubic yards) will be removed from the St. Clair Cut-off.

QUANTITY OF POLLUTED DREDGED SPOIL IN LAKE MICHIGAN

Based on the Environmental Protection Agency's 7 mandatory pollution parameters, the current pollution analyses of public harbor sediments in the dredging areas are indicated in Table 64. Sediments of private harbors have not been routinely sampled, therefore private harbors are not treated herein. The E.P.A. usually samples the public harbors prior to the scheduling of maintenance dredging. A total of 327 bottom samples were taken, for an average of 7.4 samples per public harbor. Though Milwaukee Harbor was re-sampled in 1973 and St. Joseph in 1974, the analyses data were not available.

Table 64. POLLUTION OF PUBLIC HARBORS IN LAKE MICHIGAN BY PARAMETER BY C.E. DISTRICT (55)

Harbor	Year sampled	No. of samples	Criteria limits exceeded: Vol. sol.	COD	Kjel. N	Oil & grease	Hg	Pb	Zn
Algoma	1969	8			x		nt		
Big Suamico	1970	5	x	x	x				x
Burns Waterway	1970	5	x					x	x
Calumet H. & R.	1968	4	x	x	x	x	nt	x	x
Chicago Hbr.	1971	6	x	x	nt	x		x	x
Chicago River	1968	5	x	x	nt	x	nt	nt	nt
Gladstone-Kipling	1970	5							
Green Bay	1969	36	x	x	x	x	nt	x	x
Indiana	1967	11	x	nt	x	x	nt	x	x
Kenosha	1973	8	x	x	x	x	x	x	x
Kewaunee	1969	15	x	x	x	x	nt		x
Manitowoc	1969	23	x	x	x	x	nt	x	x
Menominee	1969	17	x	x	x	x	nt	x	x
Michigan City	1970	7	x	x	x	x	x	x	x
Milwaukee	1968	9	x	x	x	x	nt	x	x
New Buffalo[a]	1968	4			x		nt		
Oconto	1968	2					nt		
Pensaukee	1968	4		x	x	x	nt		
Port Washington	1971	8	x	x				x	x
Racine	1973	13	x	x	x	x	x	x	x
Sheboygan	1969	18	x	x	x	x	nt	x	x
Sturgeon Bay/ Ship Canal	1969	16	x	x	x	x	nt	x	x
Two Rivers	1969	15	x	x	x	x	nt	x	x
Waukegan	1973	9	x	x	x	x	x	x	x
Total samples		253							
Percent of harbors polluted by each parameter			79	75	75	70	-	67	75

Table 64. (continued)

Harbor	Year sampled	No. of samples	Criteria limits exceeded: Vol. sol.	COD	Kjel. N	Oil & grease	Hg	Pb	Zn
Arcadia	Not sampled								
Charlevoix	1971	3			nt				
Frankfurt	1972	6	x	x	x	x	nt	nt	nt
Grand Haven	1972	7	x	x	x	x	nt	nt	nt
Grays Reef	Not sampled								
Holland	1972	7	x	x	x	x	nt	nt	nt
Leland	1971	2			nt				
Ludington	1967	4		nt			nt	nt	nt
Manistee	1967	4		nt			nt	nt	nt
Manistique	1967	3	x	nt		x	nt	nt	nt
Muskegon	1967	3		nt			nt	nt	nt
Pentwater	1967	15		nt			nt	nt	nt
Petoskey	Not sampled								
Portage Lake	1971	2			nt				
Saugatuck	1967	1		nt	nt	nt	nt	nt	nt
South Haven	1972	7	x	x	x	x	nt	nt	nt
St. James	Not sampled								
St. Joseph	1972	6	x	x		x	nt	nt	nt
Traverse City	1972	2	x		nt				x
White Lake	1967	2		nt			nt	nt	nt
Total samples		74							
Percent of harbors polluted by each parameter			35	25	20	30	-	-	-
Total for lake									
Percent of harbors polluted by each parameter			59	52	50	52	-	-	-

[a]New public harbor.

nt Not tested; x Parameter exceeded limits

Pollution classifications for each harbor are presented in Table 65. Of the 42 public harbors in Lake Michigan, 15 are classified as unpolluted, 10 are polluted, while the remaining 17 have been designated as partially polluted (P/U). In addition, New Buffalo, a project which is to be expanded soon into a new public recreational harbor, has already been sampled and is classified herein as partially polluted. Arcadia, Grays Reef, Petoskey, and St. James have not been sampled, but these harbors are not regarded as polluted.

The P/U classification is employed when the inner harbor contains polluted sediments while the outer harbor area is 'clean.' In some harbors such as Frankfurt and South Haven, the boundary between the polluted and unpolluted portions is located well inside the inner harbor. Other partially polluted harbors, for example, Sheboygan, Kenosha, and Waukegan, are polluted throughout except near the jetty and/or breakwater. Sturgeon Bay Harbor, which has an unusual design due to the ship canal, is polluted only in the vicinity of the city.

The most seriously polluted harbors are located in the Chicago District and include Calumet, Chicago Harbor and River, Green Bay, Indiana, Kewaunee, Manitowoc, Milwaukee, and Racine. Pollution of these harbors (Figure 17) is promoted by the large industrial and urban complexes adjacent to the navigation facilities. Conversely, most of the recreational harbors, as in the Detroit District, are not polluted. Based on the data available, parameters that most frequently exceeded the criteria limits included volatile solids and COD. In Kenosha, Michigan City, Racine, and Waukegan Harbors mercury was found in excess of its limits. Prior to 1970-1971, mercury was not considered to pose a problem, hence it was not routinely tested until after that time.

As indicated in Table 64, analyses of the harbor sediments are not complete, especially for the Detroit District. In this district many samples were not analyzed for mercury, lead or zinc concentrations. Saugatuck was classified on the basis of one sample from which only one

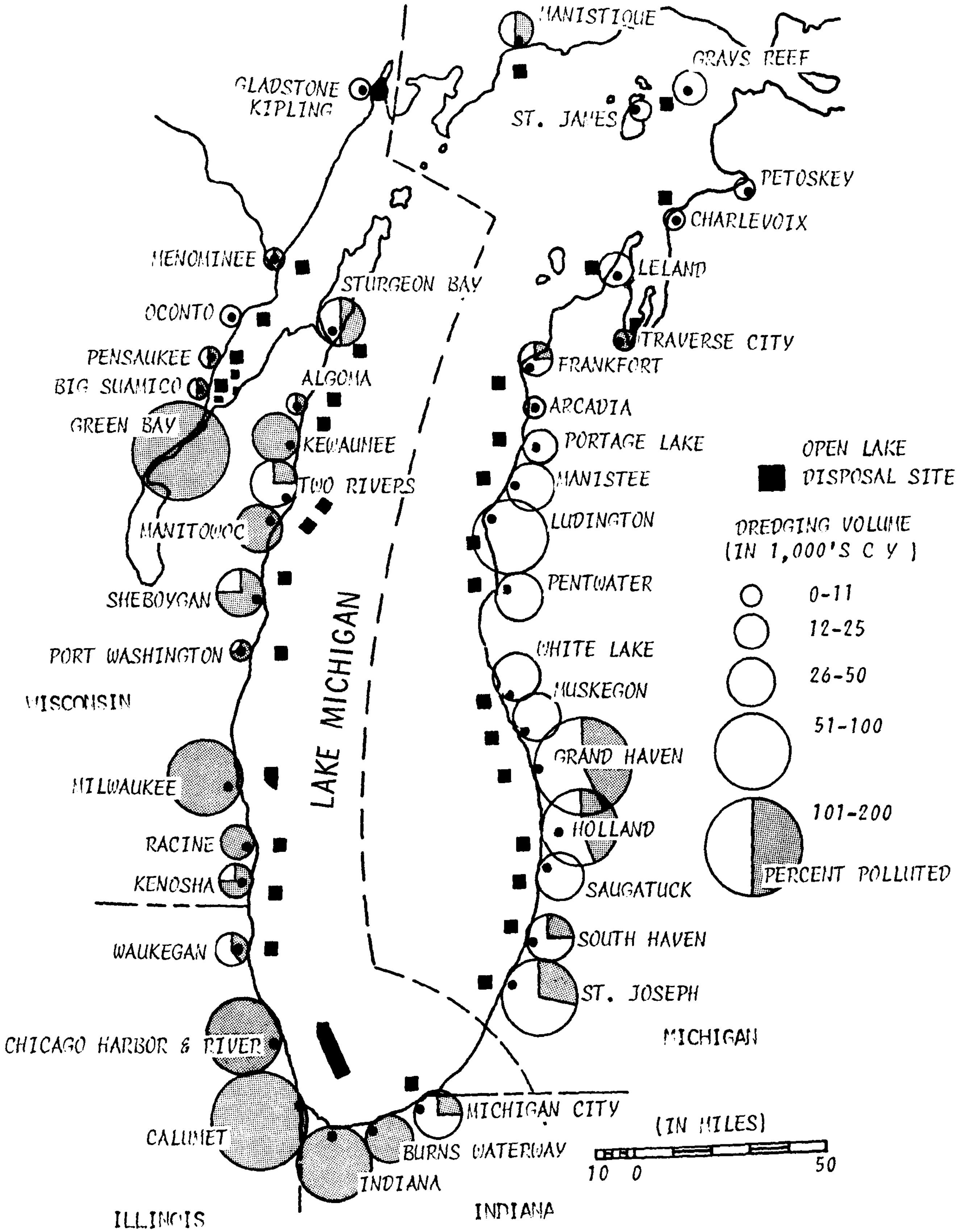


Figure 17. POLLUTED QUANTITY OF FUTURE AVERAGE ANNUAL MAINTENANCE DREDGINGS AND LOCATION OF OPEN-LAKE DISPOSAL SITES IN LAKE MICHIGAN

parameter was analyzed. In addition, COD and total Kjeldahl nitrogen were frequently omitted in the analyses of samples from this district. With the exception of mercury, analyses in the Chicago District are more complete. Pollution data for Ludington, Manistee, Muskegon, Pentwater, Saugatuck, Sheboygan, and White Lake Harbors are several years old, hence resampling may be in order.

At the specific request of the C.E., Waukegan Harbor was resampled in 1973. The analyses revealed that the outer harbor sediments near the breakwater were unpolluted. The resampling of Waukegan Harbor has emphasized the fact that many harbors are unpolluted in the outer harbor areas near the jetties and breakwaters where littoral currents are the main source of sediments. It is also being recognized that pollutants have a horizontal, vertical and seasonal distribution, and that background pollution can be produced by tree leaves and marsh drainage.

Future Quantity of Polluted Harbor Sediments

As illustrated in Table 65, a total of 28 harbors in Lake Michigan have been classified as polluted or partially polluted. Although New Buffalo Harbor has already been sampled, construction of this new recreational facility has not been completed. In an effort to determine the future average annual quantity of polluted dredged sediments, each partially polluted harbor was subdivided into unpolluted and polluted sections. This subdivision was based on the distribution of polluted samples within the dredging areas analyzed by the E.P.A. If all bottom samples taken from a given harbor, such as Indiana, exceeded one or more of the pollution parameter limits, then all spoil (i.e., 100 percent) dredged from that harbor was considered polluted.

Because maintenance dredging operations, as compared to new work, frequently involved polluted sediments, only the percentage of the average annual maintenance dredgings that may be polluted was estimated for each

Table 65. FUTURE AVERAGE ANNUAL QUANTITY OF POLLUTED MAINTENANCE DREDGING BY HARBOR BY C.E. DISTRICT IN LAKE MICHIGAN
(cubic yards)

Harbor	Pollution class	Percent of maintenance spoil polluted	Future annual maintenance dredging	Future annual polluted spoil
Chicago District				
Algoma	P/U	50	1,400	700
Big Suamico	P/U	50	2,700	1,400
Burns Waterway	P	100	30,000	30,000
Calumet H. & R.	P	100	113,800	113,800
Chicago Hbr. & R.	P	100	84,400	84,400
Gladstone-Kipling	U	0	3,000	0
Green Bay	P	100	156,100	156,100
Indiana	P	100	97,200	97,200
Kenosha	P/U	75	20,000	15,000
Kewaunee	P	100	38,000	38,000
Manitowoc	P	100	36,900	36,900
Menominee	P/U	60	7,900	4,700
Michigan City	P/U	25	36,100	9,000
Milwaukee	P	100	53,200	53,200
New Buffalo[a]	P/U	20	10,000	2,000
Oconto	U	0	2,200	0
Pensaukee	P/U	50	1,400	700
Port Washington	P/U	75	5,900	4,400
Racine	P	100	21,900	21,900
Sheboygan	P/U	75	33,100	24,800
Sturgeon Bay/ Ship Canal	P/U	50	42,200	21,100
Two Rivers	P/U	25	40,100	10,000
Waukegan	P/U	40	25,000	10,000
Totals			862,500	716,300

Table 65. (continued)

Harbor	Pollution class	Percent of maintenance spoil/ polluted	Future annual maintenance dredging	Future annual polluted spoil
Detroit District				
Arcadia	U	0	0	0
Charlevoix	U	0	6,100	0
Frankfurt	P/U	25	23,100	5,800
Grand Haven	P/U	45	130,800	58,900
Grays Reef	U	0	21,900	0
Holland	P/U	45	73,700	33,200
Leland	U	0	12,600	0
Ludington	U	0	31,600	0
Manistee	U	0	34,800	0
Manistique	P/U	50	11,900	6,000
Muskegon	U	0	49,200	0
Pentwater	U	0	42,500	0
Petoskey	U	0	0	0
Portage Lake	U	0	16,000	0
Saugatuck	U	0	50,300	0
South Haven	P/U	25	40,000	10,000
St. James (Beaver Island)	U	0	1,500	0
St. Joseph	P/U	30	54,900	16,500
Traverse City	P	100	1,500	1,500
White Lake	U	0	26,500	0
Totals for District			628,900	131,900
Totals for lake			1,491,400	848,200

[a]New harbor to be constructed.

U Harbor unpolluted, P/U Harbor partially polluted, P Harbor polluted.

harbor. These estimations, which are preliminary, are presented in Table 65. The percentages were derived by comparing the spatial distribution of polluted harbor bottom samples with the volumes of maintenance dredging that are extracted from the various areas of the harbor. Since the Corps of Engineers' dredging records do not reflect the quantities dredged from the various harbor areas, the percentages must be regarded as first-order approximations.

In the Chicago District the total future average annual quantity of polluted maintenance dredgings has been estimated to be 716,300 cubic yards place measure. This volume, which is 83 percent of the total projected quantity of maintenance dredging (i.e., 862,500 CY), reflects the relatively large number of polluted and partially polluted harbors in that district. Calumet Harbor and River, Chicago Harbor and River, Green Bay, Indiana, and Milwaukee Harbors are all projected to yield over 50,000 cubic yards annually of polluted spoil (Figure 17). Because of the relatively long flow-through time of water in the Lake Michigan basin, disposal of large quantities of polluted spoil in the open lake may have an unacceptable impact on the water quality and algal growth in southern Lake Michigan. In the Detroit District, only 21 percent of the total projected quantity of maintenance dredging (i.e., 628,900 CY) is estimated to involve polluted spoil. Grand Haven is the only harbor in that district which is anticipated to generate over 50,000 cubic yards annually of polluted spoil.

In accordance with Public Law 91-611, the C.E. is authorized to design and construct confined disposal facilities for the polluted public harbors in the Great Lakes. A summary of developments in the confined disposal program regarding the 27 polluted harbors in Lake Michigan is contained in Table 66. With the exception of Algoma, Big Suamico, Burns Waterway, Pensaukee, and Manistique, all the harbors listed are included in the Corps of Engineers' confined disposal program. Although the E.P.A. informed the C.E. that Algoma was unpolluted, one of the 2 bottom

Table 66. PLANNING OF CONFINED DISPOSAL SITES FOR POLLUTED PUBLIC HARBORS BY C.E. DISTRICT IN LAKE MICHIGAN (50, 52)

Harbor	Waiver granted	Diked disposal site selected	Completion date of diked site	Confined site now in use
Chicago District				
Algoma[a]				
Big Suamico[b]				x
Burns Waterway[a]				
Calumet Harbor & R.			1975	x
Chicago Harbor & R.			1975-76	
Green Bay		x		x
Indiana		x		x
Kenosha	x	x	1975	
Kewaunee	x	x	1975	
Manitowoc	x	x	1975	
Menominee		tentative	unknown	x
Michigan City		x		
Milwaukee	x	x	1974-75	
Pensaukee[a]				
Port Washington	pending	x	1974-75	
Racine	x	x	1975	
Sheboygan		x	1975	
Sturgeon Bay			1975-76	
Two Rivers	pending	x	1975	
Waukegan	x	x	1975	
Detroit District				
Frankfurt			1976	
Grand Haven	x	x	1974-75	x
Holland	x	x	1976	x
Manistique[a]				
South Haven			1976	
St. Joseph		pending	1976	
Traverse City			1976	

[a]Harbor not initially selected for the confined disposal program.
[b]Harbor dropped from the confined disposal program.

samples taken from the harbor is polluted. Big Suamico should be deleted from the table because it will not be maintenance dredged in the future by the C.E. Burns Waterway may not undergo maintenance dredging yet for another 3 to 4 years. Pensaukee and Manistique are small, recreational harbors with little dredging.

Seventeen of the 27 harbor projects listed in Table 66 have at least temporary solutions for the confinement of polluted dredged spoil. Calumet, Grand Haven, Green Bay, Big Suamico, Holland, Indiana, and Menominee all have confined land sites which have been or are presently in use. However, at Calumet Harbor and River, the site currently in use has been partially filled and only a year or so of capacity remains. A single 10-year confined site has been designed for Milwaukee and Port Washington, Kenosha and Racine, and for Manitowoc and Two Rivers. Small 10-year sites have already been built at Grand Haven and Holland. Construction of other facilities is currently underway at Grand Haven, Holland, Kenosha-Racine, and Milwaukee-Port Washington.

For a number of harbors with polluted sediments, only the preliminary stages of planning for 10-year confined sites has been completed. Some delays in the program appear to be the result of the reluctance of local interests to provide land to the C.E. for disposal sites. Local interest groups generally are not anxious to provide such land until waivers of the shared construction costs of the confined sites are granted. In most instances, site selection focuses on the immediate vicinity of the outer harbor areas. If land disposal sites are available and in operation, waivers and 10-year confined sites may not be required.

In the Chicago District, little progress has been made with regard to Algoma, Burns Waterway, Chicago Harbor and River, Pensaukee, and Sturgeon Bay Harbors. In the Detroit District, solutions have not been found for Frankfurt, Manistique, South Haven, St. Joseph, and Traverse City. Most of the confined disposal facilities are scheduled to be constructed by 1975 and 1976. This construction schedule suggests that if open-lake disposal of polluted spoil is not adopted as an acceptable alternative, then maintenance dredging may be postponed in a number of harbors until other solutions are implemented.

Unpolluted sediments derived from maintenance dredging are currently being used for beach nourishment by the C.E. at Holland, Manistee, Michigan City, and Muskegon Harbors. Maintenance dredging of harbors receiving sediment from littoral drift may be reduced by redesigning the breakwater and/or by artificial bypassing with sand pumps.

Summary

Of the 42 public harbors in Lake Michigan, 27 are classified as polluted or partially polluted. Only 15 public harbors do not contain polluted bottom sediments in the dredging areas, hence are unpolluted. An average of 7 bottom samples were taken per harbor. Of the 7 mandatory pollution parameters, volatile solids, COD and oil and grease most frequently exceeded the acceptable limits. In a small number of harbors there is a need for resampling as the pollution analyses are several years old. Also, in several harbors the pollution analyses were not complete, especially with regard to the testing of mercury, lead, and zinc concentrations.

For the next decade, the total average annual volume of polluted maintenance dredging in Lake Michigan has been estimated to be 848,200 cubic yards. This figure is 57 percent of the total average annual maintenance dredging quantity. However, in the Chicago District, 83 percent of the maintenance dredgings are polluted. Private dredging quantities were not included in this projection because this spoil is usually confined on the permittee's land. New work dredgings were also excluded because new work materials usually consist of relatively clean glacial till and bedrock. Most of the polluted spoil is derived from industrialized-urbanized harbors, especially inner harbor areas, and not from small, recreational harbors. If pollution elimination systems regarding municipal and industrial wastes continue to reduce artificial sedimentation, as in Calumet Harbor, then the future annual quantity of polluted maintenance dredgings is expected to decrease slightly.

With the exception of 5 harbors, all 27 of the polluted and partially polluted public harbors have been included in the C.E. confined disposal program. At present, 17 of the harbors with polluted bottom sediments have at least temporary solutions to the problem of confining polluted dredged spoil. As scheduled by the C.E., many of the confined disposal sites are to be built during the period 1974-1976. This schedule appears to be optimistic. Unless polluted spoil can be open-lake dumped or disposed in ways alternate to diked confinement, then future maintenance dredging of some harbors may have to be temporarily postponed. Because of the relatively large annual polluted maintenance dredging volumes in Calumet, Chicago Harbor and River, South Haven, St. Joseph and Sturgeon Bay Harbors, the lack of confined sites for these harbors is most serious. New E.P.A. guidelines regarding the disposal of dredged materials in inland waters (14), to be promulgated in 1975, may result in the re-evaluation of some harbor pollution classifications and in the resumption of open-lake disposal of small quantities of lightly polluted dredged spoil. If so, confined disposal sites may not be required for Algoma, Manistique, Pensaukee, and Traverse City Harbors.

QUANTITY OF POLLUTED DREDGED SPOIL IN LAKE SUPERIOR

The geological setting and the nature of the shoreline environment of Lake Superior is unique to all of the other Great Lakes. The Lake Superior drainage basin encompasses the "iron country" and the "copper country" along the western and southern shores. The northern shoreline and its contributing drainage system is heavily forested. Natural effluent drainage from the mineralized bedrock areas contributes materially to the metallic ion concentration of river mouth harbor waters and sediments (15). Discharge of these ions into Lake Superior raises the metallic ion concentration to anomalously high values as compared to the other Great Lakes. The well known counterclockwise gyre in Lake Superior tends to 'stream' the metalliferous constituents eastward along the United States coastline to cause a plume of metallic solution within the otherwise pristine waters of the lake. Although these natural contaminants are not quantitatively high, they are detectable in water and sediment analysis (16). It has been noted that zinc values, as well as copper values, in water analyses are ubiquitous and in some cases anomalously high. Zinc minerals are associated with the copper of the Keewenaw Region (17). Therefore, both elements can be expected from natural weathering, drainage and mine effluent. Several hundred square miles of copper and zinc bearing rock units underlie the glacial drift or are exposed at the surface throughout the south shore. This so called contamination or pollution by surface waters (and from the water table) is a natural phenomenon and should be recognized as such in setting the criteria of pollution for Lake Superior. It is recognized that a base level of metallic ion concentration in the waters of the south shore of Lake Superior probably exists and is beyond the control of man to alter. Pollution criteria for Lake Superior should be established independently of the other lakes, based upon norms determined from open-lake waters along the south shore.

The drainage systems of the north shore harbors, both United States and Canadian, discharge quite universally from heavily forested areas, predominantly coniferous. Normal stream waters in these systems are acidic (high pH) and often brown tinted with tannic acid and stains leached from the forest duff. Large quantities of leaves and conifer needles are transported to river mouth harbors where this organic matter becomes waterlogged and settles to bottom. During the halcyon days of logging and widespread fluming and booming of saw logs in these rivers and harbors, considerable quantities of saw logs, bark, natural pulp and sawdust were deposited in the quiet waters of north shore harbors.

Characteristically, most of the north shore harbors were dredged the first time as new work development to remove the accumulation of organic debris and whatever inorganic sediments were required to reach project depth. Most of the older and smaller harbors have not been dredged since their initial development work was completed. Removal of paper mill wastes, pulp and bark continues in those harbors where large mills have developed. A few examples are: Thunder Bay, Nipigon, Peninsula, and Michipicoten. Maintenance dredging in these harbors is sporadic. The dredging frequency is a function of the level of industrial production of paper products, and natural stream flushing action.

Decaying organic matter produces a high oxygen demand (COD value) and is typical of all of the north shore harbors. Again, a high COD value is a normal expectancy for these conditions and is one which can be little altered by the efforts of man. Sediment pollution criteria, specifically citing COD values should consider the norm of natural effluent in the streams of the north shore.

Natural inorganic sedimentation (clay, sand, silt and gravel) is virtually nonexistent in the north shore harbors by virtue of the fact that the drainage area is blanketed with a complete vegetative cover. Many north shore harbors have insufficient sediment covering bedrock to make a sediment sampling program possible (16).

Pollution of Sediments--Introduction

The C.E. in 1969 reported that 12 of the principal U.S. harbors of Lake Superior were considered unpolluted (1). Two were considered polluted on the basis of criteria then in use (Table 19, Sec. 6.9). The classification at that time listed the following harbors:

Lake Superior (1)	
Unpolluted	Polluted
Big Bay Harbor	Duluth
Black River Harbor	Superior
Cornucopia Harbor	
Grand Traverse	
Keweenaw Waterway	
Lac La Belle	
Little Lake	
Ontonogan	
Port Wing	
Presque Isle	
Saxon	
Whitefish Point Harbor	

Classification based upon E.P.A. parameters (Table 17, Sec. 6.6)

Under the heading of "Magnitude of the Problem" (page 9.19, Sec. 9.6.1) of the C.E. report, a total annual volume of dredging is predicted to be about 11 million cubic yards (all lakes) per year, of which approximately 84 percent (9.24 million CY) is polluted. This volume was tabulated from 39 harbors which were considered polluted at that time. Six of these polluted harbors accounted for one half of the total volume of polluted spoils.

It should be noted that the 1969 C.E. study worked primarily with maintenance and new work dredge volumes. The report also observes that private dredging was not compiled, but could be estimated at about 10 percent of the total.

Pollution in Lake Superior Harbors --U.S.

With the enactment of Public Law 91-611 and the establishment of E.P.A. criteria of pollution, harbors in all lakes have been undergoing extensive sampling and reclassification. The St. Paul District, for instance, has contracted with independent laboratories for investigations of harbors in their jurisdiction. National Biocentrics Inc. has been working on most of the harbors in the district for 2 years. Reclassification, based upon the E.P.A. studies and those of independent laboratories, now indicates that 17 U.S. harbors show at least one parameter of pollution in excess of the tolerable limit. Thirteen harbors are currently classed as unpolluted (Figure 18).

It should be noted, however, that the total volume of sediment removed from each of the "polluted" harbors is not necessarily all polluted. Many of the Lake Superior harbor volumes are composed largely of lake bottom sediments, sand and gravel which have been transported by littoral drift, ice-shove and violent onshore wind storms. These materials are, for the most part, clean and eligible for open-lake dumping, whereas the classification of the harbor may be "Polluted," as determined, from sampling of the inner harbor reaches. Expanded studies are now underway, with more extensive sampling programs, to delineate the volumes of polluted spoil from the unpolluted. Several field seasons and several additional samples will be required to draw lines of demarcation between polluted areas and unpolluted areas of most harbors. Once this isolation of polluted sediment has been accomplished, then a far more accurate determination of spoil volume and disposal area capacity can be made.

Under present policy, open-lake dumping of polluted spoil is restricted. Constraints may be lifted for sediments from those parts of Lake Superior harbors which can be proven to be clean and free of deleterious contaminants.

Assuming that restrictions are relaxed and using sediment analyses available for known sampling locations in Lake Superior harbors, this report attempts to estimate the percentage of total dredge quantity of each harbor which must be committed to diked or on-land disposal areas.

Based upon activities in the 10-year representative period (1961-1970) and the average annual volume predictions derived from that history,

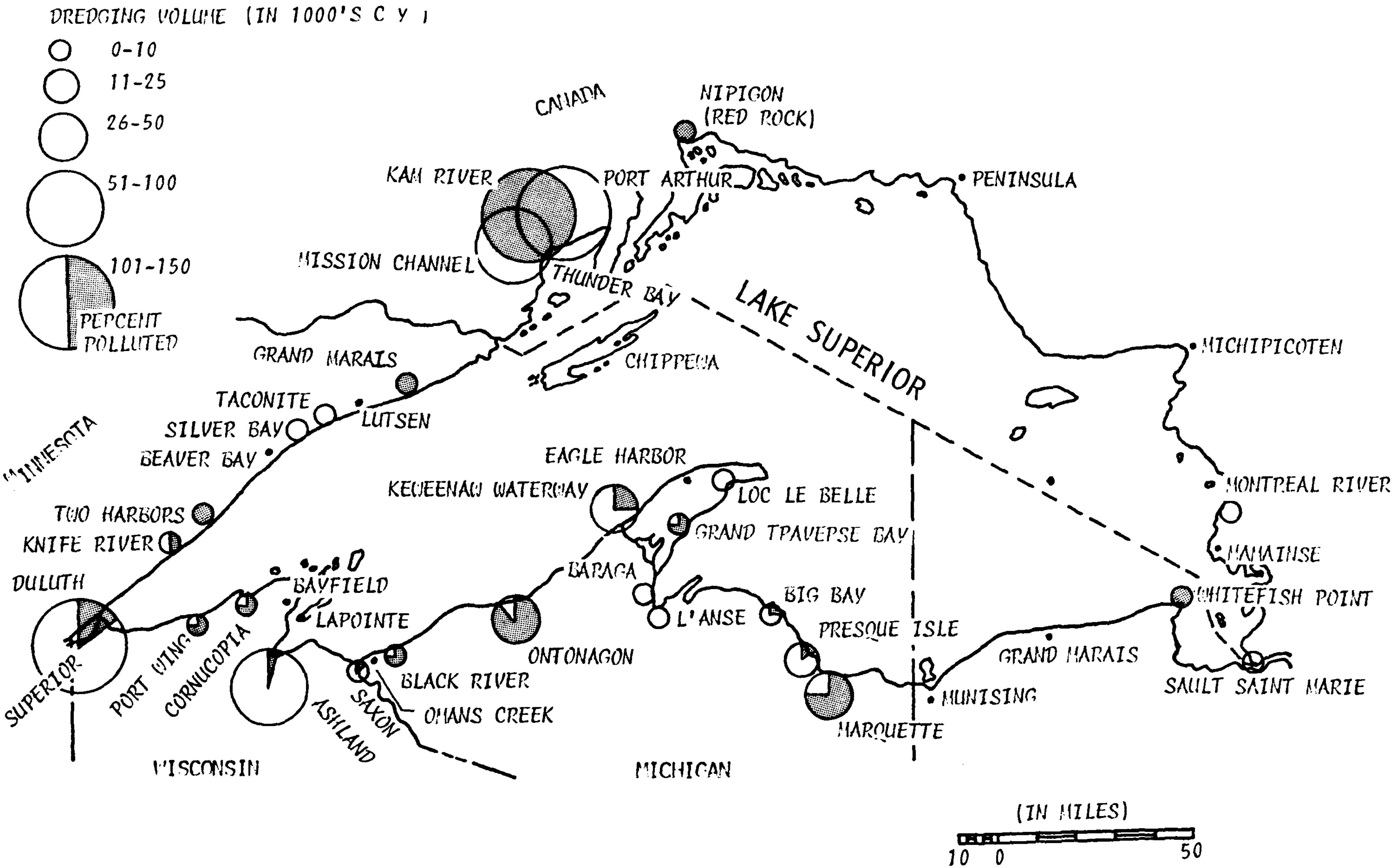


Figure 18. PROJECTED ANNUAL DREDGING VOLUMES IN LAKE SUPERIOR AND PERCENT POLLUTED (HARBORS WITHOUT VOLUMETRIC CIRCLES INDICATE NO PROJECTED DREDGING IN THE NEXT DECADE)

Table 67 is presented as a summary of this study and for comparison with the predictions of the C.E.

This study indicates a total annual average volume of 1,964,759 CY of spoil will be removed from United States harbors. Estimates of the percent of this volume which will be polluted and assigned to confined disposal are presented by harbor in the summary. Using data assembled, it appears that 236,883 CY or about 12 percent of the total spoil volume will require confinement (column 5). On March 15, 1973, the C.E. estimate of polluted spoil was reported as 206,100 CY, or approximately 1.5 percent less than this study found (column 4). The C.E. volume of 206,100 CY of polluted spoil is 10.5 percent of the total volume of sediment to be dredged (Table 67, column 4).

Using the estimates of the percent of sediment polluted in each harbor as determined in this study (column 7) and applying these values to the C.E. total annual volume projections, it is found that 159,430 CY may require confinement (column 3).

The discrepancy in polluted volumes, cited above, is apparently caused by differences in the appraisal of the size of areas of pollution within each harbor as identified by the C.E. and by this study, rather than in the total volume of sediment to be removed. It is recognized that under the present E.P.A. pollution policy, any harbor with one or more parameters showing an excess of contaminant, must be considered polluted. Many such determinations have been made, which require the C.E. to classify entire harbors polluted. Analyses assembled since 1969, extensive sampling projects and more detailed sediment mapping of harbors have made it possible to more accurately delineate polluted segments of harbors. This study has attempted to apply the current state of knowledge of polluted harbor areas, which was not available at the time of the last report of the C.E. As the sampling and testing program continues, it is anticipated that more and more realistic pollution volumes can be derived. These are expected to be considerably less than the initial estimates of polluted spoil volumes, made in 1970 and 1971.

Table 67. U.S. DREDGING IN LAKE SUPERIOR: TEN YEAR AVERAGE ANNUAL POLLUTED SPOIL AND AVERAGE VOLUME PREDICTIONS, 1961-1970 (cubic yards)

Harbor (1)	Date sampled inclusive (2)	Polluted spoil predicted--U.S. % x C.E. vol. (3)	C.E. estimate (4)	This study (5)	Annual average (6)	% poll. (7)	Pol. class (8)
Angle Inlet						0	U
Ashland	'69	2,000	2,000	2,000	60,619	100	P
Baraga					500	0	U
Baudette						0	U
Bayfield	'71,'72	1,000	None			100	P
Big Bay	'70-'73	110	1,000	1,150	4,597	25	P/U
Black River	'71-'73	1,000	3,000	1,826	2,435	75	P/U
Chippewa						0	U
Cornucopia	'71-'73	2,000	800	1,498	1,997	75	P/U
Duluth-Superior	'70-'73	27,540	150,000	143,408	796,710	18	P
Eagle Harbor	'68,'69					0	
Grand Marais (Minn.)	'70-'73	3,000	600	600	600	100	P
Grand Traverse	'71	3,750		3,697	4,930	75	P/U
Keweenaw Waterway	'70-'73	13,750	2,000-2,500	7,621	30,486	25	P/U
Knife River	'70-'72	500	800	151	302	50	P/U
Lac La Belle	'69,'72				2,630	0	U
L'Anse					800	0	U
La Pointe	'70					0	U
Little Lake	'70-'71				32,709	0	U
Marquette	'71	750		25,752	34,337	75	P/U
Oman's Creek					30	0	U
Ontonagon	'68-'73	72,000	25,000	41,197	45,775	90	P/U
Port Wing	'69-'73	3,750	None	2,926	3,902	75	P/U
Presque Isle	'70-'73	850	2,000	2,000	11,810	17	P/U
Saxon Harbor	'71-'73	440	700	700	6,291	11	P/U
Silver Creek					6,500	0	U
Taconite					200	0	U
Two Harbors	'70-'73	20,000	200-600	767	767	100	P
Warroad					11,224	0	U
Whitefish Pt.	'70,'71	6,000	6,000	1,590	1,590	100	P/U
Annual totals		159,430	206,100	236,883	1,964,759		5 P 12 P/U 13 U

P Polluted; P/U Part polluted; U Unpolluted Harbor

Pollution of Lake Superior Harbors --Canadian

Canadian harbors on Lake Superior are unusually clean as compared with U.S. harbors. Most of the pollution problem in Canada lies with the accumulation of wood pulp and the waste products of the paper industry in 2 harbors, namely Thunder Bay and Nipigon (Red Rock). The Public Works Commission of Canada (now D.P.W.) finds that inorganic sediments offer no particular pollution problem except in the aesthetics of disposal areas where clay and silt remain as suspensoids and tend to cloud the water for a short time after dumping in the open lake (18). The concern of the public and ecological interests in Ontario is more prominently directed toward the destruction of fish spawning areas and aquatic-life foraging areas than to the deleterious chemical effect of pollutants.

Inspection of Table 49 suggests that, of the average annual dredge volume in Canadian harbors (323,789 CY) some 40 percent or 130,752 CY will be polluted. On a 5-year projection, the D.P.W. suggests that 302,400 CY will be removed annually. Using the estimated total volume of polluted sediment from this study, per year, approximately 43 percent of the D.P.W. spoils will require confinement; a reasonably close agreement. Canadian port directors appear to have less of a problem with acquisition of land reclamation sites and diked disposal sites than their colleagues in the U.S., because of the differences between Canadian and U.S. real estate law (18).

Of the 10 principal harbors in Canada, as listed in Table 49, 3 are considered polluted by the M.O.E. Spoils from these are assigned to landfill projects. Canadian authorities have not yet delineated portions of harbors as polluted and unpolluted through extensive sampling programs. It is expected, however, that a large proportion of the current Canadian polluted sediments will be reclassified to unpolluted, with extensive sampling and analysis projects which are currently underway.

One of the reasons for the probable reclassification rests in the curious discovery that the dumping of organic wastes (pulp, bark, etc.) in the open lake, consistently improves the fishing, both commercial and recreational, in the dump area. This is probably a reflection of the increase in plankton and microbenthonic food supplies in the dump areas.

Table 49 shows an additional volume projected for Leigh Harbor, if proposed construction is consummated. This volume of sediment is not included in projections at this time since the project is still pending.

Statements of the D.P.W. in 1970, regarding the pollution of Canadian harbors, are quoted from the Dredging Inventory.

> "THUNDER BAY (KAM RIVER):
> At present, the O.W.R.C. has stated that all dredged material removed from that portion of the Kam River between the Westfort Turning Basin and Saskatchewan Pool Elevator #11, is unacceptable for open lake disposal because of high organic content and mercury contamination. A recent local newspaper report states that the lower extremity of the Kam is low in oxygen content and on the verge of being polluted. On the strength of this information, it is therefore necessary that for any future dredging in the Kam River, that all dredged material be deposited on a suitable land site.
>
> SAULT STE. MARIE:
> The 1,150,000 cu. yd. of sand and silt from the proposed deep water harbour at Leigh's Bay will be contained in an enclosed berm. The dredging will be done by hydraulic means which will cause some turbidity but proper engineered controls will be implemented.
>
> MICHIPICOTEN RIVER:
> In front of the public wharf is a silt island which if not sufficiently cleared out by the spring freshets will require dredging to maintain access to the wharf. The properties of this silt is not known, but it would cause considerable turbidity if dumped."

These quotations emphasize the nature of concerns of the Canadian dredging interests. Oxygen demand and turbidity (an aesthetic interest) are the principal deficiencies in most Canadian harbors.

Summary

1. Of 30 harbors sampled in the U.S. side of Lake Superior, 17 are classed as polluted or partially polluted and 13 are clean. In 9 Canadian harbors 3 are polluted and 6 are clean.

2. The most commonly occurring pollutants in U.S. projects are COD, Kjeldahl nitrogen, copper and zinc. In Canadian harbors, the pollutants are primarily COD and Kjeldahl nitrogen.

3. Approximately 10.5 percent of the total volume of dredge spoil in the U.S. harbors is polluted, according to predictions of the C.E. About 12 percent is polluted, as determined in this study.

4. Some 40 percent of the Canadian dredge spoils will be polluted in the next 10 years.

5. In the past decade, maintenance dredging removed 1,594,742 CY from U.S. harbors in Lake Superior. This is 15 percent of the 10,611,464 CY dredged from all Lake Superior harbors in all categories.

6. An adjusted average of new work volume for the 10-year period will be about 425,000 CY, in the U.S. annually

7. Permit dredging in Lake Superior during the historic period of record is 2.8 million CY or about 3 percent of the total for the same period. Adjusted averages, based on the 10-year sample period indicate about 191,000 CY will be removed annually.

8. Canadian maintenance is expected to average about 86,000 CY Per year.

9. Canadian new work and private dredging in the next decade is expected to be minimal, and thus insignificant to total volume figures.

10. Duluth-Superior dredging is predicted to be about 796,000 CY per year (41% of U.S. total) and the Thunder Bay area of Ontario, 315,482 CY (96% of total Canadian). These 2 projects are expected to produce the major percentage of all Lake Superior spoil volume.

11. Confined disposal sites in Lake Superior include 3 in Canada and 4 in the U.S. Fifteen U.S. projects were initially selected by the C.E. for their confined disposal program. However, as of July, 1974, only Ashland, Duluth-Superior, and Keweenaw remain in that program (Table 68).

Table 68. CONFINED DISPOSAL SITES FOR PUBLIC HARBORS IN LAKE SUPERIOR

Harbor	Disposal site completion date	Status
Ashland	Start May 1974	Pending litigation
Bayfield	--	Dropped from program
Big Bay	--	Dropped from program
Black River	--	Dropped from program
Cornucopia	--	Dropped from program
Duluth-Superior	Start April, 1974 new site	To award contract for 1,500,000 CY capacity
	Fill of old slips, 225 acres. 1975(?)	Possible new coal dock facility. See dredging section
Grand Marais (Minn.)	--	Dropped from program
Grand Traverse[a]	--	--
Keweenaw Waterway	Spring 1975	Pending
Knife River	--	Dropped from program
Marquette	--	Dropped from program
Ontonagon	Trucked inland	Disposed by local interests
Port Wing	--	Dropped from program
Presque Ile	--	Dropped from program
Saxon	--	Dropped from program
Two Harbors	--	Dropped from program
Whitefish Pt.[a]	--	--
Kam River	Operating landfill	Operating
Nipigon	Operating landfill	Operating
Port Arthur (Thunder Bay)	Operating landfill	Operating
(Keefer Terminal)	Landfill diked	Operating

[a]Never selected for confined site program (PL 91-611).

SUMMARY OF POLLUTED DREDGED QUANTITIES

As of July, 1974, there were 62 public harbors and waterways in the C.E.'s 10-year confined disposal program (Tables 56, 58, 66 and 68). In Lake Ontario, Oswego and Rochester are also in the confined program. Site selection has been completed for 34 of these harbors and waterways. Although 16 harbors are utilizing existing disposal facilities, most are also going through site selection for the 10-year program. For 20 of the 62 projects, site selection has not been completed, nor are there existing disposal facilities. Among these harbors are Chicago Harbor & River, Clinton River, Oswego, St. Joseph, and Sturgeon Bay. However, the polluted quantity for these harbors totals only 300,000 CY annually, which is 5 percent of the total (6.45 CY).

Data in this report indicate that there are 80 public harbors and waterways on the American side of the Great Lakes with polluted bottom sediments. E.P.A. bottom sediment analyses reveal that, in addition to the 62 harbors already in the confined disposal program, the following also have polluted sediments: Algoma, Barcelona, Burns Waterway, Great Sodus, Harrisville, Manistique, Pensaukee, and Port Austin Harbors. In addition, the following harbors in Lake Superior as of July, 1974 have been dropped from the C.E. program: Big Bay, Black River, Cornucopia, Grand Marais (Minn.), Grand Traverse, Knife, Marquette, Port Wing, Saxon and Two Harbors. The total average annual volume of polluted spoil from these 18 additional harbors is only approximately 110,000 CY. With the exception of Burns Waterway, Great Sodus, and Marquette Harbors, these are small, partially polluted harbors which are infrequently dredged. The new pollution guidelines for dredged spoil currently being drafted by the E.P.A. will probably result in the reclassification of the pollution status of many of these smaller harbors.

Table 69 summarizes the polluted volume of average annual maintenance and private dredged spoil to be removed from harbors and waterways in the Great Lakes in the future.

Table 69. FUTURE AVERAGE ANNUAL QUANTITY OF POLLUTED DREDGED SPOIL IN THE GREAT LAKES (cubic yards)

Lake	Number of projects			Volumes of polluted spoil		
	Total	Polluted	Unpolluted	United States	Canada	Total
Ontario	5/6[a]	3/6	2/0	330,000	475,000	805,000
Erie	21/5	21/5	0/0	4,500,000	125,000	4,625,000
Huron/St. Clair	20/10	13/7	7/3	532,400	276,000	808,400
Michigan	41	26	15	848,200	--	848,200
Superior	30/10	17/3	13/7	236,883	130,752	367,635
Totals	117/31	80/21	37/10	6,447,483	1,006,752	7,454,235
Percent of total				86%	14%	

[a]American harbors on left side of slash, Canadian on right.

1. The E.P.A. and the M.O.E. have determined the sediment quality of 148 navigation projects in the Great Lakes. This study reveals that 101, or 68 percent of the projects sampled are polluted or partially polluted.

2. It is estimated that future average annual maintenance dredging will involve the removal of 7,454,000 cubic yards of polluted spoil. Lake Erie, including the Detroit River, will account for about 62 percent of this total.

3. Of the 26 public harbors in Lake Erie, all are polluted or partially polluted. When considering volumes, the problem of polluted dredged spoil is basically an American one focused on Lake Erie, including the Detroit River.

4. The pollutants most frequently exceeded in United States harbors are volatile solids, COD, and oil and grease. In Canada, the principal parameters exceeding the M.O.E. criteria are COD and Kjeldahl nitrogen.

5. Based on the parameters most frequently exceeded, the principal sources of pollutants in the United States are from industrial and municipal effluents and agricultural fields. In Canada, pollutants are derived from lumber and paper industries, agricultural fields, as well as industrial and municipal effluents.

6. Where a harbor is divided into an inner and outer section, such as at Saginaw, usually the inner section is polluted whereas the outer section is clean.

7. In the United States, the 10-year confined site program of the C.E. (PL 91-611) involves 62 public harbors. At present, only for 34 harbors have disposal sites firmly selected. However, the E.P.A. analyses reveal that there are 80 U.S. public harbors and waterways in the Great Lakes with polluted bottom sediments.

8. Problems with the disposal of polluted dredged spoil may occur at Calumet, Chicago River and Harbor, Cleveland, Saginaw, South Haven, St. Joseph, and Sturgeon Bay Harbors.

9. Although sampling of bottom sediments is more thorough in Canadian navigation projects, less than one half of the harbors there have been sampled.

10. At present, the pollution criteria concerning dredged spoil in the United States and Canada are similar. However, the E.P.A. is currently drafting new pollution guidelines which may broaden the criteria for determining the eligibility of dredged spoil for open-lake disposal.

SECTION V

DREDGING AND DISPOSAL POLICIES

UNITED STATES' POLICIES

The United States Army Corps of Engineers has been delegated the responsibility of maintaining the nation's federal waterways for approximately the last 150 years. The River and Harbor Act of 1899 authorizes the C.E. to develop, maintain, and improve the waterways and harbors of the United States in the interest of navigation. Since navigation may be obstructed in those waterways, no dredging or disposal of spoil may take place without approval by the C.E.

Non-federal interests who dredge and dispose of spoil must obtain a permit from the C.E. as specified in Section 10 of the River and Harbor Act. The initial purpose of Section 10 was to prevent obstructions to navigation, including dredging and disposal of spoil as well as construction projects like marinas, sea walls, power lines and submarine pipelines in navigable waters. Before approving a Section 10 dredging permit, the C.E. has the application reviewed by concerned state and federal agencies, such as state pollution control agencies, and the E.P.A. In its review of the Section 10 permits, the E.P.A. usually recommends approval provided that the applicant will confine the dredged spoil.

The original purpose of the River and Harbor Act concerned navigation. However, since the enactment of the National Environmental Policy Act

(NEPA) of 1969 (Public Law 91-190), effects on environmental quality have been given more attention. Section 102 of the NEPA act directs all federal agencies to prepare statements of environmental impact on all major actions, such as confined disposal sites, which may have a significant impact on the quality of the human environment. The act also specified, as national policy, additional guidelines of environmental quality and established the Council on Environmental Quality (CEQ) in the Executive Office of the President.

Perhaps the most comprehensive policy for improving the quality of the nation's waters is the Federal Water Pollution Control (FWPC) Act Amendments of 1972 (Public Law 92-500). This new law mandates a federal-state campaign to prevent, reduce, and eliminate water pollution by restoring and maintaining the chemical, physical, and biological integrity of the nation's waters. The primary goals of the law are: (1) by July 1, 1983, to have, wherever possible, water clean enough for swimming and other recreational uses, and clean enough for the protection and propagation of fish, shellfish, and wildlife; and (2) by 1985, to have no discharge of pollutants into the nation's waters. Whether "zero discharge" can become a reality by 1985 has been seriously questioned by the National Water Commission (19). However, the C.E. and local municipalities in the Chicago, Detroit, and Cleveland areas are presently assessing the problem of wastewater management (20). In southeastern Michigan, for example, a survey is being made to identify and evaluate: (1) different ways to collect and treat wastewater to help clean up the streams in an eight-county study area and hence reduce the amount of pollution entering Lakes Erie and St. Clair (Figure 5); and (2) different uses for treated wastewater and the material removed from this wastewater. The objectives are consistent with the goals and objectives of the FWPC Act Amendments of 1972.

Section 404 (a) and (b) of the FWPC Act Amendments of 1972 (PL 92-500) authorize the C.E. to issue permits, after public notice and opportunity for public hearings, for discharge of spoil into navigable waters at specified disposal sites. Section 404 (c) gives the Administrator of the E.P.A. the authority to approve such disposal sites in accordance with new guidelines regarding disposal of dredged materials in inland waters. These are presently being developed by the E.P.A. in conjunction with the C.E. However, if economic stress is to be avoided, the C.E., acting through the Chief of Engineers, may issue permits for disposal in any case where the new guidelines alone would prohibit the specification of a disposal site. This policy is reinforced by the Marine Protection, Research and Sanctuaries Act of 1972 (Public Law 92-532). The latter authorizes the Secretary of Commerce to designate those areas of the Great Lakes which have conservation, recreational, ecological or esthetic values as marine sanctuaries.

In 1969, the C.E. recommended legislation for the construction of diked disposal facilities for confinement of polluted spoil. This legislation, Public Law 91-611 of the River and Harbor Act, was enacted in 1970. Section 123 of this law is unique, as it is specifically designed for confinement of polluted spoil in a specific region, i.e., the Great Lakes. At that time, the Great Lakes region was the only area of the country where specific legislation had been enacted in the interest of pollution abatement in terms of confining spoil (21). At present, 62 federal harbors and waterways are in the confined disposal program of the C.E. Before a confined disposal site can be constructed, the C.E. is required by the National Environmental Policy Act of 1969 to submit an Environmental Impact Statement to the E.P.A. This policy has caused some delays in the selection and construction of many confined disposal sites.

Although Section 123 (C) of Public Law 91-611 provides for the construction and financing of 10-year containment sites for disposing of polluted dredged materials, it also specifies that non-federal interests: (1) furnish all lands, easements, and rights-of-way necessary for the construction, operation and maintenance of the facility; and (2) contribute 25 percent of the construction costs. The 25 percent shared cost may be waived by the C.E. if the E.P.A. determines that the municipalities and industries in the drainage basin are making satisfactory progress toward improving their waste treatment facilities. At present only 11 waivers of the shared construction costs have been granted while 8 others are pending by the C.E. Cost sharing has caused delays in the diked disposal program. Local interests, such as port commissions, are reluctant to provide land to the C.E. for diked disposal sites if waivers are not first granted. The Great Lakes Commission recommended to Congress in August, 1973, that waiver requirements be deleted because of possible economic stress in harbors such as Saginaw and Calumet (13).

Basically, Public Law 91-611 is a temporary solution to the problem of the disposal of polluted dredged spoil. Whether open-lake disposal can take place is determined, in part, on the state level. The governors of the states of Minnesota, Wisconsin, Illinois, Indiana, and Michigan have objected to open-lake disposal of polluted spoil dredged by the C.E. and by private dredging firms (22). However, the governors of Ohio, Pennsylvania and New York did not request that open-lake disposal of polluted spoil be discontinued in the Great Lakes. In the Buffalo District, open-lake dumping of polluted spoil is continuing at harbors where confined disposal sites are not yet available.

During the past three years the C.E. has expanded its role in the environmental field. The C.E. has recognized that coastal marshes and wetlands constitute productive and valuable public resources. Thus, no permit will be granted for work in wetlands unless the District Engineer, in the public interest, concludes that the benefits of the proposed alteration outweigh the potential damage to the wetland resources. In addition, permits for non-federal dredging operations require the permitee to comply with the same standards as federal dredging operations with respect to turbidity, nature and location of approved spoil disposal areas, and other factors relating to protection of the environment.

CANADIAN POLICIES

Under terms of the British North America Act (BNA), the federal government of Canada can legislate for the enforcement of water quality standards and control of pollution. Also, under Section 108 of the BNA Act, transfer of dredges and authority for river and lake improvements at the time of confederation seemed to emphasize that dredging was specifically intended to fall under federal jurisdiction. However, with the exception of the Navigable Waters Protection Act (NWPA), dredging and disposal policies are basically legislated on the provincial level. The Ontario Water Resources Act, ammended in 1972, is administered by the Ministry of the Environment of Ontario (formerly the Ontario Water Resources Commission) and prohibits the discharge of any material, which may impair water quality, into or near any lake, stream, or other water body.

Under the Environmental Protection Act of 1971, the discharge of any contaminant into the natural environment in an amount, concentration, or level in excess of that prescribed by regulations is prohibited. These regulations in the case of dredging are the Water Quality Guidelines for the Review of Proposed Dredging and Spoils Disposal Operation and are specified in Section IV. The Environmental Protection Act of 1971 also concerns disposal of dredged spoil. The Ministry of Environment (M.O.E.) prohibits spoil disposal on land or in water without a certificate of approval or a provisional certificate of approval. Both of these instruments of legislation do not use explicit terms such as dredged spoil or dredgings. This implies that dredged spoil policies have not reached, until recently, the level of concern as in the United States. Based upon the present Canadian policies, quality of the environment and associated ecosystems are of primary concern. Economic stress on navigation and regional commerce, or its consequences, are not emphasized.

The Navigable Waters Protection Act (NWPA), R.S.C., 1970, is a federal statute instituted in October, 1969, and parallels the function of Section 10 of the United States' River and Harbor Act of 1899. It is designed to protect the public right to navigation by prohibiting the modification of navigable waters without the approval of the Ministry of Transport (M.O.T.). Thus, the NWPA protects navigation, not the environment. When a dredging permit is secured, additional approval must be obtained from the provincial M.O.E. and other interested provincial or municipal agencies. Although 'dredging' is not specified as such, one may presume that under Section 3, Part I, the term 'work,' defined as "any dumping of fill or excavation of materials from the bed of a navigable water," includes dredging. The M.O.E. does not issue permits, but it advises applicants as to what is considered acceptable within the terms of the Ontario Water Resources Act.

The federal government has delegated the administration of the federal Fisheries Act (Section 91 (12) of the BNA Act) to Ontario and several other provinces. Within this act, a general provision states that no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish. Deleterious substance, in this case, may conceivably include polluted and unpolluted dredged spoil.

Ancillary policies to the Canadian legislation include:

a. The Beds of Navigable Waters Act
b. Public Lands Act
c. The Conservation Authorities Act
d. The Beach Protection Act
e. Public Health Act

In an unpublished report, John MacLatchy of Environment Canada presented the following overview:

> "It is important to note that in the above mentioned provincial Acts there is no attempt to control the dredging itself, but rather the removal and disposal of the dredged material as it is related to water pollution and land use which are clearly matters of provincial jurisdiction. None of these statutes specifically refer to dredging, but rather refer to the disposal of any material regardless of its origin or the removal of material from beaches." (23).

It may be concluded that a lack of a single group of laws and regulations exists concerning Canadian dredging policies per se. However, many, if not all of the acts cited above, reveal that there are policies to control environmental effects of dredging and disposal in harbors and navigable waterways.

CANADIAN-AMERICAN POLICIES

In 1970 the International Joint Commission voiced concern over the grave deterioration of water quality on both sides of the international boundary (24). An attempt to establish a unified effort to prevent further deterioration of water quality in the Great Lakes led, in 1972, to the Agreement between the United States of American and Canada on Great Lakes Water Quality. Annex 6, "Identification and Disposal of Polluted Dredged Spoil," of this agreement specifically draws attention to dredging activities in the Great Lakes. A United States-Canadian Task Force was established to review the existing dredging practices, including laws and regulations. This group has the specific objectives of developing compatible criteria for the characterization of polluted dredged spoil and recommending compatible programs governing the disposal of polluted spoil in open water. One of the significant principles upon which the above recommendations are to be based is, "as soon as practicable, the disposal of polluted dredged spoil in open water should be carried out in a manner consistent with the achievement of the water quality objectives, and should be phased out." (25). As an interim measure, polluted spoil is to be disposed in confined areas if they are available. The U.S. Army C.E. and the D.P.W. of Canada must continue efforts to develop additional sites for confined disposal during this interim. In accordance with Public Law 91-611, Section 123, the C.E. has begun to implement this action (see Section IV of this report).

This agreement is unique in that it was designed for a specified drainage basin (the Great Lakes) on an international boundary and specifically concentrates on the identification of polluted spoil within that basin.

DISCUSSION

In Canada, dredging of Great Lakes' projects is contracted to private firms (public tenders) which, in some instances, accounts for high dredging costs. It has been estimated by the D.P.W. that contract dredging is at least 42 percent more expensive than dredging performed by departmentally owned plants (26). If the C.E. were to contract all their maintenance dredging projects to private firms, costs could realistically triple. Such a policy may lead to a greater selectivity and priority of dredging.

Recently, the M.O.T. has assumed more of the dredging responsibility. Prior to the NWPA, private dredging was regulated by the D.P.W. However, this authority and the administration of public harbors have been transferred to the M.O.T. Also, if a harbor commission in Canada plans any new work dredging projects, a permit must be secured from the M.O.T. and other concerned agencies including the Ministry of Natural Resources and the M.O.E. A unique facet of the Canadian dredging regulations is a 'marina policy' developed in 1965 to assist in non-federal marina development (27). Under this policy the D.P.W. will dredge and provide sea walls and jetties for a private marina. Such marine work, however, is limited to the value of new construction being undertaken by the developer to serve the boating public. Therefore, in a sense the federal government will subsidize industries directly related to marine activity. Although the pollution guidelines in Canada are as stringent as those of the E.P.A., dredging and disposal policies in general reveal some degree of flexibility and encourage most dredging activity to be resourceful. Spoil may be deposited on private land with few restrictions. In many harbor areas, particularly along the lower Great Lakes, land reclamation projects, parks, and civic centers are constructed with dredged spoil. In Toronto Harbor, for example, locally derived spoil is being utilized for the construction of beaches, berms, and an aquatic park (28). Moreover, unpolluted materials in Toronto Harbor are used to form dikes into which polluted dredgings are placed.

In the United States such flexibility is less evident. Private dredging is not subsidized nor is disposal by federal plants allowed on private land unless the owner provides retaining dikes and pump-out facilities. Based on Public Law 91-611 the confined disposal sites are to be constructed on public land or land purchased by the government. Normally 25 percent of the construction costs of the confined site is to be paid by the local political entities. However, if the local municipalities and industries are developing or using pollutant elimination systems in accordance with Public Law 92-500, then they are considered in compliance with current water quality standards and a waiver may be obtained.

Perhaps the most pressing problem with the confined disposal program in the United States is the high capital costs of the construction and land availability for these sites. Although construction costs of a confined disposal site range from 4 to 12 million dollars, the cost per cubic yard may be relatively low for a large site. The C.E. has determined that confinement of polluted dredged spoil from the 35 federal harbors having the highest annual maintenance dredging requirements may increase the cost by 3.5 times (1). Vacant land in harbor areas is extremely limited, particularly in industrialized projects where maintenance dredging volumes are high. In Canada, this problem has not reached a critical stage partly because maintenance dredging volumes in major projects such as Toronto and Hamilton are smaller. In the U.S. the policy for the confinement of polluted dredged spoil is ambitious; however, implementation is physically difficult and economically very costly.

Another new development which may affect spoil disposal in the near future in the United States is the new guidelines for dredged materials currently being drafted by the E.P.A. and reviewed by the C.E. (22). As discussed elsewhere, the E.P.A. pollution criteria have received constructive criticism (21). Based on the 5th draft of these new guidelines, which are to be finalized in 1975, the list of pollution parameters which determine the eligibility of dredged spoil for disposal in open waters of the Great Lakes will be expanded beyond the 7 mandatory parameters. These will include a wide range of pollutants such as insecticides, bacterial quality and toxic substances. A 'shake' or standard Elutriate Test will also be introduced to distinguish between contaminants in the dredged spoil and background pollutants occurring naturally in the lake waters. The draft guidelines specify that each harbor is to be considered individually and more completely. Sampling schedules have been prepared through 1976. All sampling analyses will be more complete in that subjective as well as chemical testing will be done on all samples taken.

The draft guidelines also indicate that less stress will be placed on the pollution capability of the dredged sediments per se and more emphasis on the potential impact of the spoil on the disposal area. The following areas are not to be selected as sites for the diked proposal facilities:

a. Municipal water supply and intake areas
b. Shellfish beds and fishing areas, to include spawning and breeding areas
c. Wildlife areas
d. Recreational areas

Since 1970 a decline in maintenance dredging has occurred in public and private harbors of Lake Michigan and Lake Huron due to a lack of disposal sites for the confinement of polluted spoil.

The volume of dredged spoil and industrial waste such as fly ash disposed in wetlands of the Great Lakes is not known. Since wetlands are recognized as beneficial from many points of view, an assessment of the impact of private dredging and industrial disposal in such areas is recommended. For example, from Toledo Harbor northward to Lake St. Clair (Figure 5), C.E. confined disposal facilities are in use or being planned. The C.E. has designed offshore diked disposal areas for Toledo and for the Detroit and Rouge Rivers to accommodate dredgings from federal projects. However, power plants and industries are continuing to dispose industrial wastes and dredgings in limited onshore wetlands.

Spoil dredged from private harbors and adjacent to private docks in public harbors in the United States will continue to be confined on the permittee's own land or in alternate ways approved by the C.E. It is anticipated that in the future the C.E. will regulate private dredging operations more closely. Proposed Change 6 of the 1899 River and Harbor Act requires that the C.E. consider non-federal activities, including private dredging, in the planning and maintenance of federal projects. In addition, the permit applicant is to comply with the following: (1) the FWPC Amendments of 1972; (2) the Marine Protection, Research and Sanctuaries Act of 1972; and (3) the Coastal Zone Management Act of 1972 (Public Law 92-583). Although future private dredging volumes in Lakes Erie, Michigan and Ontario are expected to remain relatively high, some decrease in dredging may result as waste treatment facilities reduce municipal and industrial deposition.

The C.E., in their pilot study of dredging, reported that the effects of open-lake disposal of dredged material had not been researched (1). At present the effect of open-lake disposal of dredged spoil on water quality is still in a research phase (29). Moreover, the C.E. concluded that in the future, at some of the harbors with low maintenance dredging requirements, small quantities of moderately polluted spoil may be disposed in the open lake (1). Although few confined disposal sites are available, most large volume projects such as Toledo and Buffalo do have confined facilities. If economic stress is to be avoided while permitting maintenance dredging, then open-lake disposal of small volumes of lightly polluted spoil could be a temporary solution to the problem of confining polluted dredged spoil. In emergency situations small volumes could be trucked to nearly landfill areas or confined behind earthen dikes.

SECTION VI

FACTORS RELATED TO DREDGING

INTRODUCTION

Dredging and disposal of sediments from Great Lakes harbors are related to physical and economic activities. In this section sources of dredged material, lake levels, and future economic changes in the Great Lakes Basin are briefly discussed and their association with Great Lakes dredging activity examined.

SOURCES OF DREDGED MATERIAL

Dredging is required to remove sediments which have accumulated in navigation channels in Great Lakes' harbors and waterways. The three main sources of the dredged sediments are: (1) stream sedimentation; (2) littoral drift; and (3) industrial and municipal discharges. The sources of sediments vary from harbor to harbor and depend upon harbor site and design. In most instances the sediments are unconsolidated and can be removed with a hydraulic or mechanical dredge. Occasionally bedrock is encountered (Class A material in Canada) such as in the Amherstburg Channel in the Detroit River. Harbors such as Saginaw and Green Bay receive large quantities of sediment from the drainage basin. Other projects, such as Ashtabula and Hamilton, are located on the lake front where sediments are transported by longshore currents which introduce sediment into the harbors. Here the detritus is derived directly from the nearshore area and is usually comprised of sand-sized particles. A third source of harbor sediments is from industrial and municipal effluents as noted in Buffalo and Cleveland Harbors.

Although there is a variety of glacial drift and bedrock in the Great Lakes region, sediment transport by streams tributary to the lakes is generally low. The surface geology of the Great Lakes region is largely composed of unconsolidated glacial deposits. However, in much of Ontario the glacial drift is thin or absent exposing the ancient Precambrian Shield. Stream concentrations of suspended sediments, in the Great Lakes region, are usually less than 270 parts per million. A notable exception is the Maumee River basin where concentrations ranging between 270 and 1900 parts per million have been determined (30). By comparison, in the American southwest suspended load concentrations are often in excess of 1900 parts per million. As a whole, the Great Lakes basin contributes only 0.4 percent of the nation's total sediment volume to the oceans (31).

Factors other than sediment or soil composition will influence the amount of sediment contributed by streams to the lakes. Table 70 illustrates land use in the Great Lakes basin. As indicated, almost one half of the basin is characterized by forested land which, in part, accounts for the

Table 70. LAND USE IN THE GREAT LAKES BASIN (31)
(percent)

Land use	Percent of area
Forest	47.4
Agriculture	38.4
Urban	8.4
Other	5.8

low erosion rates, hence low sediment yields of streams therein. The most significant source of sediment for the basin is the cultivated agricultural land (Table 71).

Table 71. ESTIMATED SEDIMENT SOURCES FOR THE GREAT LAKES BASIN (31)
(Percent)

Sources	Percent of Total Sediments
Agricultural land sheet erosion	37
Geologic erosion	30
Range and forest	10
Construction sites, roadsides, and development sites	10
Streamland, flood basin erosion	8
Gully erosion	5

The lack of sediment transport into the Great Lakes by tributary streams is reflected in the morphology of many coastal areas of the basin. Normally where great volumes of sediment are introduced to a coastal zone, deltas, coastal plains, and extensive marshlands characterize the coast. With few exceptions, considering the length of the Great Lakes' shoreline, such features are uncommon. Thus, in part, due to the low sedimentation rates of streams tributary to the Great Lakes, dredging volumes are relatively low.

Rivers contribute sediments to river mouth harbors. Although stream data are available for many rivers in the Great Lakes region, it is difficult to equate stream sediment loads to maintenance dredging volumes. In Table 72, pertaining to river mouth harbors, estimated stream loads derived from upland sources in tons per year and mean annual maintenance

Table 72. A COMPARISON OF RIVER SEDIMENTATION AND MAINTENANCE DREDGING IN SELECTED PROJECTS (7, 50)

Project	Stream load (tons/yr)	C.E. maintenance dredging (cubic yards)	Conversion 1 CY=0.675 tons
Lake Superior			
Ashland	10,240	2,000	1,350
Duluth/Superior	14,410	120,000	81,000
Ontonagon	5,130	30,000	20,250
Lake Michigan			
Manistee	26,800	50,000	33,750
Manistique	3,250	10,000	6,750
Manitowoc	44,000	40,000	27,000
Menominee	26,000	8,000	5,400
Oconto	33,000	4,000	2,700
Racine	34,969	30,000	20,250
St. Joseph	255,000	87,000	58,725
Lake Huron			
Alpena	9,540	10,000	6,750
Au Sable	7,800	30,000	20,250
Clinton R.	48,000	30,000	20,250
Saginaw	135,800	500,000	337,500
Lake Erie			
Buffalo	23,000	600,000	405,000
Cleveland	200,456	1,220,000	823,500
Fairport	22,500	400,000	270,000
Lorain	67,100	300,000	202,500
Monroe	118,800	200,000	135,000
Port Clinton	89,000	10,000	6,750
Toledo	1,179,000	1,250,000	843,750
Lake Ontario			
Oswego	136,500	80,000	54,000
Rochester	76,100	360,000	243,000
	2,566,395	5,371,000	3,625,425

dredging volumes (1961-1970) are compared. If it is assumed that a dry weight of sediment averages 50 pounds per cubic foot (32), then the volume of sediment can be converted to tons. As illustrated in Table 72, some general compatibility between sediment yield and average annual maintenance dredging is evident, particularly in harbors where dredging volumes and sediment yields are low (i.e., Manistee and Racine). However discrepancies are equally obvious, especially in Lake Ontario and Lake Erie where, as in Buffalo, Lorain, and Rochester Harbors, average annual maintenance dredging volumes greatly exceed the annual sediment load. An explanation, recognized by the Great Lakes Basin Commission, is that the assumed density of the dredged material could be too high (32). Another possibility is that sediments derived from littoral drift accumulate in outer harbors and approach channels (i.e., Cleveland, Oswego). Perhaps more important, in some river mouth harbors, such as Cleveland and Buffalo, sediment sources from industrial and municipal effluent may be considerable. Thus, in many river mouth harbors sediment sources other than or in addition to stream transport are significant. Also, based on data in Table 72, open-lake disposal of dredged spoil may in some areas significantly accelerate sedimentation in the Great Lakes Basin. Prior to the turn of the century, many harbors were located in estuaries a short distance from the lake. However, through decades of expansion, harbor facilities have expanded upriver as well as along the coast. A number of commercial harbors in the Great Lakes today have this dual characteristic (e.g., Buffalo, Cleveland, and Thunder Bay). Thus, the sediment sources may be derived from stream deposition and littoral transport as well.

Harbors, such as Buffalo, are located on the lake front where sediments are transported by longshore processes. Although a lake-front harbor with its jetty and breakwater system may be well designed, sediments may accumulate near the outer harbor structures. Since the detrital material is derived directly from the nearshore environment, in most instances the sediment is composed of sand-size particles. In some instances the sediment is not polluted and can be used for beach nourishment. In harbors on the east coast of Lake Michigan, littoral drift accounts for most of the maintenance dredging volumes which are extracted from these projects. Normally, sand bars will form adjacent to the jetties as the current velocities decrease in these areas.

As indicated in Table 73, the annual quantity of littoral drift generally exceeds the average annual maintenance dredging volume in the harbors. Differences between the littoral transport rate and the maintenance dredging may occur for a number of reasons. For example, at Muskegon Harbor the breakwater is relatively new, therefore sediment is being trapped in the lee of the structure and little material is bypassing the breakwater. Research is required to quantitatively relate the observed alongshore sediment transport to the theoretical energy conditions offshore. However, on exposed coasts where lake front harbors are located, the volume of sediments accumulating in the outer harbors is probably a function of the magnitude and direction of littoral drift.

A significant source of dredged material is industrial and municipal wastes discharged and settling in navigable waterways. Table 74 represents total and suspended solids from selected harbors in Lake Erie and Lake Ontario. Some of the suspended solids are adsorbed onto the suspended load in the rivers and are then deposited as fluvial sediments which must eventually be dredged. At Cleveland, during dredging operations in 1966 and 1967, 660,000 tons of dry solids were removed which included 17,600 tons of oil and grease (24). The suspended sediment load of the Cuyahoga River south of Cleveland is about 200,000 tons annually, however annual maintenance dredging volumes therein exceed 800,000 CY. Materials such as flue dust and fly ash can contribute significantly to the dredging volumes in highly industrialized harbors. At Thunder Bay, Ontario, it has been estimated that 85 percent of the

Table 73. COMPARISON OF LITTORAL DRIFT AND MAINTENANCE DREDGING (50)
(cubic yards)

Public harbor	Annual quantity of littoral drift volume	Average annual maintenance dredging (mean 1963-1972)
1. Grand Haven	63,000-70,000	127,553
2. Frankfurt	60,000	23,114
3. Grand Marais, MI	60,000	--
4. Hammond Bay	7,500	--
5. Harbor Beach Lake Huron	60,000	22,825
6. Harrisville	10,000	600
7. Holland	100,000	80,000
8. Leland	20,000-40,000	4,448
9. Ludington	81,500	26,549
10. Manistee	75,000	32,390
11. Muskegon	100,000	45,689
12. Pentwater	90,000	43,085
13. Port Sanilac	40,000-50,000	7,670
14. South Haven	45,000-50,000	42,438
15. St. Joseph	110,000	57,409
16. White Lake	48,000	23,482
Totals	approximately 1,072,500	547,252

Table 74. TOTAL AND SUSPENDED SOLIDS IN SELECTED PROJECTS (24, 55) (tons)

Project	Total solids	Suspended solids	Annual maintenance dredging (CY)	Conversion 1 CY=0.675 tons
Detroit River	30,600,000	1,600,000	800,000	540,000
Rouge River	3,560	433	300,000	202,500
Monroe	95,700	4,700	200,000	135,000
Toledo	3,400,000	2,000,000	1,250,000	135,000
Port Clinton	114,400	27,400	10,000	6,750
Sandusky	600,000	150,000	600,000	405,000
Lorain	81,000	15,000	300,000	202,500
Cleveland	509,000	89,000	1,220,000	823,000
Fairport	--	--	400,000	270,000
Buffalo/Tonawanda	--	--	600,000	405,000
Buffalo River	434,000	74,000	as above	--
Vermilion	90,000	17,000	500	338
Rochester	1,050,000	318,000	360,000	243,000
Oswego	3,540,000	334,000	80,000	54,000

material dredged from the Kam River and its turning basin is fine wood pulp from local paper plants. At Calumet Harbor perhaps as much as 90 percent of the spoil is due to industrial sedimentation. Dredging rates in the lower Rouge River are far greater than estimated erosion and delivery rates would indicate (32). A more detailed study at Buffalo illustrated that 13 percent of the 1967 dredging activity represented solids such as oil and grease (33). A small decrease in permit dredging, as in Calumet and Indiana Harbors, may result from a reduction of industrial sedimentation by large private industries such as Youngstown Sheet and Tube and Inland Steel Company.

In addition, a considerable amount of dredging in many harbor projects is the result of slumping or sloughing which occurs naturally or due to propeller wash (wheeling) of a vessel. This is particularly evident at bends or meanders of rivers. Another locally significant source of sediments in dredged channels is ice shoving or rafting associated with storms or onshore winds particularly on the south shore of Lake Superior. Drifting of sand by wind waves on exposed Lake Michigan beaches into jetty systems is, in part, responsible for the occurrence of sand bars inside the jetty systems. Also, as a vessel increases speed, the stern settles deeper in the water (squatting) which increases turbulence and sediment transport in the navigation channels. This acceleration of sedimentation due to vessel traffic is noteworthy in waterways such as Lake St. Clair. Thus, the dredging frequency of a given harbor may be controlled by natural and man-induced sedimentation. The sources of sediments are numerous, and are not solely limited to natural river and marine deposition.

Areas of Sedimentation Within a Harbor

Although each harbor is unique and the areas of sediment deposition vary, some generalizations may be made. Most large, commercial harbors on the

Great Lakes may be subdivided into two sections. The outer harbor extends from the shoreline lakeward and is protected by breakwaters. Landward of the shoreline is the inner portion of the harbor which may extend several miles upriver. Racine Harbor is an example of such a river-mouth and lake-front harbor. Here, the outer harbor is enclosed by a permanent breakwater extending from the shoreline into Lake Michigan. The outer harbor is maintained at project depth of 21 to 23 feet. The inner harbor extends from the shoreline upriver for approximately 1.5 miles, and has a project depth of 19 feet.

Before and after a project is dredged by the C.E., soundings are made and corrected to the low water datum. By comparing pre-dredging and post-dredging sounding charts, the areas of submarine deposition and erosion may be determined. Figure 19 is such a contour map illustrating areas of sediment accumulation and deposition in Racine Harbor. It is based on soundings made in June, 1968, immediately after the harbor was dredged, and in April, 1973. During this interval the harbor was not dredged, thus the contours represent changes in sediment distribution and sediment accumulation over a five-year period.

Figure 20 are cross sections taken along selected traverses in Racine Harbor. Although some erosion has occurred in the outer harbor, the prevalence of sedimentation is clearly evident. Most of the sedimentation occurs in upper and lower ends of the project. Upriver, cross sections A and B reveal that 2 to 3 feet of detritus has accumulated in 5 years. The principal sources of these deposits are erosion from the drainage basin and municipal wastes. Additional sources of detritus for the dredged channel are erosion and slumping of the channel walls due to wheeling and fluvial transport processes. This is most evident in meanders of the Root River. On the map, east of Cross Section C (Fig. 20) is a tongue of sediment extending downstream. Sedimentation occurs when the river flow joins a large body of water, causing a sudden decrease in the velocity of the river (34, 35).

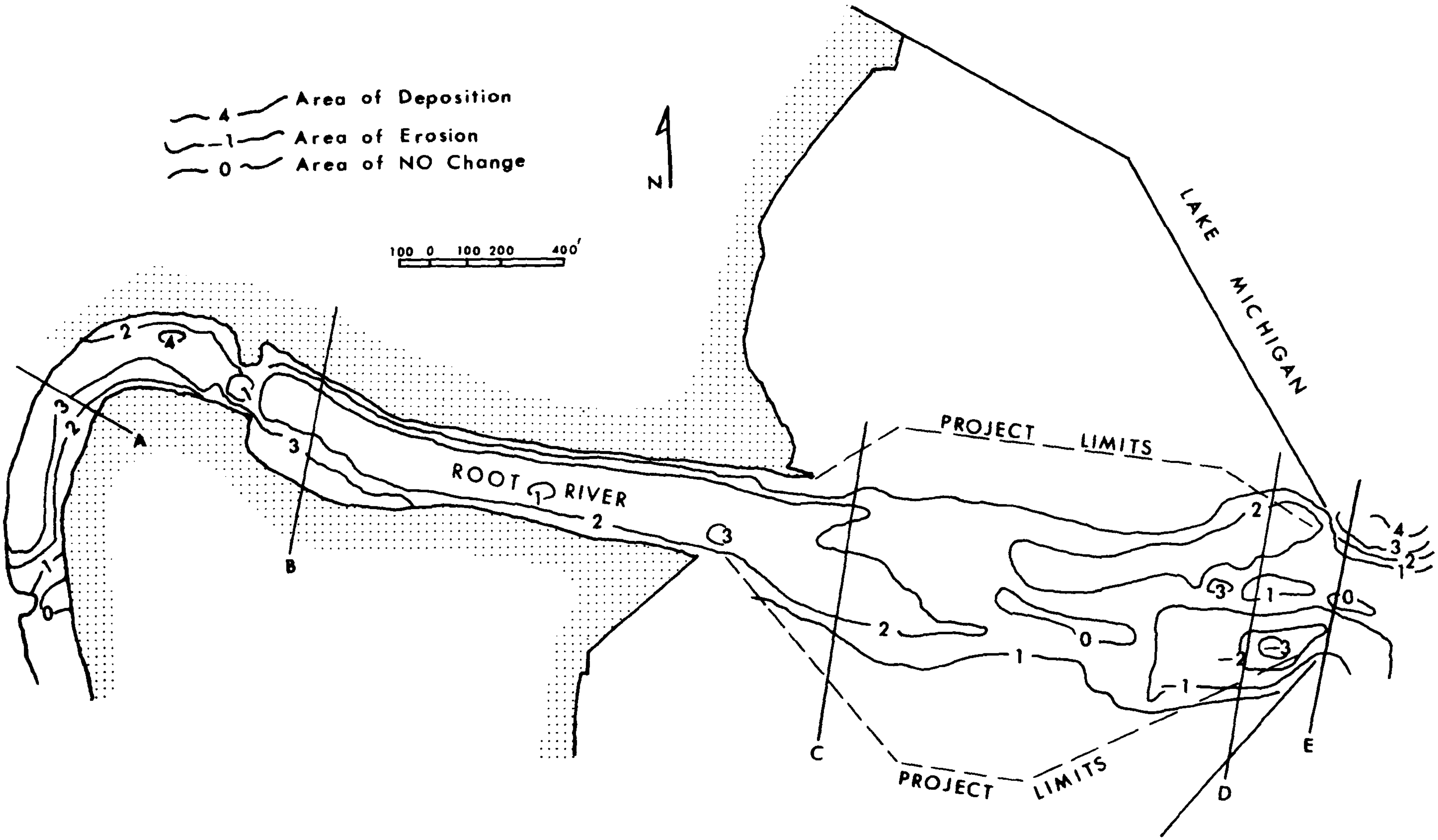


Figure 19. AREAS OF SEDIMENTATION IN RACINE HARBOR, WISCONSIN

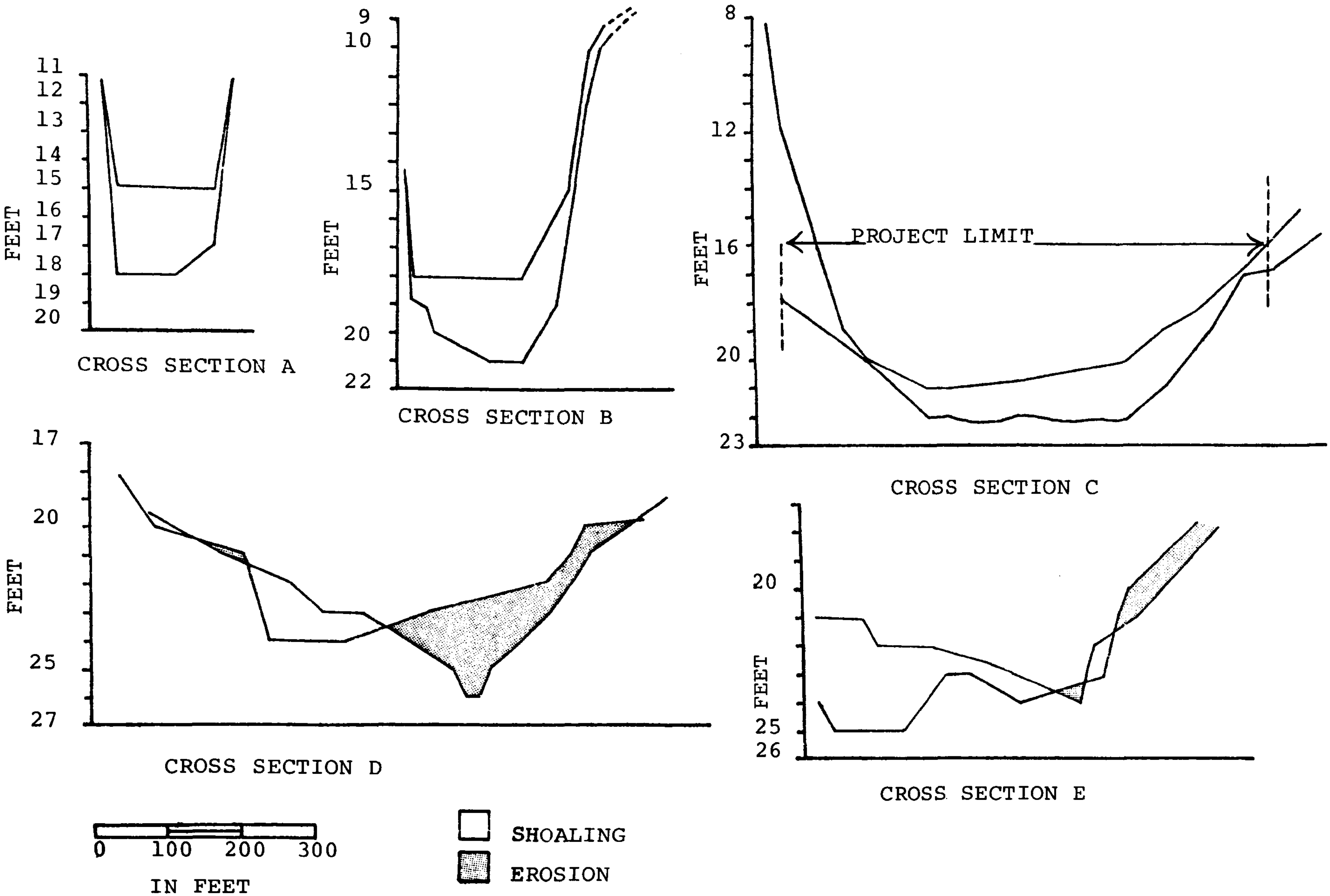


Figure 20. *SELECTED CROSS SECTIONS OF THE ROOT RIVER AT RACINE, WISCONSIN*

Thus, the principal source of this sediment is the Root River. The contours immediately east of the jetty system indicate the influence of the littoral current causing a southerly migration of the channel. The shift of the channel is clearly evident in cross section D. In this area the sediment source is principally the littoral current flowing from north to south. In such areas sediment accumulation is a constant problem.

Table 75 summarizes the sedimentation in Racine Harbor. As noted by the dredging frequencies, the area which must be constantly maintained is in the vicinity of the jetties. Although low sedimentation in the inner harbor due to stream transport results in considerable dredging quantities, small volumes must frequently be dredged from the approach channels.

Table 75. SEDIMENTATION IN RACINE HARBOR, 1968-1973

Sediment area	Source of sediment	Accumulation in feet	Dredging frequency, 1958-73
Upriver	Industrial wastes Slumping Geologic erosion	2 to 3	4
River mouth	River detritus natural and municipal	2	4
Harbor entrance	Littoral zone Some fluvial and municipal	Variable, 1 to 4	8

Summary

In summary, average annual maintenance dredging volumes from river-mouth harbors are not a simple function of sedimentation by streams therein.

Using Racine Harbor, Wisconsin, as an example, it has been demonstrated that there are three main areas of sediment deposition. Sedimentation occurs in the upstream section of the harbor at the head of navigation where sediments transported as river bedload accumulate in the dredged channels. Like a tongue extending downstream toward the lake front, sediments are also deposited throughout the inner harbor, including the turning basin. Because deposition is most conspicuous on the outside of meander bends in the river, the source of these sediments is probably from suspended river load. Finally, the third area of sedimentation is in the outer harbor and approach channels where littoral drift results in continual sediment bypassing of the breakwater and/or jetty system. As the entire harbor is polluted, industrial and municipal sedimentation probably occurs throughout the project.

In many of the commercial public harbors of the Great Lakes, particularly where there are industrial-urban complexes adjacent to the harbor, man-induced sedimentation by industrial and municipal wastes may significantly increase maintenance dredging. Although the sediments in the Great Lakes have a certain level of 'background' pollution and some 'natural' pollution is caused by tree leaves and marsh drainage, pollution of inner harbor areas by industrial and municipal discharges appears to be much more important. As along the east coast of Lake Michigan, sediment transport by beach drift and longshore currents cause considerable deposition in the outer harbor areas. Because these sandy sediments are relatively clean, the C.E. has utilized some of this spoil for nourishing eroding beaches at Holland, Muskegon, Michigan City, and Ontonagon. Using the pre-dredging and post-dredging sounding charts, it is possible to document the areas of sedimentation for each harbor. In addition, if sediment abatement programs are to be successfully implemented to reduce the volume of future maintenance dredging, then the various sources of dredged sediments must first be determined. Sediment abatement programs directed toward the reduction of natural stream sedimentation, industrial-municipal discharges, and interruption of littoral drift by public harbor structures may significantly decrease the maintenance dredging requirements of many harbors.

LAKE LEVELS AND DREDGING VOLUMES

The historical records of annual dredging in each of the Great Lakes indicate that the total quantity of dredged spoil varies considerably from year to year. In an attempt to explain part of this variation, the effect of lake levels on the historical dredging volumes was investigated. It is hypothesized that an inverse relationship exists between mean annual lake level and the total quantity of maintenance and private spoil dredged annually in each lake. New work or capital dredging quantities were excluded from the analysis. Maintenance dredging depths in C.E. and D.P.W. projects are measured from the low water datum for each lake referred to mean water level at Father Point, Quebec (Table 76). In addition, the C.E. allows 1 to 2 feet of subgrade, whereas in Canada one foot of overage is common.

Table 76. DATUMS FOR THE GREAT LAKES (7)
(feet)

Lake	Elevation (low water datum)
Ontario	242.8
Erie	568.6
Huron-Michigan	576.8
Superior	600.0

To determine whether or not annual maintenance and private dredging quantities are associated with varying lake levels, a correlation analysis, using the Pearson-Product Moment formula, was tested on the two variables. Except for Lakes Erie and Ontario, the data covered the period 1940 to 1970. Lake level stations included Oswego, Cleveland, Harbor Beach, Calumet, and Marquette. Lake level data are by calendar year, whereas dredging data is reported by fiscal year. The C.E. fiscal year begins July 1st, while the Canadian fiscal year begins April 1st. This factor must be entered into any correlation analysis. Dredging may be started in April or July and be completed and reported in May or June of the following calendar year.

In Table 77, the simple correlation coefficients are presented by lake. For each lake, the analysis yields an inverse relationship between annual maintenance and private dredging volumes with mean annual lake level. The correlation coefficient exceeds -0.5 only in Lakes Huron and Michigan, indicating a strong relationship where the amplitude of lake level fluctuation is high. When the dredging volumes are lagged one year behind lake levels, then the correlations are slightly strengthened, as compared to direct annual correlation. This reflects the fiscal year

Table 77. CORRELATION BETWEEN LAKE LEVELS AND MAINTENANCE/PRIVATE DREDGING VOLUMES, 1940-1970, IN THE GREAT LAKES

Lake	Correlation coefficients: Direct annual correlation	Correlation coefficients: One-year lag	Maximum range of lake level
Erie[a]	-0.1070	-0.3659	2.97 feet
Superior	-0.1134	-0.2569	0.90
Ontario[a]	-0.3208	-0.3329	3.52
Huron	-0.5192	-0.6265	3.85
Michigan	-0.5845	-0.6400	3.88

[a]Dredging volume data only 1951-1970.

data lag and the delay between the time of scheduling and funding of a project and the actual completion of the dredging. Using the one-year lag, the improvement in correlation is most apparent in Lake Erie. In Lake Erie, priority appears to be given to maintenance dredging of the large commercial harbors during periods of low lake levels.

During periods of low lake levels, as in the middle 1960's, groundings are more frequent, especially in the spring. In response to complaints of groundings, the C.E. and the D.P.W. strictly maintain all commercial public harbors at their project depths including subgrade. At such times the C.E. usually engages more contract dredgers to insure that the harbors and waterways are free of impassable shoals. Conversely, when lake levels are above normal, as during the early 1970's, maintenance dredging operations may be postponed temporarily. For example, Chicago Harbor and River were last dredged in fiscal year 1967. Since then some shoaling has occurred, but the higher than average lake level has provided sufficient draft for most vessel traffic.

An analysis of the Great Lakes hydrographs reveals that lake levels oscillate (36). Long term oscillations are recognized by the C.E. and G.L.B.C. (37, 7), but cannot be forecasted with sufficient accuracy to assist with dredge planning. The C.E. and the D.P.W. program their operations on the basis of periodic sounding surveillance of all project harbors.

Basically, the variations in lake levels can be classified as follows (37):

1. Long term periodic cycles.
2. Seasonal fluctuations.
3. Short term oscillations.

As demonstrated by Liu (38), a persistent oscillation for all the lakes is an 8 year cycle. Climatic variations appear to control these long term periodic cycles (8). The effect is regional, in that the lakes appear to oscillate in phase. This long term oscillation influences maintenance dredging when extreme lake levels are reached. Seasonal precipitation produces high lake levels in the summer and low lake levels in winter and early spring as a result of the Great Lakes water budget (39). The small range of seasonal fluctuations in lake levels and occasional vessel groundings in the spring do not significantly effect dredge planning. Short term oscillations, due to local storms, seiches, ice jams and prevailing winds bear no relationship to dredge volumes. These factors primarily influence local sailing schedules, docking and undocking, and piloting functions.

Future long term lake level changes are not applied, in this study, in establishing predictions of future average annual maintenance and private dredging volumes. At the present, the C.E. and the U.S. Lake Survey, using water balance equations, predict lake levels for only 6 months in advance. Nevertheless, a general relationship between future long term lake cycles and future maintenance dredging can be suggested. If lake levels oscillate on an 8-year cycle, and a peak in the present high lake level period is attained in 1974, then low levels can be anticipated in 1978-1979. This low water period may result in somewhat higher than average dredging volumes in 1979 – 1980, applying the lag factors. Prior to that time, maintenance and private dredging volumes may be below the projection of this report. In some polluted harbors, maintenance dredging may be postponed until confined disposal sites or other acceptable means of disposal are developed.

ECONOMIC FACTORS AND FUTURE DREDGING VOLUMES

The purpose of this subsection is to discuss some general economic aspects in relation to dredging volumes in the next decade. Particularly important in this regard are: (1) factors which may increase or decrease future dredging quantities; and (2) rapidly increasing dredging costs, especially costs of dredging operations and confinement of polluted spoil.

Historical dredging data presented in this report reveal that maintenance and private dredging volumes are slightly increasing, while the new work dredging quantity varies greatly over the years (Table 78). The increase in maintenance and private dredging, including the projected figure, is probably due to widening and deepening of navigation channels to accommodate vessels with deeper drafts. During the 1960's the major commercial harbors, connecting channels, and turning basins were widened and deepened to meet the 27-foot maximum draft requirement of the St. Lawrence Seaway. Although new work dredging may cause some increase in maintenance dredging, the new work associated with the Seaway system was not accompanied by a sharp rise in maintenance dredging. This is because most of the new work dredging involved deepening of existing harbors and connecting channels as well as the construction of locks. Apparently, then, the rate of shoaling in the artificial channels due to sedimentation is relatively constant and is not dramatically affected by increased depths.

Table 78. DREDGING TRENDS IN THE GREAT LAKES, 1951-1983
(millions cubic yards)

Period	Average annual maintenance and private dredging	Average annual new work dredging	Total
1951-1960	9.17	1.79	10.96
1961-1970	10.82	9.74	20.56
1973-1983	11.45	4.11	15.56

The decrease in the number of new work projects scheduled through 1979 suggests that a temporary economic plateau may have been reached in the Great Lakes. Moreover, most of the scheduled new work is designed to accommodate the boating public as several new recreational harbors with 12 to 14 foot drafts are anticipated. Conversely, a projected increase in bulk traffic from 188 million tons in 1973 to 276 million tons by 1995 (40) should create some demand for new harbor facilities, i.e., docks, slips and berthing areas. In addition, in 1973 the first southbound movements of coal from the Rocky Mountain region occurred in the Great Lakes. A few declining harbors such as Michigan City may actually be revitalized by new coal imports or by increased activity in bulk and general cargo movements. However, these new developments are not yet reflected in the future new work projects.

To handle the increase in bulk shipments of iron ore, limestone, coal, and to some extent, grain, Great Lakes vessels of longer length, greater beam and increased draft are being constructed (41). Since 1970, two 1,000-foot bulk carriers with beams exceeding 100 feet have appeared on the Great Lakes. Several more of these large vessels are in the planning stage. Even though they cannot be loaded to full capacity due to the 27-foot draft limit of the Seaway, these vessels transport about twice the cargo of conventional lake carriers. Many older ships have also been lengthened to the 800-foot category. To achieve economies of scale, the trend in the United States toward larger carriers will probably continue during the next decade, resulting in record bulk cargo volumes but fewer ship transits.

With regard to the effect on future maintenance dredging, the longer vessels with broader beams may cause increased turbulence and sloughing in approach channels, as in Green Bay and Saginaw Harbors. Bow thrusters will permit the vessels to turn essentially in their own length, thus turning basins will not have to be enlarged. However, to avoid grounding of such large carriers, especially due to squatting, connecting and approach channels will have to be dredged to maximum project depth plus subgrade at all times. Therefore, as more of these large carriers are deployed, maintenance dredging requirements in the connecting channels and major commercial harbors may slightly increase, especially during low-water periods.

An increase in the draft of the Seaway system may be limited by cost constraints. As estimated by the U.S. Department of Transport in 1968, the cost of converting and deepening the entire seaway system to a 31-foot capacity was estimated to be 3.5 billion dollars (41). Nearly one-half of this cost involves the deepening of the Welland Canal, which currently has a draft of 27 feet plus subgrade. In the upper Great Lakes, the Poe Lock at Sault Ste. Marie has sills at 32 feet, and it can accommodate vessels of 110 foot beam. To extend the draft of the upper Great Lakes to 32 feet, St. Marys Channel, St. Clair River, and Detroit River would have to be dredged to 32 feet. To date, deepening of these connecting channels has not been justified.

The economic feasibility of an extended navigation season is currently being investigated (42). To many shippers, particularly in the U.S., an extended season is vital to the future vitality of the Great Lakes navigation system. Although an extension seems likely in the near future, no significant effect on future maintenance and new work dredging is anticipated.

Several economic factors may cause a levelling off of future maintenance and new work dredging volumes. First, a few small, commercial harbors which are no longer economically justified (such as Saugatuck and Pentwater) may be downgraded to recreational status and maintained at 12 to 14 foot depths. In Canada, a number of small semi-commercial harbors have been reclassified and transferred. Projects such as Grand Bend, Killarney and Blind River have been transferred from the M.O.T. to the Fisheries and Marine Section of the M.O.E.

Other factors which may depress future maintenance dredging volumes include rising dredging costs, competition from other modes of transport, and sediment abatement programs. In Canada, all maintenance dredging is contracted to public tenders. As has been pointed out in the Policy Section, government-owned dredging plants can reduce the cost of maintenance dredging operations by about 50 percent. In addition, the C.E. has estimated that the transport and disposal of polluted maintenance dredgings in confined disposal sites could increase dredging costs 350 percent (1). Rising costs of dredging will probably result in dredging priorities, perhaps by comparing cost-benefit ratios of the harbors to be dredged. In Canada, the M.O.T. has recently assumed the administration of the public harbors from the D.P.W., thus reflecting some economic concern over navigation and dredging.

Competition from other carriers for non-bulk commodities traditionally moved by lake carriers may result in less dredging in the future. Improvements in land transportation such as unit trains or pipelines may cause lower demand for shipping on the Great Lakes. In fact, cost feasibility of transporting taconite from the Lake Superior area to Chicago by pipeline has been established (43). In addition, Canadian railroads have been competing successfully for containerized freight which customarily moved by ship along the Seaway route from Halifax to Detroit (44). Conversely, if the energy crisis in the U.S. worsens, hampering future rail and truck traffic, then shipping volumes on the lakes may increase since water transport is significantly more energy efficient. Studies by the St. Lawrence Seaway Development Corporation conclude that 15 to 20 million gallons of fuel could be saved each year if 50 percent of the import-export cargoes originating in or destined for states bordering the Great Lakes were moved on the Seaway rather than overland to ports on the East Coast (45).

If implemented, sediment abatement programs could significantly reduce shoaling and hence reduce dredging. It has been estimated that the stream load of the Maumee River could be significantly reduced of sediment traps on the upper river were installed (1). Along the eastern shore of Lake Michigan, where littoral drift results in shoaling near the breakwater and jetty systems, some reduction in sediment bypassing may be feasible. New policies in the U.S. and Canada regarding the effect of federal harbor structures on littoral transport of beach sediments could promote the development of abatement programs along exposed coasts.

Perhaps the most important economic factor which may influence future dredging volumes is the high cost of the confined disposal program for polluted spoil. Costs of dredging and disposing spoil in diked sites, including construction costs, are approximately $10 per cubic yard, while disposal in the open waters of the Great Lakes averages about $1.00 per cubic yard. Even though larger sites are generally less expensive to construct and maintain, the confined disposal program of the C.E., involving 35 polluted harbors, may require an expenditure of $85 million (1). Should construction of confined disposal sites be delayed, maintenance dredging of some polluted harbors may have to be postponed. At present the construction of the diked site for Cleveland Harbor is 6 months behind schedule, and although lake levels are at a record high, groundings have been reported.

Though the cost of confining polluted dredged spoil is high, the total cost may be lower than some preliminary projections. In this report the future average annual quantity of polluted spoil in the Great Lakes has been estimated to be about 7.5 million CY place measure. In their 1969 report, the C.E. projected that the future average annual quantity of polluted spoil from only 35 harbors in the U.S. will be 8,573,000 CY (1). Our projection of future polluted spoil includes private and maintenance dredging of all polluted and partially polluted harbor sediments in the U.S. and Canada, whereas the C.E. projection includes only polluted maintenance dredgings to be derived from 35 American harbors and waterways. The projection of the C.E. appears high because some of the volumes were not converted to place measure and, in partially polluted harbors (P/U), the polluted portion was not separated from the unpolluted portion. The new pollution guidelines, to be promulgated by the E.P.A. in 1975, may result in the reclassification of some of the small harbors which are currently considered partially polluted. In addition, the confined disposal sites may actually contain as much as 25 percent more spoil than anticipated. For example, at Buffalo Harbor, the diked site was designed for a capacity of 400,000 cubic yards, but more than 500,000 cubic yards were disposed there.

In summary, economic factors regarding future planning of new work projects and scheduling of maintenance dredging will probably be given more consideration. In Canada, this change is evidenced by the assumption of harbor administration by the M.O.T. Rising costs of dredging and disposal of spoil may result in the necessity for the establishment of dredging priorities based on cost-benefit comparisons. Such priorities based on cost-benefit ratios and the trend toward larger vessels with economy of scales will probably promote the decline of the small, commercial harbors. Maintenance dredging may actually increase slightly in connecting channels and major industrial harbors. The projected increase in bulk commodity movements and the pressure for an extended navigation season should offset the competition for containerized freight and general cargo by other modes of transport. However, future maintenance and new work dredging volumes are not expected to be affected by these developments. With the rising cost of dredging and the high capital costs of confined disposal sites for polluted spoil, dredging and disposal site priorities are foreseeable. The C.E. anticipated the need for priorities by designing diked disposal sites first for the large, commercial harbors which are unequivocally justified and heavily polluted.

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SECTION VIII

LIST OF ABBREVIATIONS

BNA Act	British North America Act
C.E.	United States Army Corps of Engineers
COD	Chemical Oxygen Demand
CY	cubic yards
D.P.W.	Department of Public Works of Canada
E.P.A.	United States Environmental Protection Agency
F.Y.	fiscal year
G.L.B.C.	Great Lakes Basin Commission
M.O.E.	Ministry of the Environment of Ontario
M.O.T.	Ministry of Transport of Canada
NEPA	National Environmental Policy Act of the United States
N.O.A.A.	National Oceanic and Atmospheric Administration
NWPA	Navigable Waters Protection Act of Canada
P.W.C.	Public Works Commission of Canada (now D.P.W.)
S.L.S.A.	St. Lawrence Seaway Authority

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE FUTURE DREDGING QUANTITIES IN THE GREAT LAKES		5. REPORT DATE December 1974
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) C. N. Raphael, E. Jaworski, C.F. Ojala and D.S. Turner		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Geography and Geology Eastern Michigan University Ypsilanti, Michigan 48197		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. R-801062
12. SPONSORING AGENCY NAME AND ADDRESS EPA, National Environmental Research Center Corvallis, Ore. 97330		13. TYPE OF REPORT AND PERIOD COVERED Final Report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Based on historical records, an overview and projection of U.S. and Canadian dredging quantities in the Great Lakes are presented. Using current pollution criteria, future quantities of polluted maintenance dredging are estimated for each lake. Recent environmental policies have influenced dredging and particularly disposal practices. These policies, as well as sedimentation, lake levels, and economic factors are discussed in relation to dredging.

During the next decade, maintenance and private dredging volumes will not change significantly, whereas new work will decrease. As in the past, most maintenance dredging will occur in U.S. projects, particularly in Lake Erie.

A factor which will determine future U.S. maintenance dredging is the availability of confined disposal sites. If the 62 sites are completed for commercial harbors as planned, 300,000 of the 6.45 million cubic yards of annual projected polluted spoil will not have disposal facilities. Where pollution elimination systems are in use, shoaling in some industrial harbors may be decreasing. Although long-term lake levels are not predictable, an inverse relationship between maintenance dredging and lake levels is evident.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Great Lakes Dredging volumes Disposal Lake Levels Policy Sedimentation Disposal Sites Navigation		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
	20. SECURITY CLASS *(This page)*	22. PRICE