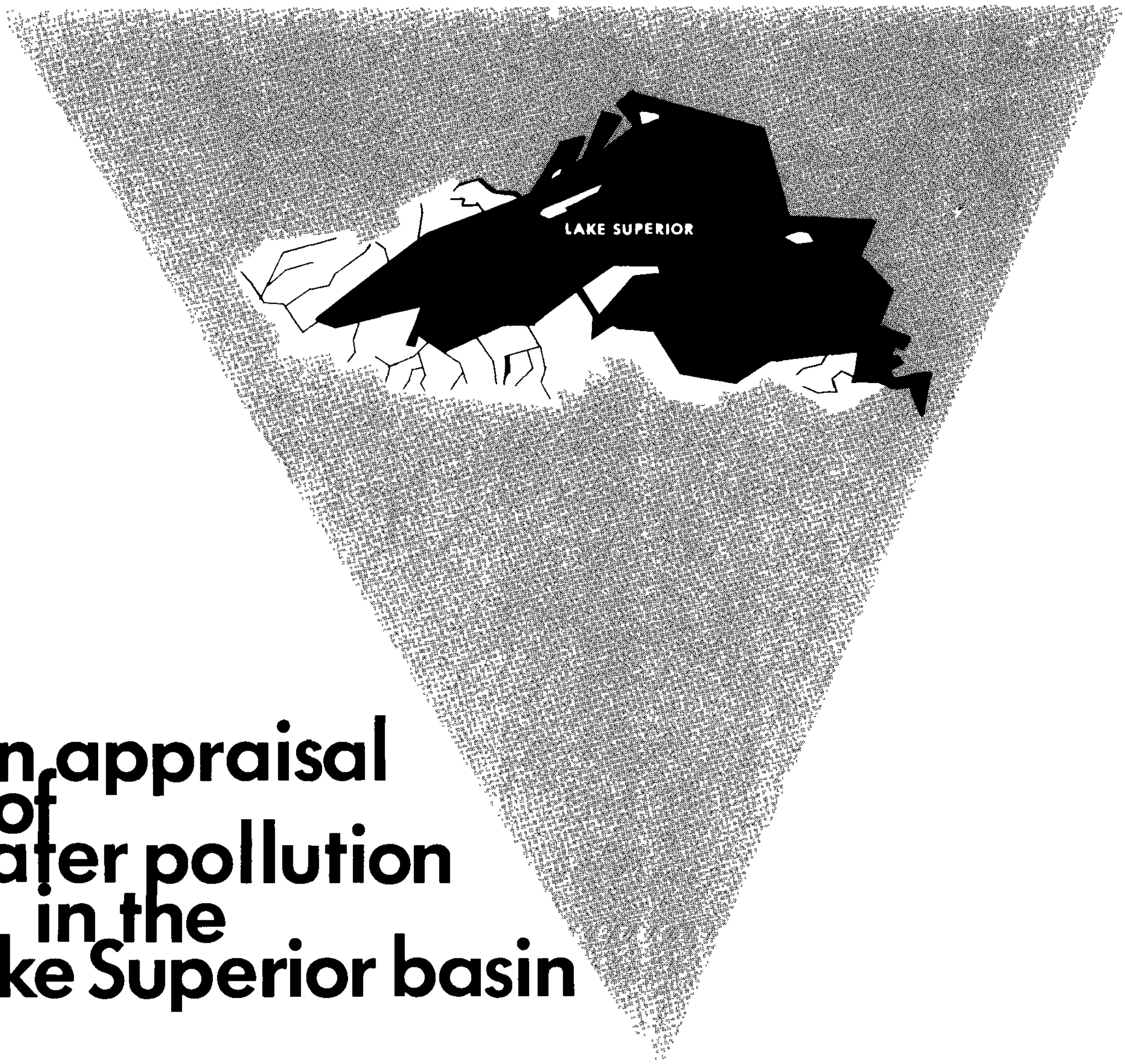

an appraisal of water pollution in the lake Superior basin

U. S. Department of the Interior
F W P C A
Great Lakes Region

APRIL 1969

an appraisal of water pollution in the lake Superior basin

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ACTION FOR CLEAN WATER

PL 84-660

U. S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
GREAT LAKES REGION

FOREWORD

"Lake Superior is apart from the other Great Lakes – it is the storied 'Shining Big Sea Water,' the symbol, the spirit of an intrinsic part of the [American] heritage. To those individuals fortunate enough to have witnessed the crashing of great seas on age-old rock, or the chilling, quiet blanket of fog suddenly lifting to the near blinding of a blue-white summer day; to have seen water so clear that the phantom trout were visible at 5 fathoms; to have experienced the purity that is the Big Lake – to them there is no need to justify any conservation effort on behalf of Lake Superior."

Adopted from Michigan Water Resources Commission
"Water Resource Uses, Present and Prospective
for Lake Superior and the St. Mary's River,"
June 1967

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I. INTRODUCTION

On the basis of reports, surveys and studies indicating that interstate pollution is occurring, and in accordance with Section 10 of the Federal Water Pollution Control Act (33 U. S. C. 466 et. seq.) Secretary of the Interior Stewart L. Udall called a Conference in the Matter of Pollution of the Waters of Lake Superior and Its Tributary Basin (Michigan-Minnesota-Wisconsin). The area covered by the conference is shown on Figure 1.

This report was prepared for the information of the conferees and other interested parties, and for use by the conferees in their consideration of actions needed to preserve the high quality of waters in the conference area and improve presently degraded waters. The report is based on studies and investigations by the Federal Water Pollution Control Administration (FWPCA), investigations made through cooperative agreements by other agencies of the Department of the Interior, studies and reports furnished by the three Lake Superior States and information obtained from other Federal agencies, universities, and others. All data presented in this report are for the United States portion of the Lake Superior basin, unless otherwise noted.

The contributions of all who have provided assistance and information is gratefully acknowledged.

Scale: 50 0 50 100 miles

LAKE SUPERIOR BASIN

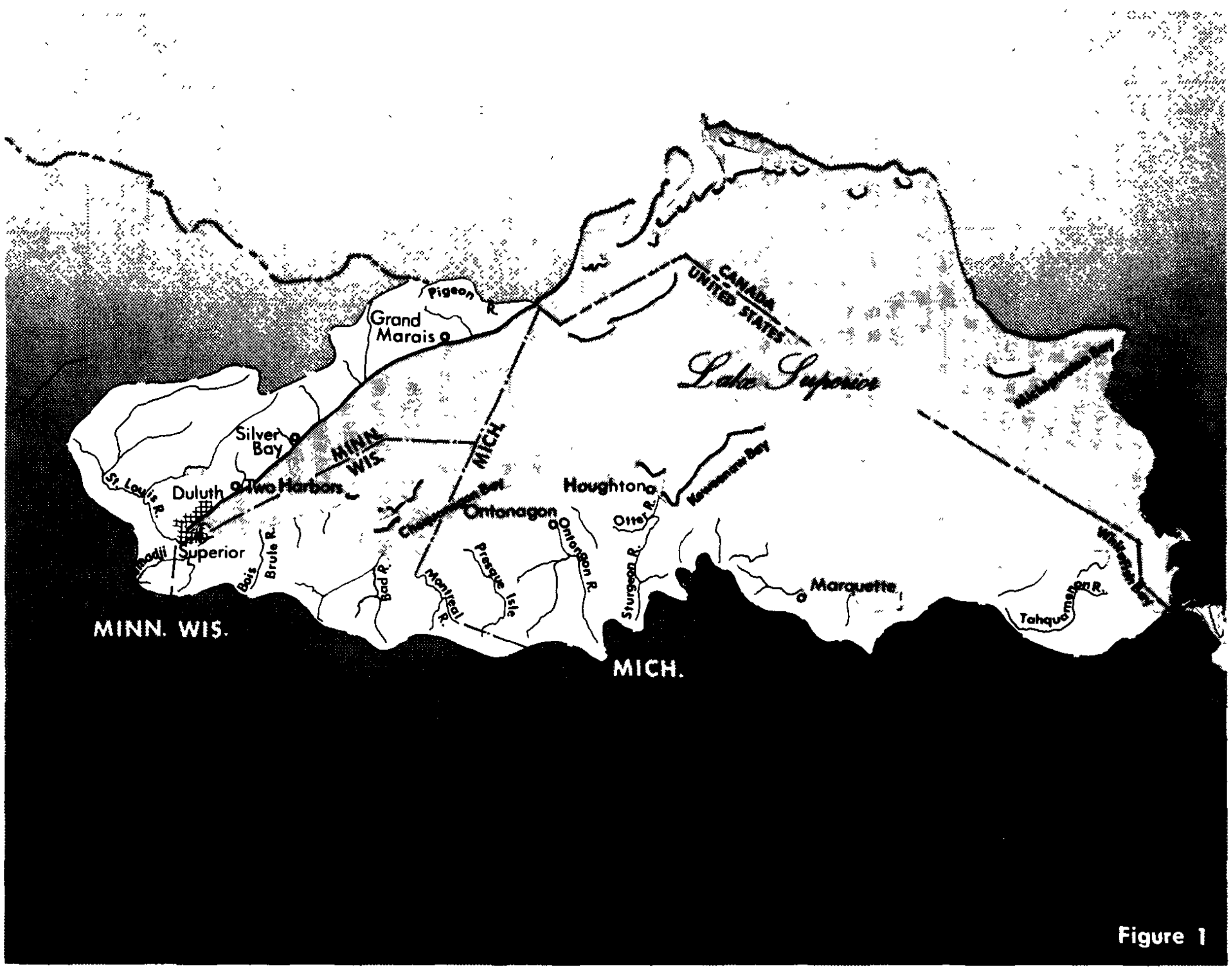


Figure 1

II. THE BASIN AND ITS FEATURES

GENERAL DESCRIPTION

The largest body of fresh water on the earth is comprised in the five Great Lakes covering 95,170 square miles water surface area. Lake Superior is the largest of the Great Lakes and the largest lake in the world – 31,820 square miles in surface area, approximately 350 miles long, 160 miles wide, 1,333 feet maximum depth, and a volume of approximately 3,000 cubic miles. Other physical data concerning Lake Superior are shown on the following table.

	Total	Canada (Ontario)	United States	Mich.	Minn.	Wisc.
Drainage Basin (sq. mi.)	80,511	42,570	37,941	23,931	8,354	5,656
Water Surface (sq. mi.)	31,820	10,702	21,118	16,231	2,212	2,675
Land Area (sq. mi.)	48,691	31,868	16,823	7,700	6,142	2,981
Shoreline (miles)	2,976	1,549	1,427	913	189	325

The topography of the basin, in general, is rough and with certain exceptions, the lake is surrounded by a ridge 400 to 800 feet high. In most areas the highland is either immediately adjacent to the shoreline or close to it. The Wisconsin-Michigan area along the southern shore rises less abruptly, but the height of the ridge is about the same as in Minnesota.

The soil has developed from glacial debris and shallow-lying bedrock. It is a mixture of sand and sandy loam to clay. The low soil fertility and the short growing season are not favorable for extensive agricultural activities.

The climate of the basin is continental in the interior, while a modified marine climate is found near the lake shore and particularly in the peninsular areas. These two distinct types of climate are reflected in the temperatures, precipitation, and growing seasons. Extreme temperatures range from -47°F. to 106°F., while the basin's average temperatures range from 8°F. to 12°F. for January, and 60°F. to 66°F. for July. The average annual precipitation is 28 to 32 inches with 16 to 19 inches falling during the warm season. Snowfall varies from 55 inches to 276 inches in different portions of the basin, and the growing season, which also reflects the wide climate range, varies from 80 to 130 days in the basin.

The principal river of the basin is the St. Louis which has a drainage area of about 3,700 square miles and is an interstate stream that forms part of the Minnesota-Wisconsin boundary. A portion of the Michigan-Wisconsin boundary is formed by the interstate Montreal River, one of the smaller streams in the basin draining an area of about 281 square miles. The boundary between Minnesota and the Province of Ontario, Canada, is formed by the Pigeon River. Other principal rivers are the Bad River in Wisconsin and the Ontonagon River in Michigan.

Scale: 50 0 50 100 miles

POPULATION CENTERS

LEGEND:

- ● 100,000
- ■ 20,000 - 50,000
- ▲ 10,000 - 20,000
- △ 5,000 - 10,000

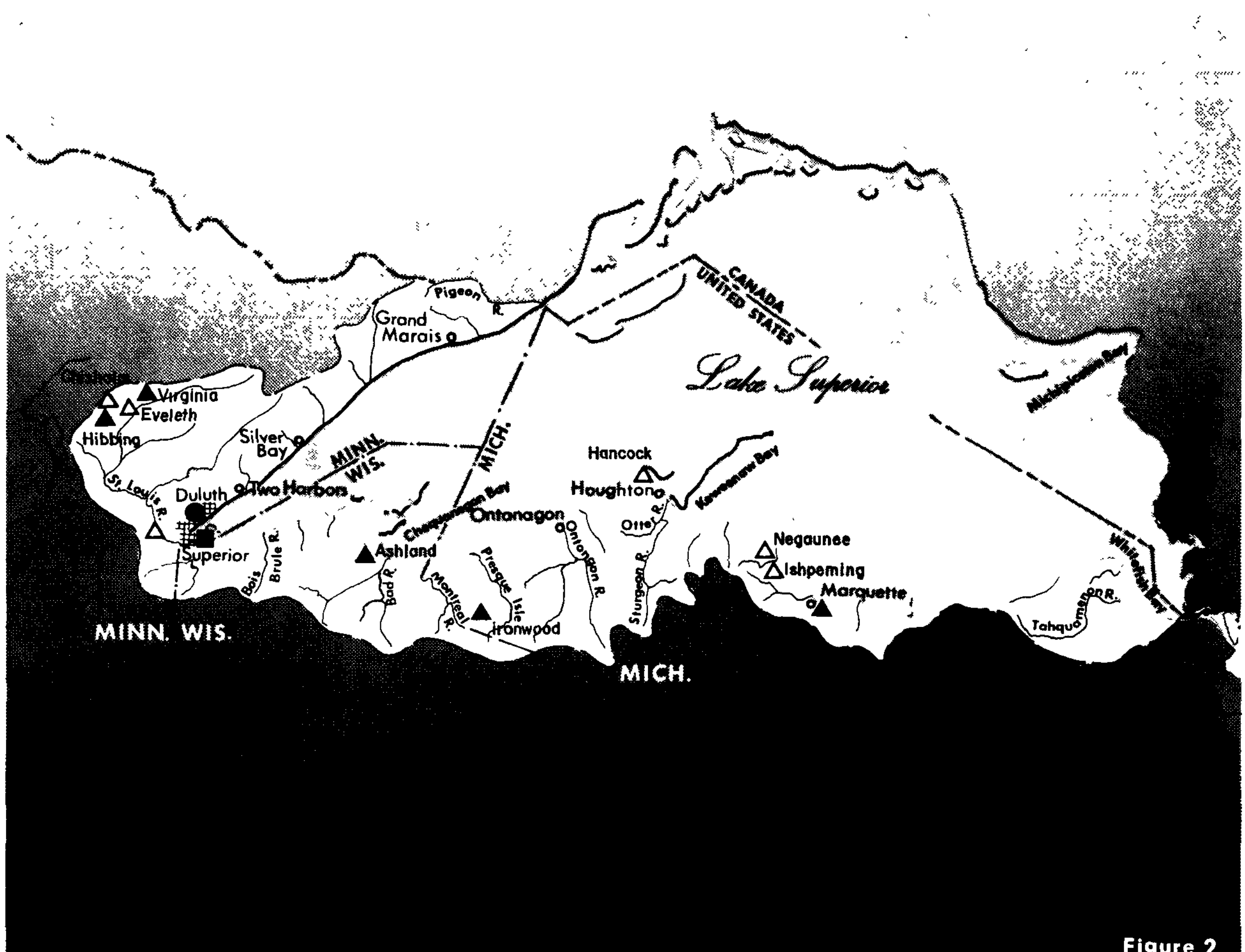
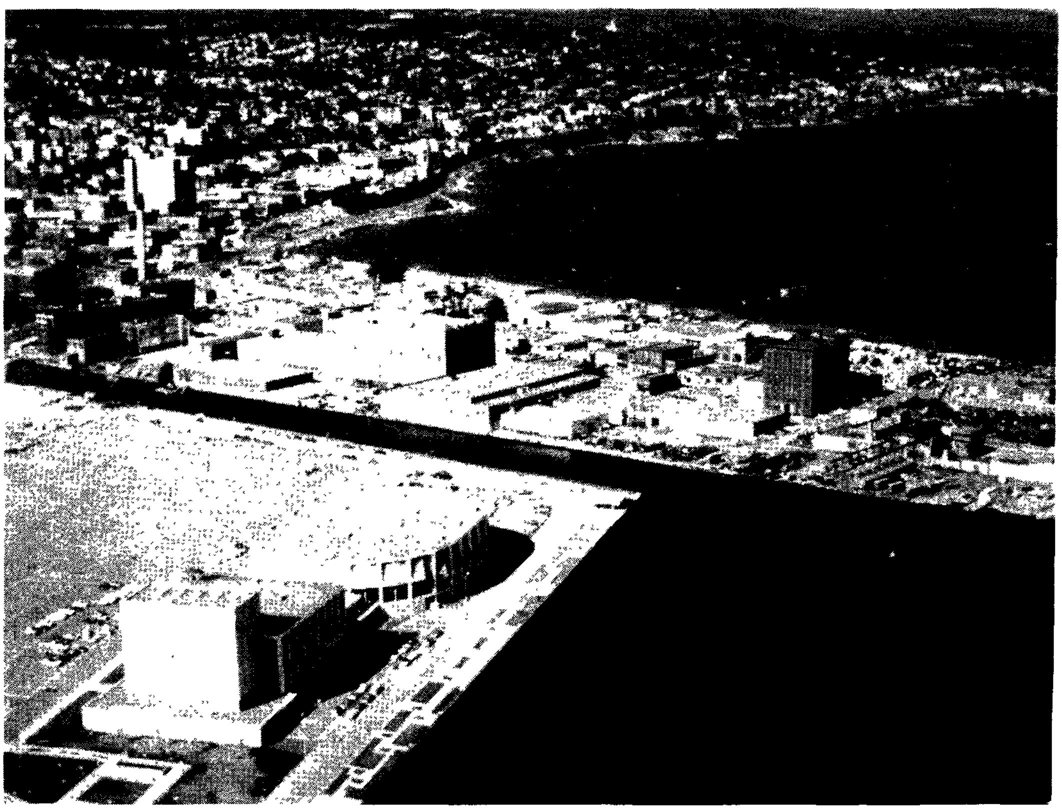


Figure 2

POPULATION

The population density in the United States portion of the basin is low, 30 people per square mile. Approximately a half-million people live in the basin with Minnesota counties (primarily St. Louis County) accounting for about half of the total population. Michigan and Wisconsin counties account for about 34 percent and 16 percent, respectively. The major cities in the Lake Superior watershed with their 1960 populations are: Minnesota, Duluth – 106,884, Hibbing – 17,731, and Virginia – 14,034; Wisconsin, Superior – 33,563, Ashland – 10,132; Michigan, Marquette – 19,824 and Ironwood – 10,265. Figure 2 shows these population centers.

Even though during the past 20 years there has been a considerable emigration from the Lake Superior basin, the population is expected to increase by approximately 100,000 in about two decades with the municipal portion of the population experiencing most of this increase at the expense of the rural areas. The areas most likely to show relatively rapid growth are: Chippewa and Marquette Counties in Michigan, Douglas County in Wisconsin, and St. Louis County in Minnesota. Carlton and Lake Counties, which border on St. Louis County, will experience some of the expansion trend of that county.



Duluth, Minnesota at the head of Lake Superior is the largest city in the basin

Scale: 50 0 50 100 miles

INDUSTRIAL CENTERS

LEGEND:

- F Food and kindred products
- P Paper and allied products
- C Chemical and allied products
- O Petroleum and coal products
- M Primary metal industries
- Metal mining

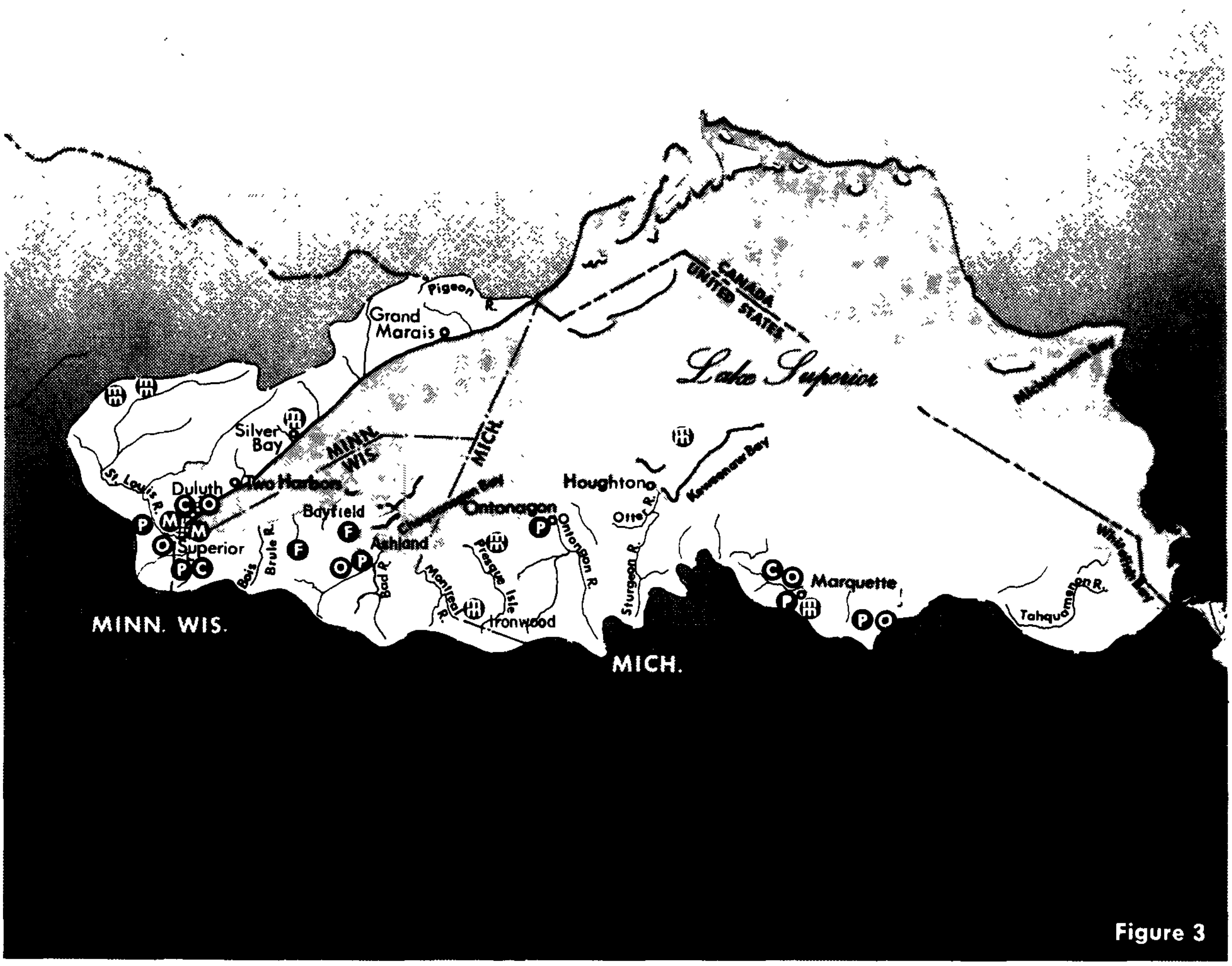


Figure 3

ECONOMY

While the economy of the basin has in the past few decades been uncertain, developments in recent years favor a general uptrend in activity. Continued research activities relating to iron ore processing, dramatic developments in processing of taconite ores, plus progress in research concerning the use of timber resources is creating a new confidence in the future.

Industrial activity in the watershed is diversified both in character as well as location. Figure 3 shows the principal centers of industrial activity. While iron ore mining is the dominant feature of the watershed, value added by manufacture amounted to approximately $250 million in 1963. Duluth – Superior is the major industrial center, but, significant industrial developments are located elsewhere, such as Silver Bay, Minnesota; Ashland, Wisconsin; and Houghton-Hancock, Michigan.

The history of iron ore mining is closely associated with the development of the iron range area of the basin. With the advent of the taconite process whereby low grade iron ore undergoes a beneficiation process to produce pellets containing a higher concentration of iron, the iron mining industry in the basin has economically taken a sharp upturn. As of 1966 pelletized iron ore was firmly established as the most desired form of blast furnace feed in the United States. Taconite beneficiation plants have been established at a number of locations in Minnesota, Michigan, with a potential for their establishment in Wisconsin.

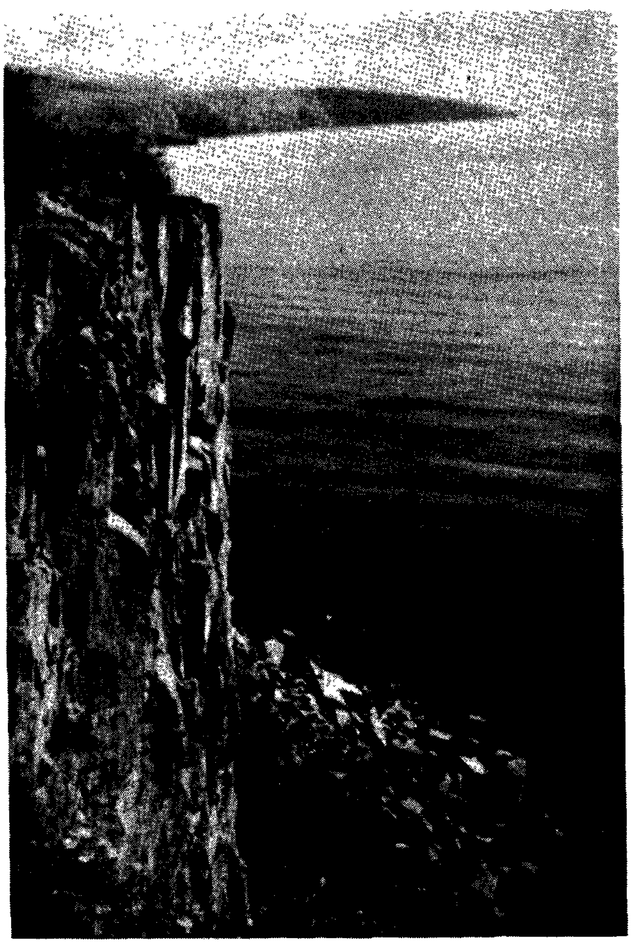
Other mining activities, primarily sand and gravel, are widespread throughout the basin. Copper mining is an important segment of Michigan's economy in the upper peninsula.

Forestry and forest products manufacturing are important in a number of locations in the Lake Superior basin. Virgin timber stands have been greatly depleted but sustained lumbering, pulp logging and Christmas tree harvesting continue to be important contributors to the economy. New technology in processing wood products should enable the area to capitalize to a greater degree on the extensive forest resources. Considerable expansion of the paper and allied products industry is likely.

Some manufacturing activity occurs in all counties of the watershed although in 1963 St. Louis and Carlton Counties of Minnesota and Douglas County in Wisconsin accounted for 70 percent of the total. Manufacturing output is expected to triple in the next 20 to 25 years. Petroleum refining, chemicals, steel rolling and finishing, and food and kindred products are the major categories having installations within the watershed.

Although agriculture is not a major land use, farms are scattered throughout the basin and in some limited areas farming is a dominant feature.

Some of the Nation's most unique and scenic shoreline is a part of the Lake Superior coast line. The wide sand beaches of Whitefish Bay, the great perched dunes near Grand Marais, the sheer cliffs of the Pictured Rocks, the remoteness of the Huron Mountains, the Apostle Islands, Split Rock Lighthouse, Isle Royale National Park and all the many miles of primeval wilderness constitute a most valuable recreation and esthetic resource. Therefore, recreation resources including commercial resorts are very important to the economy and are expected to have even greater significance in the future as a greater number of people from locations outside of the area seek to utilize its existing and planned recreation facilities. An estimated $50 million was spent in the basin on tourism in 1964 (44). It can be assumed this is a conservative figure based upon estimates of growth for the tourism industry.



The use of high quality water extends beyond the bounds of physical contact with the resource. Here towering cliffs and spectacular shoreline provide scenic enjoyment.

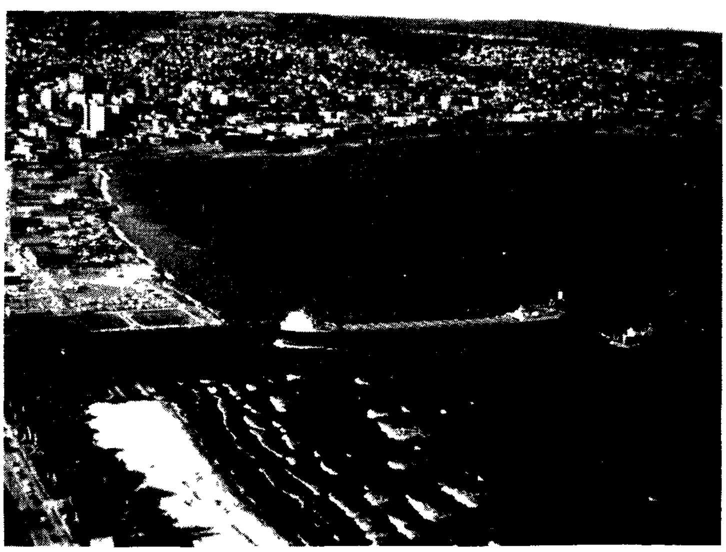
WATERBORNE COMMERCE

The economy of the Lake Superior basin is naturally stimulated by the presence of the lake. The "fourth seacoast" of the United States and Canada became a reality upon completion of the St. Lawrence Seaway in 1959. There is now a continuous channel from the Great Lakes to the Atlantic Ocean making an ocean port of every deep draft harbor situated on Lake Superior.

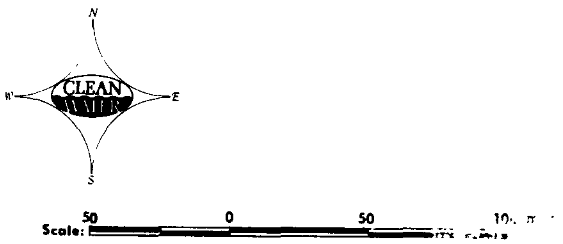
The Soo Locks at Sault Ste. Marie and navigable channels of the St. Mary's River are of major importance to commercial navigation in Lake Superior. This busy channel passes approximately 100 million tons of freight annually. With the deep connecting channels and harbors and the new lock (1,200 feet long, 105 feet wide) at Sault Ste. Marie, vessels 1,000 feet in length and 100 feet wide with carrying capacities of 50,000 tons can now be accommodated. Major commodities shipped include iron ore, coal, grain and stone.

The harbor facilities of Lake Superior are also a major asset to the continuing development of the natural resources potential of the basin. The Duluth-Superior port is one of the largest inland shipping ports for waterborne commerce on the Great Lakes. The harbor is the fifth largest in the United States in tonnage, surpassed only by New York Harbor, New Orleans, Houston Harbor and Channel, and the Philadelphia Harbor. Total tonnage exceeds 46 million net tons annually. Annual direct overseas imports and exports total over 3 million tons and consist of more than one-third of the direct overseas commerce from all Great Lakes ports. The facilities of the Duluth-Superior harbor, which include the largest ore docks in the world, handle the majority of the iron ore which is shipped to the steel mills of the lower lakes. Approximately three-fourths of the total tonnage at the port consists of iron ore. Other major commodities are grain, coal, limestone, cement, scrap iron, iron and steel products, salt, petroleum products, and general merchandise.

In addition to the outstanding facilities at Duluth-Superior there are other commercial harbors throughout the area, including Two Harbors, Silver Bay, Taconite and Grand Marais in Minnesota; Ashland in Wisconsin; and Ontonagon, Keweenaw, Presque Isle, Marquette and Grand Marais in Michigan. Figure 4 depicts the commercial harbors on Lake Superior.



Facilities of the Duluth-Superior Harbor include the largest ore docks in the world. Above is an ore boat entering the habor.



COMMERCIAL HARBORS

LEGEND:
■ Harbors

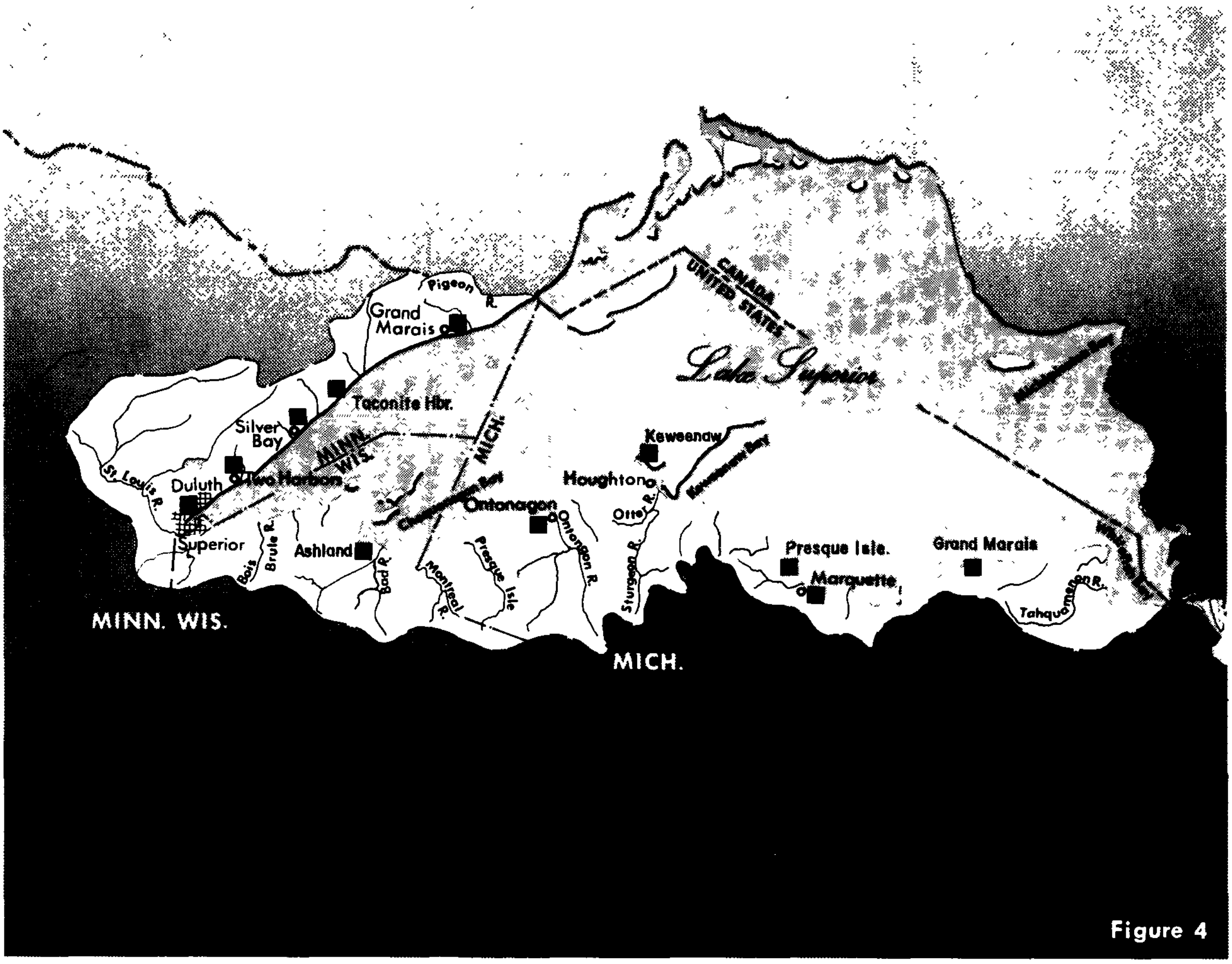


Figure 4

WATER RESOURCES

Lake Superior is the largest of the Great Lakes and in terms of surface area is the largest fresh water lake in the world. In terms of volume of water it is the world's second largest fresh water lake. The average flow out of Lake Superior is 73,100 cubic feet per second (cfs).

Since 1922 the level of Lake Superior has been regulated by operations of control works in the St. Mary's River above the rapids at Sault Ste. Marie. (47) These works, including a 16-gate control structure, powerhouses and canals and locks, were built as a condition of an order of the International Joint Commission granting a permit to divert water around the rapids for power generation (to prevent lowering of Lake Superior). The same order also created an International Lake Superior Board of Control, consisting of an officer of the Corps of Engineers and an officer appointed by the Canadian government.

It is the function of the Board to determine the amount of water available for power generation and to maintain as nearly as possible the level of Lake Superior to its low datum of 600 feet. Since 1957, the level of Lake Superior from extreme low to extreme high has varied only about one foot.

In addition to precipitation and runoff, Lake Superior receives water by importation via the Long Lake-Ogoki hydroelectric projects located in Canada. This diversion averages nearly 5,000 cfs of water which formerly flowed north to Hudson's Bay. Because of the regulatory works at the "Soo" this diversion has not affected the level of Lake Superior.

There are over 100 streams in the three States which outlet to Lake Superior. Discharge information concerning the major streams is shown on Table 1. By far the largest stream tributary to Lake Superior is the interstate St. Louis River which enters the lake at Duluth-Superior. The lower St. Louis River has been extensively developed for production of hydroelectric power.

Most of the streams draining the north shore of Lake Superior are approximately 20 miles in length, characterized by a steep gradient and a high fluctuation in flow level. The one exception to this is the St. Louis River.

The Lake Superior drainage in the State of Wisconsin consists of a series of small streams flowing through the escarpment which exists around the south shore. Falls and rapids are characteristic along the escarpment line with some streams having hydro-power development. There are six hydroelectric power installations on the tributary streams.

There is a total of 78 streams in Michigan which outlet to the lake. The largest of these streams is the Ontonagon which has a drainage area of approximately 1,400 square miles.

There are approximately 2,000 lakes having areas of ten acres or more within the watershed. Most of the lakes occupy depressions in glacial deposits or are in ice block basins formed after the retreat of the glaciers. Approximately 600 of the lakes are in the north shore watershed area in Minnesota.

The ground water resources of the area bordering Lake Superior are quite variable. In many cases the glacial drift is too thin and discontinuous to provide adequate supplies of water. In portions of the basin, namely the St. Louis River watershed, there are extensive areas of unconsolidated sand and gravel which, in general, yield large quantities of water. In general, the quality of ground water is satisfactory for all uses.

TABLE 1

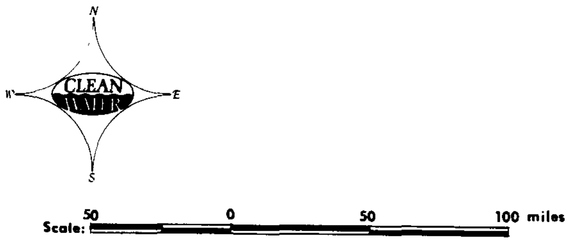
MAJOR UNITED STATES TRIBUTARIES TO LAKE SUPERIOR*

Name of River	Total Drainage Area (Sq. Mi.)	Gaged Drainage Area (Sq. Mi.)	Mean Discharge (cfs)	Period of Record (Water Yrs.)
Pigeon	610	600	483	1923-67
Brule	282	0	–	–
Baptism	146	140	159	1927-67
St. Louis	3,652	3,430	2,202	1908-67
Nemadji	446	0	–	–
Bois Brule	185	113	169	1942-67
Bad	1,016	611	605	1914-22 1948-67
Montreal	281	262	325	1938-67
Black	257	200	227	1954-67
Presque Isle	359	261	264	1945-66
Ontonagon	1,390	1,340	1,374	1942-66
Sturgeon	729	705	795	1942-66
Dead	166	0	–	–
Chocolay	161	0	–	–
Tahquamenon	820	790	849	1953-66
Waiska	147	0	–	–

*Counterclockwise from U.S. (Minnesota) – Canadian Border

Data Source: USGS Surface Water Records of Minnesota and Wisconsin, 1967
USGS Surface Water Records of Michigan, 1966

Whitewater rapids and cascading falls are characteristic of Lake Superior's tributary streams.



NET SURFACE CIRCULATION OF LAKE SUPERIOR

LEGEND:
Synthesized current patterns

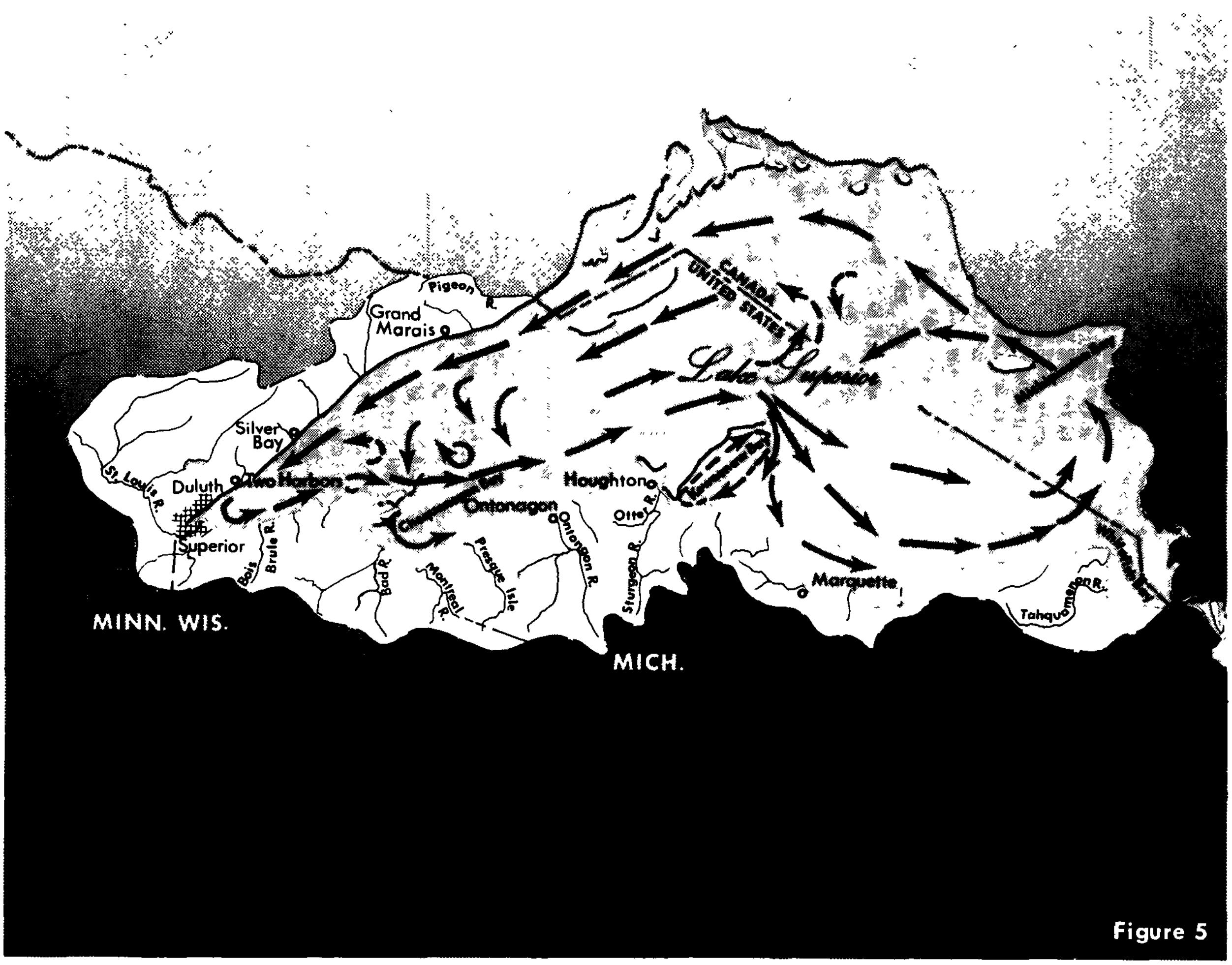


Figure 5

LAKE CURRENTS

Circulation studies of Lake Superior were begun in October 1966 by the FWPCA to determine the water circulation pattern of the lake, to establish the cause and effect relationships so as to be able to predict the movement of pollutants occurring in, and being discharged to the lake, and to develop a more accurate description and understanding of the physical, biological, and chemical phenomena of the lake.

To accomplish this, seven current-metering stations were emplaced in Lake Superior in October 1966. In May 1967 these meters were recovered and replaced and the current-metering network was expanded to a total of 17 stations. These stations were recovered in October 1967.

The current-meters were Richardson type, self-contained recording instruments, clock-activated periodically (every 30 minutes), recording directional and speed data for one minute on 16mm film then shutting off until the start of the next cycle. At each station current-meters were suspended at depths of 30, 50, 75 and 100 feet and every 100 feet thereafter. Temperature recorders were also installed at these depths.

The data from these stations were analyzed using accepted oceanographic techniques. What follows is a discussion of the findings.

Waterborne wastes reaching Lake Superior are dispersed into the main water mass by three means; molecular diffusion, turbulent mixing, and lake currents. Considering the lake as a whole, currents are the predominant mechanism for the movement and subsequent dispersion of these wastes into the lake's water mass.

While the inflow and outflow rate from Lake Superior is extremely small in comparison to the water mass of the lake proper, the lake water is not standing still. It is kept in constant motion principally by the wind which not only generates the visible surface waves but stirs and mixes the water throughout the lake.

Both water movements and rate of mixing are materially influenced by the formation of thermoclines, or zones of temperature transition between two layers of water which differ in temperature and density. In the summer, Lake Superior water becomes divided into an upper layer of warm readily circulating water, called the epilimnion, and a lower layer of cold, relatively undisturbed water called the hypolimnion. A region between these two layers where rapid temperature change takes place, is called the thermocline. When the lake water is thus stratified, the water in the hypolimnion (lower stratum) is essentially physically and chemically isolated from the remaining waters of the lake. In Lake Superior, nearly 95 percent of the lake's volume is in the hypolimnion. The summer stratification begins to develop in mid-June, with the epilimnion (upper stratum) reaching its maximum temperature in August. The thermocline is somewhat transient in Lake Superior in that it will move in and out of an area of the lake. When there is no thermocline, the water is isothermal (without a thermocline). In the winter months, the lake can be considered, for all practical purposes, to be isothermal and water mixing occurs throughout the lake.

Thermal bars, a phenomena resulting from a difference in temperature between adjacent waters along a vertical plane, occur in the spring and fall in shallow waters parallel to the shoreline. The fall thermal bar is not as extensive nor as well developed as is the one that occurs in the spring. A thermal bar inhibits mixing between the shallow waters along the shore and the deeper lake waters. Wastes discharged into the inshore side of the thermal bar tend to be held in the inshore area.

Because currents in the lake are motivated principally by the wind, and winds are variable, horizontal movement of the lake water exhibits an infinite variety and frequent changes in both direction and speed. A current change in less than six hours after a wind shift is common in mid-lake. The nearshore response may be even more rapid. However, certain recurring patterns have been identified, resulting principally from the fact that winds from one direction predominate.

The net circulation of Lake Superior is counter clockwise, with the possibility of large cyclonic eddies occurring in the western arm, or Duluth embayment, between Isle Royale and the Kewennaw Peninsula, and in the eastern basin. See Figure 5.

Superimposed on the net circulation pattern of the lake are other factors that affect water movement. The net circulations, while on a long-term basis may be considered the circulation pattern of the lake, exist for only short periods of time. One week would be considered a long period of time for the total net circulation pattern to exist.

Upwelling occurs in the lake when winds cause horizontal surface movement of water away from the shore. The surface waters are replaced by colder, deeper waters. Upwelling frequently occurs along the north shore during periods of northwest and west wind. Winds from the east and south produce upwelling along the south shore.

Other forces that affect water movement are internal waves, caused by storms and/or pressure differences acting on the lake's surface, and inertia currents resulting from decaying wind stresses.

In summary, while there is a net circulation pattern in the lake, a great many forces are acting which have a modifying effect upon water movements. These water movements are such that any persistent pollutant entering directly into Lake Superior or discharged into the water that feeds the lake, mixes with and becomes an integral part of the lake water as a whole.

There is a pleasure in the pathless woods,
There is a rapture on the lonely shore.

Lord Byron "Childe Harold"

WATER USES

The waters of Lake Superior are used for municipal and industrial water supply; recreation, including swimming, boating, fishing and other water oriented sports; commercial fishing; propagation of fish and aquatic life; commercial navigation; and esthetic enjoyment.

The waters of Lake Superior are of excellent quality for municipal water supply. Twenty-four municipalities and communities withdraw water from the lake for domestic usage. These systems serve approximately 184,000 people which use 25 million gallons per day (mgd). Communities in Michigan use approximately 5.7 mgd; Wisconsin approximately 1.3 mgd; and Minnesota approximately 18.0 mgd. The largest domestic supply is for the city of Duluth, which uses approximately 16 mgd, more than 60 percent of the total. Eight other communities in the basin utilize surface sources other than Lake Superior, withdrawing about 1.8 mgd. The remaining communities in the basin rely on ground water for their supply.

A twenty-three mile long water line is being constructed from Duluth to Cloquet, Minnesota to convey Lake Superior water to Cloquet for domestic and industrial water supplies. The pipe line will also serve the city of Superior, Wisconsin. The ultimate design capacity of the pipe line is 40 mgd. The initial capacity of the system will be 25 mgd. The scheduled completion date for the project is March 31, 1969.

An estimated 563 mgd of Lake Superior water is withdrawn for industrial purposes. Of this total 518 mgd are used by Minnesota industries, 42 mgd by Michigan industries and 3 mgd by Wisconsin industries. The largest single water user is the Reserve Mining Company taconite beneficiation plant at Silver Bay, Minnesota, which accounts for more than 90 percent of the total Lake Superior water used by industry. The use of industrial water on the tributaries of Lake Superior total approximately 200 mgd of which approximately 70 percent is used by the iron mining industries on the eastern end of the Mesabi Range in Minnesota.

Total electric power generation in the Lake Superior basin, including hydroelectric and steam generation, is estimated at about 850 megawatts. The largest hydro-power development in the basin is on the St. Louis River in Minnesota with a total installed capacity of 88,860 kilowatts. Steam power generation is estimated at approximately 650 megawatts, of which more than 60 percent is produced in Minnesota. A total of approximately 500 mgd of Lake Superior water is used for cooling purposes. Surface water other than Lake Superior used for cooling purposes totals approximately 130 mgd. There are at present no nuclear generating plants in the Lake Superior basin.

Records on commercial fish catches in Lake Superior have been kept since 1879. The catch averaged 7.8 million pounds from 1879 to 1908; 10.5 million pounds from 1913 to 1928; and 15.6 million pounds from 1929 to 1963. The catch reached a maximum of 22.1 million pounds in 1941 but since has declined to a 1967 level of 7.9 million pounds. The decline is related to biological and economical factors. In 1967 Lake Superior ranked third in commercial fish catches for the United States portion of the Great Lakes. Lake Michigan, 59.0 million pounds and Lake Erie 11.6 million pounds ranked first and second respectively.

There are relatively few fish species that constitute the bulk of the commercial catch in Lake Superior. Lake trout are undoubtedly the most popular and valuable fish. The maximum lake trout catch of 5.6 million pounds occurred in 1903. Between 1903 and 1955 the catch ranged between two and three million pounds, reaching 3.7 million pounds in 1944. The catch since 1955 has declined steadily, with the 1961 catch dropping to 323,000 pounds. From 1962 to the present lake trout fishing has been allowed under permit only. The chief cause of the decline of the lake trout was predation by the parasitic sea lamprey. Only drastic reduction of the sea lamprey population and intensive stocking by State and Federal agencies prevented total collapse of the lake trout fishery. A small amount of natural lake trout reproduction has now been found but the fishery at the present still depends upon stocking from hatchery raised fry. Indications are the population of lake trout in Lake Superior is increasing.

Drastic changes in the production of lake herring have occurred in the past twenty years. A maximum production of approximately 18 million pounds occurred in 1941 in United States waters, and declined to 10.8 million pounds in 1960. The abundance of herring has dropped significantly in the 1960's declining to 3.8 million pounds in 1967. White fish production, which typically fluctuates between 400,000 to 800,000 pounds, is currently about 500,000 pounds. A maximum catch of 1.3 million pounds was recorded in 1949. The smelt population, which at present produces a catch of 1.5 million pounds, is suspected as a causative factor in the decline of a number of native fish species. Chubs have been harvested to an increasing extent beginning in the late 1950's with production reaching 1.3 million pounds in 1959. The catch for 1967 was 1.9 million pounds. This fishery increased only out of economic necessity arising from the decline of lake trout.

The Lake Superior basin is an area of outstanding natural resources and great recreation potential. However, at the present only moderate demands are being placed on the basin's recreation reasouces. The relative inaccessibility of many recreation areas, because of their considerable distance from large population centers and a lack of better destination routes, in conjunction with a short tourist season are primary factors creating this situation. The current annual recreation demand is estimated at nearly 16 million recreation days. By the year 2000 this amount is expected to nearly double. Approximately 80 percent of the present demand can be attributed to vacation use.

In 1964 an estimated 1.4 million vacationists came to the Lake Superior basin for the primary purpose of outdoor recreation. The vacation sector comprises approximately 80 percent of the basin's total effective population. This approximation does include a few basin residents but by far the greater number are non-residents.

While the list of recreation activities available in the basin is quite endless, the vast majority of recreation activities in the basin are centered around or near water. These include boating, fishing and those activities significantly enhanced by the presence of water such as hiking, camping, sight-seeing and driving for pleasure.

Pleasure boating is rapidly increasing in the Lake Superior basin.

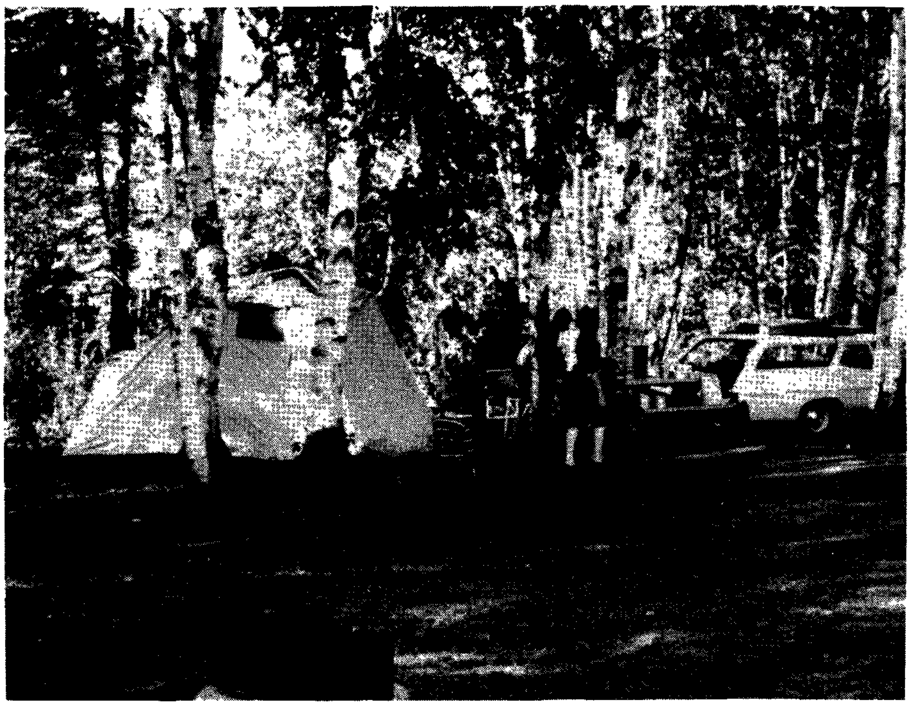
The United States Bureau of Outdoor Recreation report, "Water Oriented Outdoor Recreation - Lake Superior Basin" (44), presents a detailed discussion of recreation in the basin including information on existing facilities, the problems that are developing, and the action that must be taken to preserve this natural heritage.

Even though it is recognized that recreationists participate in all the other basic activities in addition to sight-seeing, it is the attraction of this latter activity which draws most recreationists to the basin. Probably Lake Superior's greatest asset is its scenic shoreline.

Water quality is a most important factor influencing the recreational uses which are made of the water, as it affects the quality of the outdoor recreation experience. Water oriented recreational activities may be divided into two categories -- one of which involves actual contact with the water. This category is further broken down into activities involving the whole body contact such as swimming and water skiing and those involving limited contact such as pleasure boating and fishing. The other category involves the esthetic enjoyment of viewing the body of water and its surroundings. This includes such activities as driving and hiking for pleasure along the shore of the body of the water. An important part of the recreational value of water is its esthetic aspect. Camping, picnicking, sight-seeing, while not directly water oriented activities, are considerably enhanced as an experience by esthetically pleasing water. Some pollution robs the water of its esthetic value for such activities.

The severity of a pollution problem can vary from place to place on a given body of water and in many instances from time to time depending on weather and other factors. In addition, people vary widely in their opinions as to the point at which water quality has deteriorated to the extent that it is no longer suited for a certain recreational activity.

Therefore, it can be seen that water quality per se has a demonstrable effect on recreational use. Many of the factors which contribute to the degradation of water quality can be measured readily; for example, rise in water temperature due to thermal pollution and amount of silt added to a stream as a result of land runoff. However, sociological factors which are very difficult to measure, play a key role in determining the extent to which quality will influence recreational use. These latter factors become very personal and differ with the individual depending upon his education and environmental background.



Numerous State and Federal lands in the Lake Superior basin offer recreational opportunities that can be enjoyed by all.

III. THE POLLUTION PROBLEM

Lakes may be classified according to their level of primary productivity. The productivity or "fertility" of a lake depends on nutrients received from regional drainage, on the depth, plus other interrelated factors which affect the metabolism of the lake. A eutrophic lake is at one end of the classification series and on the other end is an oligotrophic lake. While there are a number of characteristics associated with oligotropic lakes, in short they are still "biologically young" and have changed little since the time of their formation.

Lake Superior is an excellent example of an oligotrophic lake having very clear, cold water and very few living organisms. The lake is an exceedingly young lake in terms of its biological aging processes. It is thousands of years behind the other Great Lakes considering only natural againg. The lake nearly resembles its pristine condition as created eons ago.

Lake Superior has been the least studied of all the Great Lakes. Most of the studies conducted have been in the western portion of the lake. There are very little data for the lake during the winter season and essentially nothing is known about bottom organisms, bottom character, and fish species in the deeper portions of the middle of the lake.

Lake Superior is a delicate lake and therefore great caution must be exercised when weighing the potential dangers to its ecology. Increases normally considered insignificant or acceptable in most lakes will dramatically alter this lake, because even such small changes will represent a large percentage of change. For example, an increase in 5 units in turbidity will result in a reduction of many feet in light penetration and significant loss of fish food organisms. The very cold temperatures keep production of phytoplankton at a very low level. The growth of algae in the lake can be loosely compared to algal growth that would occur in a beaker of water placed in a lighted refrigerator.

It is also true that a slight reduction in the food producing capacity of the lake is likely to evidence itself in lower fish production because food appears to be limiting in the lake. Shallow shore areas, one of the major fish food producing areas in the lake, are limited and therefore are extremely important to the survival of the fish species of the lake. These are the same areas first to be affected by man-made waste discharges. Because algae productivity is low, the depth to which light penetrates is important for producing sufficient plankton, periphyton and benthos in the shore areas.

The native fish species in Lake Superior such as lake trout have long egg incubation periods; some of them reaching two to three months. Conditions must be ideal during this critical period to enable the eggs to hatch. Because the eggs are deposited on the lake bottom, small quantities of silt or settleable solids are likely to smother the eggs as they are left unattended by the adult fish.

The addition of certain kinds of toxic materials into Lake Superior is of prime importance. The heavy metals (i.e., copper, iron, zinc, etc.) are highly toxic at low concentrations because the water is soft, the fish species found in the lake are sensitive to metals and because the metals are persistent and will remain in the lake for longer periods of time due to the lake's slow flushing rate. Many of the common metals found in the surface waters could seriously affect the reproductive potentials of the fish species in Lake Superior at concentrations in the range of 2 to 50 parts per billion.

The quality of Lake Superior water is so high compared to other lakes that the early signs of damage may go undetected or may be excused as being insignificant. Using standards of clean water normally considered appropriate in pollution control programs, Lake Superior could be degraded considerably and changed significantly before water uses would be damaged.

Pollution problems have occurred in the Lake Superior basin. Some of the existing problems, both in the lake and on the interstate tributaries are discussed in the following sections.

CHEMICAL POLLUTION

Pollution by dissolved chemicals covers a broad range of substances including heavy metals such as copper, iron and zinc, phenolic compounds, oil nitrogenous materials, phosphorus, chlorides, and colored waters. Two general types of effects are produced by such chemicals: (1) local and immediate effects in the vicinity of the source, and (2) a progressive buildup in the concentrations of certain persistent chemicals in the lake as a whole. Concerning the latter effect, great caution must be exercised in order to avoid long-term damage in Lake Superior as the self-purging rate has been estimated to be well in excess of 500 years (45). In addition, eddy currents that may occur in the western end of the lake tend to limit the intermixing of these waters with the rest of the lake.

Lake Superior and Lake Michigan are the headwaters of the Great Lakes as their outflow passes through Lakes Huron, Erie and Ontario. Constituents dissolved in Lake Superior waters such as nutrients which tend to accumulate in a lake could therefore add to the accumulated levels in these downstream lakes. While the effects of these dissolved constituents may not be felt in Lake Superior due to other limiting factors, conditions may be suitable in the downstream lakes to result in a degraded water quality.

The heavy metals, as a group, are especially important in Lake Superior for several reasons. Because there is a low mineral concentration in the lake, metals are more toxic than they would be in average waters in the United States. In addition, several important species of fish, especially lake trout, whitefish, and lake herring, are unusually sensitive to such metals as copper, zinc and chromium. Natural agents are lacking in the lake to bind such metals and render them inactive.

An industrial waste discharge to a tributary stream in Wisconsin causes a discoloration of Lake Superior waters.

Heavy metals are reaching Lake Superior through natural erosion of the mineral laden rock in the drainage basin and as a result of mining activities. Amplification of aspects related to mining activities is found in another section of this report.

Very important chemical constituents in a lake are the levels of nitrogen and phosphorus. Aquatic vegetation including algae are capable, through photosynthesis, of utilizing inorganic elements in support of growth -- including nitrogen and phosphorus. These nutrients have been given the most attention because following carbon, they are required in the greatest amounts for the production of green plants. Bodies of water receive these nutrients from many sources such as natural runoff from agricultural and urban land, ground water, precipitation and sewage and industrial waste effluents.

Information available shows that in Lake Superior, overgrowth of algae is not a problem. The low temperature of the water is very likely a limiting factor in the lake's productivity. The harbor areas and inshore lake water near the harbors are most susceptible to nuisance aquatic vegetation growths because they are more easily affected by man's activities and because other conditions, such as higher water temperatures and phosphorus concentrations necessary for nuisance conditions, more frequently occur.

The three States in the basin have included statements on phosphorus removal in their interstate water quality standards. In addition, the Michigan Water Resources Commission adopted a resolution in October 1967, which calls for the removal by June 1, 1977 of phosphorus compounds from wastes discharged to the waters of the State. Minnesota has adopted statewide effluent standards which require the removal phosphorus from waste discharges to certain lakes and reservoirs. The cities of Duluth, Two Harbors, and Grand Marais have been required to install phosphorus removal facilities by 1971; Silver Bay by 1972.

OXYGEN DEPLETION

Dissolved oxygen (oxygen held in solution in water) provides the basic respiratory supply for most living organisms, including not only fish but also the bacteria which consume organic matter. Therefore, dissolved oxygen is a most important ingredient necessary for a healthy, balanced aquatic life environment. Decomposable organic matter can cause an excessive reduction of the dissolved oxygen concentrations in the water because oxygen is consumed by the respiration processes of some living organisms. The oxygen is replenished by absorption from the atmosphere and through the photosynthetic processes of aquatic plants provided a well balanced environment exists. Organic pollution alters the environmental balance. The bacteria in the water or introduced with the waste, utilize the organic matter as food, multiply rapidly and reduce the dissolved oxygen. The resulting oxygen deficiency may be great enough to inhibit or destroy fish and other desirable organisms, and result in taste and odor problems. Excessive depletion of the dissolved oxygen results in the generation of many nuisance conditions.

At the present time the main body of Lake Superior has not shown any signs of oxygen deficiency. (13, 22, 31, 32, 35) This coincides with the characteristic of an oligotrophic lake in that there is ample oxygen at all water levels within the lake. In this case, the oxygen levels are at or near the saturation point at all depths.

Oxygen depletion is occurring in some of the tributaries draining into Lake Superior. In the Minnesota drainage, reaches of the lower St. Louis River from Cloquet to the Duluth - Superior harbor have on numerous occasions been excessively depleted of oxygen. (38, 55) Inadequately treated sewage effluent and inadequately treated industrial wastes discharged into this reach have been the source of the problem. The condition is aggravated by the operation of the hydroelectric plants on the river which cause wide fluctuations in river flow.

Industrial waste discharges to the lower St. Louis River have caused serious pollution problems.

Sources of waste in the Duluth - Superior harbor have also created localized areas of substantial oxygen depletion. Sources of pollution include inadequately treated municipal wastes plus inadequately treated industrial wastes from various points.

The interstate Montreal River downstream from Hurley, Wisconsin and Ironwood, Michigan has experienced oxygen depletion problems. (12) The proportion of the oxygen depletion caused by the waste discharges from each of these two cities has not been determined.

Under the provisions of interstate water quality standards, the State regulatory agencies have initiated actions to eliminate the oxygen depletion problems occurring on the tributary streams.

BACTERIAL POLLUTION

The presence of coliform organisms in water is considered an indicator of degraded water quality and a possible indicator of a health hazard. Coliform organisms are significant because they occur in the fecal matter of all warm-blooded animals, including man. Consequently, the presence of these bacteria in a body of water is considered evidence of fecal contamination. Since such contamination is one avenue of transmission of certain waterborne disease, the presence of coliforms is also an indication of a health hazard from accompanying pathogenic bacteria and viruses.

The largest coliform concentrations in water are usually produced by human contamination, but elevated counts will also occur after rainfalls due to land runoff and/or storm and combined sewer overflows. Pathogenic bacteria from human sources can be adequately controlled by proper treatment and disinfection of waste discharges.

The bacterial quality of the main body of Lake Superior is excellent. The problems of bacterial contamination that have occurred were found along certain tributaries and some harbor or inshore areas around the lake. Instances of impairment of water use in the basin by bacterial pollution have been documented by the Bureau of Outdoor Recreation. (44) Some of the areas that have experienced bacterial pollution are portions of the St. Louis River and Duluth Harbor area in Minnesota; and Superior Harbor area, Ashland inshore area and reaches of the Montreal River in Wisconsin.

Some cities in the basin are served by combined sewer systems so that quantities of a mixture of storm water and sewage are discharged without treatment during and after every heavy rain. This has resulted in bacterial pollution of some reaches of rivers in the basin. Bacterial pollution in most cases is amenable to correction. This is the case wherever the waste can be put through a treatment plant followed by disinfection.

The State regulatory agencies have taken actions to eliminate existing bacterial pollution problems and to prevent future undesirable conditions. The States of Michigan and Wisconsin require year around disinfection of waste treatment plant effluent. Minnesota requires year around disinfection at all waste treatment plants in proximity to water supply intakes and seasonal disinfection of effluents discharged to waters used for recreation. In addition, all three States have required separation of combined sewers or other remedial action to prevent pollution from this source.

MINING ACTIVITIES

There are 151 active mineral operations within the Lake Superior basin. Table 2 shows the distribution by State and mineral commodity of these operations. Not all of these operations are "wet" industries, i.e., utilize quantities of water in their processes. The waste disposal practices followed by the "wet" operations are shown in Appendix A.

There have been water quality problems associated with mining operations in the basin. Wastewater originates from open pit iron ore mining as a result of the entrance of rainwater and seepage into the mines. The water must be pumped out to maintain a dry area for mining operations. The quantity of water may range from almost nothing to several thousand gallons per minute. This water may be highly colored and very turbid or may be crystal clear, depending upon the type of ore body and manner of collection.

Ordinarily pit water which is pumped from the bottom of an open iron ore pit is extremely turbid, has a bright red color, and may have a very high suspended solids content. The term "red-water" is frequently applied to this and similar wastes for obvious reasons. The occurrence of red-water resulting from natural drainage is also quite common in the streams near ore dumps.

The discharge of water or drainage containing large quantities of suspended material into surface waters may create unfavorable conditions for fish and wildlife. It also may affect the use of recreational areas, and stream shore property. If large amounts of suspended materials settle out in shallow areas, fish spawning beds may be covered and the penetration of light so reduced as to have an adverse effect on the growth of aquatic plant and animal life. The red color of the material in the water from mining areas emphasizes the presence of suspended material which tags the waters in the area.

Although periodic problems do arise as a result of red-water, control measures by the State regulatory agencies have proved to be effective in combating this problem.

TABLE 2

ACTIVE MINERAL OPERATIONS IN LAKE SUPERIOR BASIN

MINERAL COMMODITY	MICHIGAN	MINNESOTA	WISCONSIN
Iron Ore	9	27	
Copper	7		
Sand & Gravel	32	50	10
Iron & Steel		1	
Cement		1	
Clay		1	
Granite			2
Lime		1	1
Peat		4	
Stone	4	1	
Total	52	86	13

Reserve Mining Company's E.W. Davis taconite beneficiation plant at Silver Bay. Light areas are tailings being carried by a stream of water a few inches deep over the solid delta beach to the lake.

Active underground mines must continually be drained and previously abandoned shafts that are being reopened to development must be drained to allow full operation. This water is characteristically quite high in total dissolved solids such as chlorides and sulphates. Depending upon the nature of the underground strata, heavy metals such as copper, iron and zinc will be leached from the soil and be contained in this discharge water. As stated previously in this report, the discharge of heavy metals to the waters of Lake Superior is of concern due to the extreme sensitivity of aquatic life in the lake to these metals and due to the long-term buildup of these metals in the lake. A quantification of the past practices of draining mines is not available. Care should be exercised in the future to prevent the adverse effects on aquatic life in the receiving streams and also to Lake Superior from such drainage practices.

With the development of the taconite beneficiation process, vast new areas were opened up to the mining of taconite ore. As can be seen by Table 2, there are 36 mineral operations related to taconite processing in the basin including 15 concentrator plants. As shown in Appendix A, 14 of these utilize a closed system whereby their wastewater is allowed to settle in a lagoon and the waters recirculated for use. One of these concentrator plants, Reserve Mining Company, E. W. Davis Works, discharges its wastes directly to Lake Superior. The operations of this plant are discussed below.

Reserve Mining Company, E.W. Davis Works

In response to a request from the U. S. Army Corps of Engineers for comments on revalidation of the Corps' permit to Reserve Mining Company, several agencies of the U. S. Department of the Interior and other units of government reported continuing concern over the deposition of taconite tailings into Lake Superior. In response to these concerns an Interior study group was formed to investigate the effects of the taconite tailings on Lake Superior. Participating Department of the Interior agencies in the Taconite Study Group were Regional Coordinator, Office of the Secretary, Chairman; Bureau of Sport Fisheries and Wildlife; Bureau of Commercial Fisheries; Bureau of Mines; Geological Survey; and FWPCA. The U. S. Army Corps of Engineers, Minnesota Department of Conservation, Minnesota Pollution Control Agency, and Wisconsin Department of Natural Resources provided information to the study group and acted as observers in the group's activities.

Based on data gathered by the individual agencies comprising the Taconite Study Group (49, (50, 51, 52, 53) and other State reports (54), the following conclusions were reached:

1. Approximately 45 percent of the tailings waste discharged between 1956 and 1967 were deposited on the delta off shore from the plant. The remaining 55 percent, or approximately 95 million tons, traveled down the face of the delta into the lake. Tailings are are deposited on the lake bottom at least 10 miles off shore and 15 miles southwest of the plant.

2. Approximately 60,000 long tons of taconite waste are discharged daily from the plant. Fifty-four hundred long tons per day of the waste solids discharged to Lake Superior are less than 4 microns (1 micron equals 1/25,400th of an inch) in diameter. Particles of this diameter are capable of remaining suspended in water for a considerable time after discharge.

3. Current measurements in the vicinity of Silver Bay show that the prevailing current is to the southwest and of sufficient velocity to transport particles of 4 microns or less more than nine miles per day.

4. As the tailings meet Lake Superior water, "billowy gray clouds" of waste were visible leaving the density current, both at and under the water surface near the shore line. Extending off shore as far as 300 feet, these clouds were observed and photographed at at a depth of 35 feet. It appeared that "green water" was formed as gray tailings clouds diffused (became less concentrated) and more daylight penetrated among the particles.

5. The occurrence of tailings was evident in "green water" masses. In one instance the "green water" containing tailings was visibly present 18 miles southwest from the plant. "Green water" was observed along the Wisconsin shore line and did not contain tailings.

6. "Green water" containing tailings has a measurably increased turbidity and contains at least two to three times more suspended solids than does water that appears clear to the eye.

7. The State of Minnesota report (54) reported a reduction in the abundance of fish food organisms associated with the deposition of taconite tailings on the bottom of Lake Superior. It was estimated the reduction in fish food organisms could be expected to result in a reduction of the total annual fish catch (commercial and estimated sport fishing) of 5 percent or less for the area having tailings on the bottom.

8. The study area selected (nine miles by five miles) for sampling was too small to define the full extent of the area adversely affected. Analysis of data by the Study Group indicates that the area affected extended beyond the furthest sampling point.

9. High concentrations (10 percent and 25 percent) of taconite wastes caused mortalities among sac fry of rainbow trout in 4-day exposure. The wastes were not acutely toxic to fingerling sized coho salmon, rainbow trout, white suckers, black bullheads, blue gills, and yellow perch in 96-hour, static bioassays.

10. Chemical analysis projected to the probable daily discharge shows the following discharge, measured in pounds of certain parameters: copper, 4,100; nickel, 2,500; zinc, 2,500; lead, 6,100; chromium, 6,200; phosphorus, 51,500; and maganese, 629,000. Other elements in the discharge include silica, arsenic, and substantial quantities of iron. The chemical state of these metals was not assessed and it would be presumptious to say at this time what portion of the elements enter into solution.

11. A distinguishing characteristic of tailings discharged by the Reserve Mining Company is the presence of large quantities of the amphibole cummingtonite.

Data gathered by the FWPCA since April 1, 1969 has shown the presence of taconite tailings, (utilizing cummingtonite as a tracer) in the municipal water systems of Beaver Bay, Two Harbors, and Duluth, Minnesota. There has not been sufficient time to determine what effects, if any, the presence of the tailings has on the quality of the water supply or the users thereof.

A large portion of the south shore of Lake Superior is discolored by the sediment contained in discharges from streams draining the red clay area of northwestern Wisconsin.

SOIL EROSION

Tributary streams to Lake Superior discharge many tons of sediment annually to the lake. The sediment is derived from the natural processes of weathering and erosion of the rock and soil and by the activities of man in the basin, and is transported to the lake by the surface streams. The sediment yield is low when compared to the yields in other areas of the country. The estimated average annual yield of north shore streams tributary to Lake Superior is 10 tons per square mile. The low yield is due to the geology, soil types, vegetation and land uses in the basin.

An exception to the generally low sediment yields of Lake Superior tributaries are the streams along the south shore of the lake in the northwestern red clay area of Wisconsin. This area, containing 880,000 acres of land in Ashland, Bayfield, Douglas and Iron Counties is the most severely eroded and high sediment producing area in the basin. Limited data on the Bad River near Odanah indicates a long term average sediment yield of 278 tons per square mile.

Damage to valuable trout and recreational streams by sediment resulting from erosion of the red clay area has occurred. A large portion of the south shore of Lake Superior is discolored by the sediment contained in the discharges from these streams. This adversely affects the aquatic life in the lake by reducing the depth of light penetration and in settling on the lake bottom.

These problems have been recognized by interested Federal, State, and local agencies and are currently under investigation. The Red Clay Interagency Committee, comprised of Federal, State, and local representatives, issued a report in 1967 which identified the sources and causes of erosion and sedimentation and proposed an action plan for corrective measures. (28)

WASTES FROM WATERCRAFT

Commercial, recreational, and Federal vessels ply the waters of Lake Superior and are contributors of both untreated and inadequately treated wastes in the open lake and in the harbor areas. A study conducted by the Minnesota Water Pollution Control Commission (predecessor of the Minnesota Pollution Control Agency) in 1965 of the Port of Duluth concluded that raw and partially treated sewage and significant quantities of solid refuse and grease are discharged into Duluth harbor from both foreign and domestic vessels. They also concluded that facilities for collection and disposal of garbage, dunnage and similar refuse from foreign vessels exists at the port but are too small to serve all the shipping entering the port. As a result, domestic vessels and possibly a few foreign vessels dump this accumulated material overboard while out on Lake Superior and the other Great Lakes. The report recommended a vigorous program to control the disposal of all types of wastes from watercraft in the port. The report also recommended that the facilities for collecting the wastes be expanded and collection and disposal of solid refuse from all vessels both domestic and foreign be required.

Certain aspects of water pollution from watercraft have been documented in the report "Wastes from Watercraft" (48). This report principally considered pollution caused by the discharge of sewage, bilge and ballast waters, compartment washings, and litter. The report points out that the problem of pollution from watercraft is both widespread and varied; widespread because vessels and boats frequent all navigable water areas of the Nation and may trigger local pollution at any point along their path; varied because of the assortment of materials which may be spilled or discharged from vessels. A proposed program for the control of pollution from vessels set forth in the report covers four major waste categories: (1) sewage; (2) bilge and ballast waters; (3) litter and related solids; and (4) oil.

Item 10 of the Summary of Findings contained in the "Wastes from Watercraft" report states: "Federal laws and regulations prohibiting the dumping of litter, sewage, and wastewaters in specific locations are intended primarily to prevent impairment of navigation and the spread of communicable disease, animal diseases and plant pests. They are not now wholly effective in preventing water pollution." Bills have been introduced into the 91st Congress to control wastes from watercraft.

The States of Minnesota, Wisconsin and Michigan have laws dealing with the vessel pollution problem. Minnesota's law is applicable to pleasure craft registered in the State and permits the use of marine toilets equipped with a suitable treatment device approved by the Minnesota Pollution Control Agency. Registration is contingent upon certification that watercraft with marine toilets are equipped with an acceptable device. Types of devices accepted include macerator/chlorinators, holding tanks and incinerators. The State prohibits the discharge of other wastes and the abandonment of containers holding sewage or other wastes which may create a nuisance, health hazard, or water pollution. All waters of the State are included in the law.

The Wisconsin law applies to the inland waters of the State and, therefore, by definition does not apply to Lake Superior. On applicable waters the law requires the use of a holding tank on any boat which is equipped with a toilet that is not sealed. Chemical type toilets and incinerator type toilets may also be used provided the material cannot be disposed of into the water and that the toilet is of sufficient capacity to handle the passenger load. Wisconsin has prepared a similar bill for introduction into the current session of the Legislature that would apply to all waters within the jurisdiction of the State, which would include Lake Superior.

Michigan laws are specific in prohibiting garbage, oil, and refuse dumping from watercraft 25 feet or more in length. Also, the disposal of such wastes from smalller watercraft and the disposal of wastes from marine toilets could be prosecuted under the State's general health laws. The Michigan Water Resources Commission in January 1968 adopted a rule to control pollution from marine toilets on watercraft. The rule does not allow the macerator/chlorinator and does authorize the use of holding tanks or incinerators. The rule becomes effective January 1, 1970.

OIL POLLUTION

People throughout the world became aware of the destructive characteristics of oil spilled in the water environment, and the inadequacy of current measures for dealing with a major spill when the Torrey Canyon ran aground and broke up off the coast of England in March 1967. On May 26, 1967 the President of the United States directed the Secretaries of the Interior and Transportation to undertake a joint study to determine how the resources of the Nation could best be mobilized to counteract the pollutional effects of spills of oil and other hazardous materials in our waterways. One of the major needs disclosed by the study was for the development of a contingency plan to deal with emergencies involving Federal, State, and local agencies with due regard for each agency's statutory responsibility and capability. On June 7, 1968 the President directed the Secretaries of the Interior, Defense, and Transportation and the Director of the Office of Science and Technology to assume special responsibilities in strengthening our preparedness to act in the event of a major oil spill. The Secretary of the Interior was directed to assume primary responsibility for completing by July 31, 1968, a draft of a national multi-agency contingency plan for responding to major pollutional spills. The National Plan was approved by the President on November 13, 1968. The National Plan provides guidelines for the establishment of regional contingency plans. Regional Offices of the Federal Water Pollution Control Administration have developed framework regional contingency plans and are now expanding these plans in accordance with provisions of the National Plan.

Although oil pollution is presently not a significant problem in Lake Superior, steps have been taken to insure that a coordinated response of effort among Federal, State, and local agencies will occur in the event of a major spill. A Contingency Plan for Lake Superior has been developed in accordance with provisions of the National Plan by the Great Lakes Region of the FWPCA. The purpose of this Plan is to present guidelines to minimize the pollutional effects of a major spill of oil, or other hazardous materials in Lake Superior. The objectives of this plan are to develop effective systems for discovering and reporting the existence of a pollution incident, promptly instituting measures to restrict the further spread of the pollutant, application of techniques to clean up and dispose of the collected pollutants, and institution of action to recover cleanup costs and effect enforcement of existing statutes.

Major legal capabilities available to the United States to control oil pollution include the Federal Water Pollution Control Act as amended, the Oil Pollution Act of 1924 as amended, and the River and Harbor Act of 1899.

DISPOSAL OF DREDGED MATERIAL

Responsibility for the improvement and maintenance of the waterways of the United States in the interest of navigation has been delegated by acts of Congress to the U. S. Army Corps of Engineers. In carrying out this responsibility, the Corps dredges approximately 10 million cubic yards annually from Great Lakes harbors and in calendar year 1968 dredged about one million cubic yards from harbors on Lake Superior. Two-thirds of this total represented deepening of a portion of Duluth - Superior harbor. The normal annual maintenance dredging program in Lake Superior is around 300,000 cubic yards. This is conducted in some of the commercial harbors shown in Figure 4, and in small boat harbors maintained by the U. S. Army Corps of Engineers.

The Corps has followed the practice of disposing of most dredged material in authorized dumping grounds in the open waters of the Great Lakes. Dredging of areas outside the authorized navigation channels, in the vicinity of the docks, loading facilities, marinas, etc., is accomplished by private interests under permit from the Corps. The dredged material ranges from clean lake sand to river sediments which may be seriously polluted by industrial and municipal wastes. The dredgings may contain oil and grease, dissolved solids, nutrients and toxic materials.

Attention has been directed to the problem of the disposal of polluted dredged materials by the Great Lakes Region, FWPCA. The FWPCA is concerned about the long-term cumulative effect on incremental additions of these pollutants to the Great Lakes.

During the past two years the Corps of Engineers and Federal Water Pollution Control Administration have been carrying out a joint study of the water quality problems associated with dredging. A report of findings is now available for perusal at the Corps District Offices and various other locations. In the meanwhile, the Corps has provided alternate disposal of materials dredged from several of the most polluted harbors on the Great Lakes. No harbors in the Lake Superior are included in this pilot program.

Results of sediment analysis by the FWPCA in Lake Superior harbors indicate the presence of polluted materials in certain areas of Duluth - Superior, and Ashland harbors. The analysis showed the sediment contained unacceptable levels of oil and grease, phosphorus and chemical oxygen demand. The FWPCA will continue to assist the Corps of Engineers by classifying harbor sediments as to their suitability for open lake disposal. The Corps should continue their program of developing alternate disposal areas for polluted sediments.

PESTICIDES

In general, the problems associated with pesticides are problems involving biological magnification of the pesticides in food chains or human food. Furthermore, there is not enough information at this time to understand or even estimate the importance of a given concentration of an insecticide such as DDT in the water or the bottom sediments. Based on these reasons, the concentration of insecticides in fish tissues is one of the best ways of monitoring the contamination of pesticides in a lake.

The word insecticide will be used henceforth in this report because no information is available to suggest that any significant amount of pesticides, other than insecticides has been detected in Lake Superior.

Information necessary to determine the kinds and quantities of insecticides used in the Lake Superior basin was not available. Some data on the concentration in fish were found. Concentrations of insecticides are lower in the fishes of Lake Superior than in the fishes of any other of the Great Lakes according to data furnished by the Bureau of Commercial Fisheries. Compared to similar species from Lake Michigan these fishes have from four to seven times less DDT and two to seven times less dieldrin. The absence of a Dutch Elm disease problem, very little industry, and little farming, probably account for the low values reported. The persistent insecticides, such as the chlorinated hydrocarbons must be kept from entering Lake Superior. If they do accumulate there, damage will be apparent for a long period of time due to the slow flow-through time of the lake. Since the harvested organisms, fish, comprise a larger percentage of the lake's biomass than in the other Great Lakes, less insecticide need be added before unacceptable amounts will occur in the important fishes. This is especially important since the most important species, lake trout, it a long-lived, predatory species and therefore is an efficient accumulator of insecticides. The low organic matter content of the water and sediment will also favor accumulation of insecticides in fishes.

Studies made by the Bureau of Commercial Fisheries indicate that dieldrin presently poses no problem in Lake Superior. Dieldrin levels are little above usual detection limits. One important reason may be that little or no corn is grown in the basin and so the commonly used insecticide for corn, aldrin (that converts to dieldrin) in not extensively used.

DDT (including DDT, DDD and DDE) is also much lower in Lake Superior than in the other Great Lakes but in several species, chubs, lake herring, and larger lake trout, the concentrations are approaching 1.0 microgram per gram, or above, of wet weight of fish.

As part of the Lake Michigan enforcement conference, a Technical Committee on Pesticides was established to evaluate the pesticide problem in Lake Michigan and to recommend to the conferees a program of monitoring and control. The Committee determined that controls should be instituted to insure that the concentration of various insecticides did not increase above existing levels in Lake Superior as there are no indications of problems in Lake Superior fish resulting from these levels. The recommended levels by that Committee therefore were that the concentration of DDT in fish not exceed 1.0 microgram per gram; DDD not exceed 0.5 microgram per gram; dieldrin not exceed 0.1 microgram per gram and all other chlorinated hydrocarbon insecticides, singly or combined, should not exceed 0.1 micorgram per gram. Limits apply to both muscle and whole body and are expressed on the basis of wet weight of tissue (56).

The Food and Drug Administration officially informed that same Committee that concentrations of 0.3 parts per million of several insecticides, including dieldrin, in the edible portion of a fish would be considered sufficient to warrant legal actions.

Indications are that uses of pesticides in the Lake Superior basin are at relatively low levels. Even with a low usage, insecticides are being concentrated in fish and underline the importance of caution and surveillance to avoid a future problem.

Scale: 50 0 50 100 miles

MAJOR INTERSTATE WATERS

LEGEND:
Interstate waters

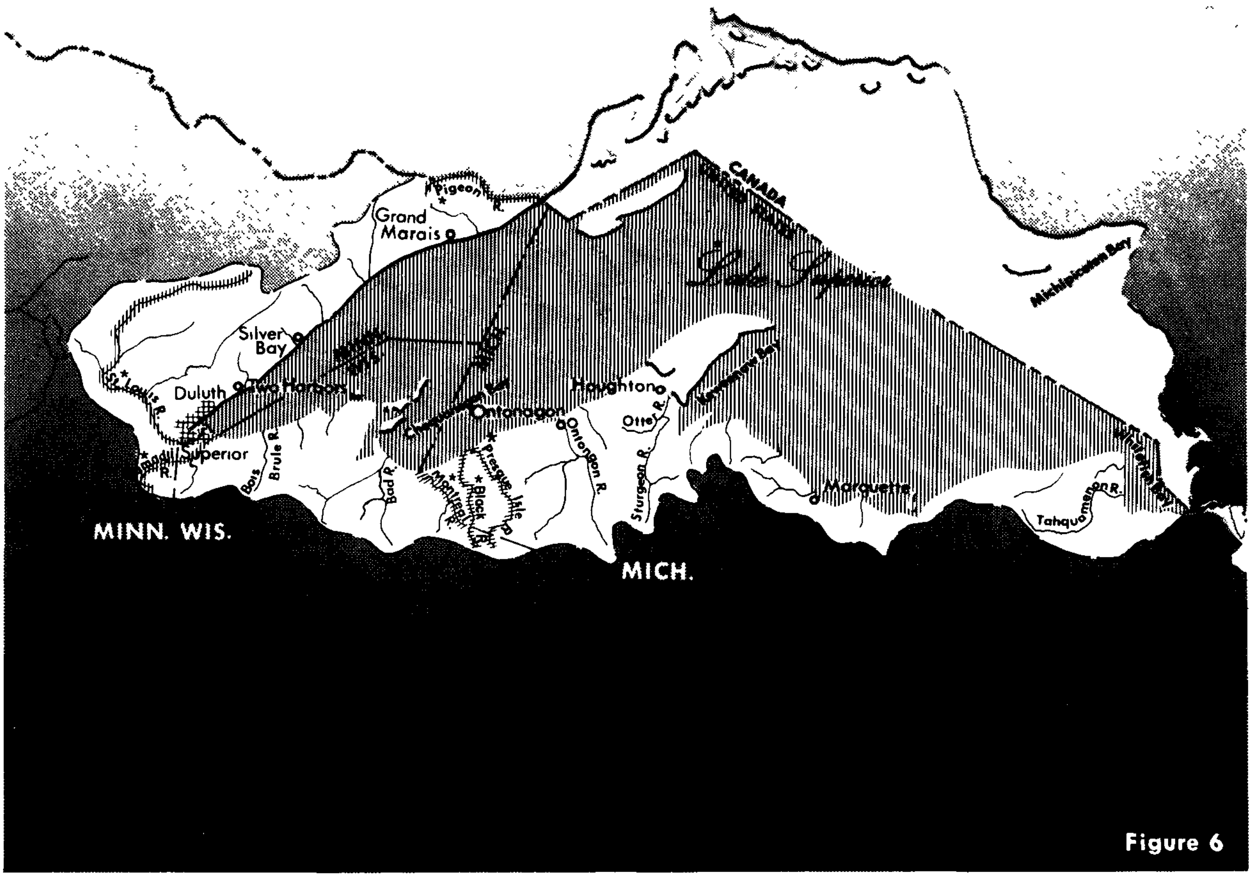


Figure 6

IV. POLLUTION CONTROL ACTIONS AND PROPOSALS

The necessary pollution control actions needed to prevent, control, and abate water pollution depend upon close cooperation with Federal, State, and local units of government. By working together and applying their respective capabilities the needed pollution control actions come into fruition. While the Federal role in water pollution control has become a very significant one, the basic Federal law recognizes the primary right and responsibility of the State agencies for the necessary pollution control actions in any State. Some of the actions taken by the State to abate pollution have been discussed in previous sections of this report. This section presents the Federal Water Pollution Control Administration program plus additional aspects of the State programs.

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION ACTIVITIES

The responsibilities of the Federal Water Pollution Control Administration were set forth by the Congress in the Federal Water Pollution Control Act passed in 1956 and subsequently amended in 1961, 1965 and 1966. The FWPCA, through the Great Lakes Regional Office, is pursuing a vigorous water pollution control program in the Great Lakes basin through close cooperation with the States and local agencies. The following is a brief description of some of the activities being taken in carrying out the agency's responsibilities. Particular reference is made to those activities relevant to Lake Superior and its drainage basin.

Water Quality Standards

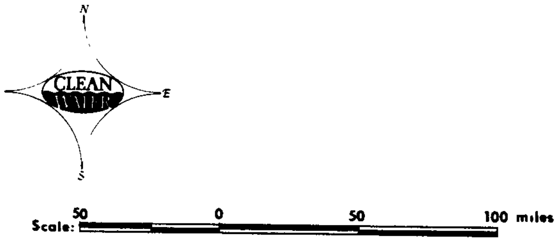
The Federal Water Pollution Control Act as amended by the Water Quality Act of 1965 authorizes the State and the Federal Governments to establish water quality standards for interstate waters. The water quality standards submitted by the States are subject to review by the Department of the Interior and if found consistent with the intent of the Act, are approved also as Federal standards by the Secretary of the Interior. Water quality standards include water use classifications, criteria necessary to support these uses and a plan for implementation and enforcement.

As part of the adoption procedure, public hearings are held to elicit citizens' views on proposed standards and to ascertain popular wishes as to the use of specific areas of lakes and streams. This action precedes formal State adoption of the standards.

Water quality standards have been adopted by the Lake Superior basin States under provisions of the Water Quality Act of 1965 and have been approved by the Secretary of the Interior. Michigan's temperature criteria as well as portions of Minnesota's standards have been excepted from approval. Figure 6 shows the major interstate waters of the Lake Superior basin, and Appendix B lists the criteria adopted by the States of Michigan, Minnesota and Wisconsin for the open waters of Lake Superior. A copy of the complete set of each State's standards is available from the appropriate State agency.

In addition to interstate standards, Michigan, Minnesota and Wisconsin have also adopted statewide intrastate water quality standards.

Lake Superior and many of the tributary waters have long been noted for excellent water quality and the resultant beneficial uses. Commitments to the preservation of existing high quality waters will play an important role in the preservation of the waters in the Lake Superior basin. The Lake Superior states have adopted policy statements establishing their intent to protect the present high quality of the interstate waters.



CONSTRUCTION GRANT PROJECTS

LEGEND:
● Completed Projects

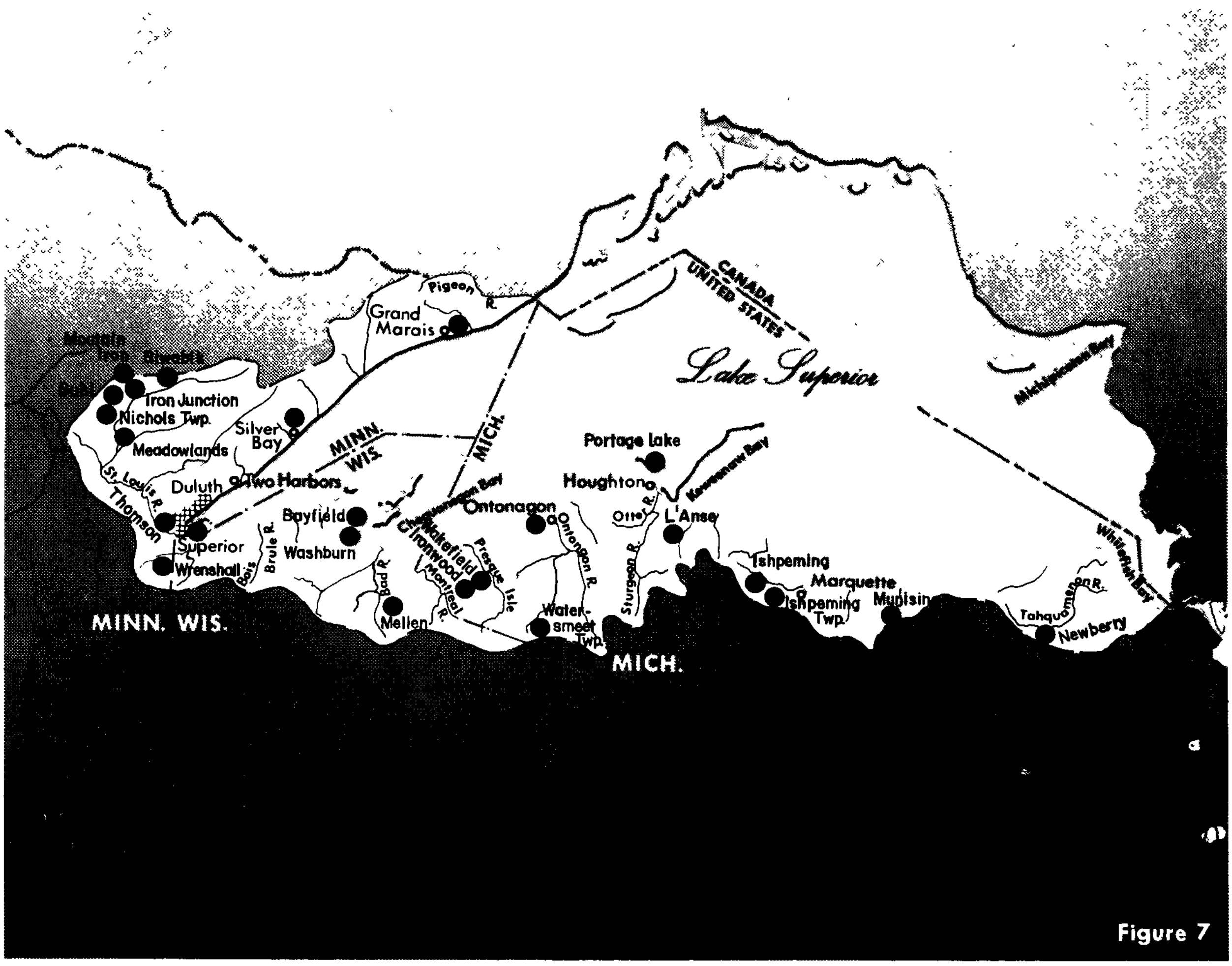


Figure 7

Great Lakes - Illinois River Basins Project

The Great Lakes - Illinois River Basins (GLIRB) Project was established in 1960 as a special task force in what is now the Federal Water Pollution Control Administration. With headquarters in Chicago, the project was charged with developing comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof in the Great Lakes, the Illinois River, and their tributaries.

The major objectives of the comprehensive program developed by the GLIRB Project in cooperation with other Federal agencies, with State water pollution control agencies and interstate agencies, and with the municipalities and industries involved were:

- Identification of the causes of water pollution and the effects of such pollution on the quality of water resources and on beneficial uses.
- The development of agreements on the desired beneficial uses and the water quality rerequired to accommodate those uses.
- The development of water quality control measures to achieve the desired objectives, including the establishment of a timetable for their accomplishment.
- Provision of the mechanism for carrying out program objectives, including continuing surveillance for the purpose of updating the programs to accommodate changing technology and changing water quality needs.

Through reorganization of the FWPCA, the fulfilling of the major objectives of GLIRB ceased being the mission of a specific project. The objectives are being fulfilled under the total FWPCA program.

The established timetable of the GLIRB Project was such that only limited emphasis was placed upon the Lake Superior basin prior to the reorganization. The major accomplishment of the project with respect to the Lake Superior basin was the lake current study which is described in another section.

Construction Grants

With the enactment of the Federal Water Pollution Control Act of 1956, the Federal Government established a Federal sewage treatment works construction grants program to help finance the building of municipal sewage treatment plants. The Federal Government recognized that wastes discharged from municipal sewers are one of the major causes of water pollution. The growth of population and industry, coupled with the backlog of needed treatment works, resulted in a situation that called for increased treatment plant construction at the local level.

Since the 1956 Act, a total of 26 Federal grants have been made to communities in the Lake Superior basin to help build required sewage treatment facilities. Figure 7 locates these grants. Grant funds involved in these projects have totaled over $2. 9 million in support of total project expenditures in excess of $8. 8 million. All the Federally-assisted grant projects have been completed and placed in operation.

The Construction Grants Section of the Federal Act has been amended three times since its initial 1956 passage. The trend of financial assistance has been upward with each amendment. Today's legislation enables municipalities to qualify for consideration for a basic Federal grant of 30 percent of the eligible cose of a project. A grant of 40 percent can be made in those States which agree to match the basic 30 percent Federal grant. The Federal grant may be increased to 50 percent if the State agrees to pay at least 25 percent of the project cost and enforceable water quality standards have been established for the waters into which the project discharges. A grant may be increased by 10 percent, to 33, 44 or 55 percent, as appropriate, if the project is certified by a metropolitan or regional planning agency as conforming with a comprehensive metropolitan area plan.

All three States in the Lake Superior basin either have legislation to qualify their municipalities for consideration for the higher grant percentages or have introduced enabling legislation into their State Legislatures. In November 1968, Michigan electors, by a three to one margin, authorized the sale of $335 million worth of bonds for purposes of assisting communities in improving existing and constructing new waste treatment plants; $50 million of this total bond program is to be used for sewer construction assistance for communities without sewers which are contributing to an existing pollution problem and have low property valuation. A draft copy of a State law to implement the State grant bond issue which will spell out the details of administrating and funding specific projects has been completed. Passage of this legislation is expected in the near future.

Wisconsin provides financial assistance of not less than 25 percent or more than 30 percent of the cose of construction of waste treatment facilities. Wisconsin statutes authorize a sum sufficient appropriation up to $6 million per year.

In addition to this program Governor Knowles of Wisconsin has proposed an Outdoor Resources Action Plan - 200. This plan would establish a $200 million bonding program, of which $144 million would be used for construction of sewage treatment facilities. The plan was approved by the citizens of Wisconsin in an advisory referendum. Implementation details are currently in progress.

In Minnesota, a $20 million statewide bonding program to aid local communities with 30 percent of construction costs has been proposed by Governor LeVander. The State fund would be a grant to municipalities unless or until the Federal Government appropriates sufficient money to fully fund the presently authorized Federal program. At that time Federal funds going to a municipality would reimburse the State. A bill to implement this $20 million bonding program has been introduced into the 1969 session of the Minnesota State Legislature. A second bill has been introduced into the Legislature that would provide for a $6 million per year appropriation for State aid to municipalities. Under this proposal the local communities would be eligible to receive full financial benefit from the Federal program.

Program Grants

Section 7 of the Water Pollution Control Act authorizes an appropriation of $10 million annually for Fiscal Years 1968-71 for grants to State and interstate agencies to assist them in meeting the costs of establishing and maintaining adequate pollution control programs. Each State is allotted $12,000, and the remainder of the funds are distributed on the basis of population, financial need, and the extent of the water pollution problems facing the State. Since program grants were first authorized in Fiscal Year 1957, a total of $4,433,930 in Federal funds has been allocated to the Lake Superior States for their pollution control programs. By June 1969, Michigan will have received approximately $2,158,273; Minnesota, $1,013,585; and Wisconsin, $1,262,072. During the current fiscal year Michigan is allocated $338,500; Minnesota, $148,000; and Wisconsin, $185,500.

Research, Development and Demonstration Grants

The Research, Development and Demonstration Program is mission oriented, employing the use of grants and contracts for investigations and demonstrations relating to the solution of problems confronting the attainment or retention of clean water. The program deals with the full range of water quality problems -- from pollution definition and control to water resources management and planning.

The Federal Water Pollution Control Act specifically authorizes projects concerned with (a) storm and combined sewers; (b) advanced waste treatment and joint treatment systems for municipal and industrial wastes; and (c) methods for prevention of pollution by industry, including treatment of industrial wastes.

In addition, research, training, demonstration, and research fellowship grants are available for the intended purpose to encourage and assist appropriate agencies, institutions, and individuals in the conduct of studies and training which will achieve clean water.

The information being gathered through the above programs will have a wide range of applicability and therefore will be of use in pollution control actions in the Lake Superior basin.

An intramural research program of the FWPCA is carried out in eight ongoing laboratories located across the country. Within the Great Lakes basin, the Administration has established the National Water Quality Laboratory at Duluth, Minnesota. The mission of this laboratory is to determine permissible limits of water quality for any water use and the impairment that can be expected if these limits are exceeded.

In addition to the above, the Federal Water Pollution Control Act specifically authorizes the Federal Water Pollution Control Administration to conduct research and technical development work, and make studies with respect to the quality of the waters of the Great Lakes.

Federal Installations

The Federal Government has not overlooked the pollution hazards created by its own activities. By Executive Order 11288, President Johnson directed the heads of the departments, agencies, and establishments of the Executive Branch of the Government to provide leadership in the nationwide effort to improve water quality.

Federal installations in the Lake Superior basin have initiated pollution abatement programs in accordance with the Order. Excluding those facilities that discharge to municipal systems there are approximately 124 installations within the basin. These are distributed as follows: Michigan 73, Minnesota 37, and Wisconsin 14. The size of the installations vary from camp and picnic grounds at Federal parks to major military installations such as Air Force Bases. These installations discharge waste after varying degrees of treatment to ground or surface waters of the basin. Some of the smaller installations provide no treatment at present. Tabulated in Appendix A of this report is an inventory of these installations showing the waste treatment provided and the status of pollution abatement.

The more significant Federal vessels which frequent the waters and the harbors of Lake Superior are also listed in the Appendix. The U.S. Coast Guard, Navy, and Army Corps of Engineers are all acutely aware of the problems associated with vessel pollution. They are actively pursuing abatement and research and development programs in an effort to obtain waste treatment devices suitable for shipboard use.

All Corps of Engineers vessels and floating plants (tugs, dredges, derricks, etc.) operating in Lake Superior have been fitted with macerator/chlorinator units. Efforts are being made to insure that these devices will be replaced with upgraded disposal units such as holding tanks at the earliest possible date.

Federal water resources projects and facilities and operations supported by Federal loans, grants, or contracts are also included in Executive Order 11288. Water resource projects must be designed, constructed, and operated in a manner which will reduce pollution from such activities to the lowest practicable level.

The head of each Federal department, agency and establishment has been directed to conduct a review of the loan, grant, and contract practices of his own organization to determine to what extent water pollution control requirements set forth in the Order should be adhered to by borrowers, grantees, or contractors. This review has resulted in practices designed to reduce water pollution in various programs. Urban renewal projects now require the construction of separate storm and sanitary systems rather than combined sewers. The nationwide highway construction program financed with Federal funds and administered by the Bureau of Public Roads, is now being conducted in accordance with practices aimed at preventing water pollution, either during construction or in operation and maintenance. The various agencies have consulted with the Federal Water Pollution Control Administration in an effort to insure maximum consideration of water quality in their activities.

This Order represents a major step forward in the battle to preserve and enhance quality of our Nation's waters. It has sparked a keen awareness on the part of Government officials of the need for corrective action and vigorous abatement programs. The effort being shown by these various Federal agencies provides leadership in the nationwide quality improvement program.

Technical Programs

The Regional Technical Program provides technical assistance in solving pollution problems to Federal, State, and local agencies, and to industry. Current technical assistance projects affecting Lake Superior include:

1. Participation with the Corps of Engineers in a joint study of the water pollution problems associated with dredging. This includes collection and analysis of samples of bottom sediments from Lake Superior harbors.

2. Participation in the International Joint Commission study of the feasibility of further regulation of the levels of the Great Lakes, including Lake Superior. The object of such further regulation would be to reduce damages resulting from excessively high or low lake levels.

3. Participation in the Department of the Interior study concerning the effects on water quality by the discharge of taconite tailings.

The Technical Program also has responsibility for surveillance of water quality throughout the Region for purposes of water quality standards compliance, basic planning, and long-term water quality trends. A Regionwide surveillance plan is being developed in cooperation with the State water pollution control agencies which will include the streams of the basin and the lake itself.

Basin planning for water pollution control and water quality management is also a responsibility of Technical Programs. This includes inhouse planning studies, participation in the Great Lakes Basin Commission Type I, or framework study, and the administration of the planning grants program authorized by the Federal Water Pollution Control Act, as amended.

Public Information

The Public Information Program of the Federal Water Pollution Control Administration is designed to present facts about water pollution control to the news media, interested groups and organizations, and the public, generally. The program serves the public's right to know what FWPCA is doing and trying to accomplish. It also serves those who need particular information in order to participate effectively in water pollution control programs.

STATE WATER POLLUTION CONTROL PROGRAMS

Michigan, Minnesota and Wisconsin each have water pollution control programs which provide for surveillance and enforcement, surveys and special studies and long range water quality management planning activities. Their programs also include review of municipal and industrial waste treatment plant plans and specifications for conformity with Federal, State and local pollution control regulations, review of treatment plant maintenance and operation procedures and plant efficiencies and technical assistance in waste treatment problems to both municipalities and industries. Each State has a program for the certification of waste treatment plant operators and a commensurate program for the training of operators to meet certification requirements, and each State conducts a public information program for the dissemination of water pollution control news to the general public as well as special information to those professionally interested.

Michigan

The Michigan Water Resources Commission planned in Fiscal Year 1969 to continue to emphasize the enforcement of pollution abatement with subsequent water quality improvement and prevention of water quality degradation. The Commission is charged with control over the pollution of any waters of the State and the Great Lakes and to protect and conserve the water resources of the State. Michigan's plans call for expanded action in many elements of water pollution control. The program of establishing intrastate water quality standards is to be completed in Fiscal Year 1969, and with the passage of a $335 million bond issue, the State is now able to provide 25 percent grants to municipalities for the construction of waste treatment facilities.

The State's water quality surveillance program is accelerating with plans for automated sampling analysis and data processing. Commission rule concerning watercraft pollution will go into effect January 1, 1970, and new statutory requirements for certifying industrial and commercial waste treatment operators will require a new agency program for training and certification of those operators. The Michigan Water Resources Commission chairs an interdepartmental committee on water and related land use planning.

Michigan's current fiscal year water pollution control budget is $995,000 and approximately 74 man-years are assigned to that effort. Increases are proposed in Fiscal Year 1970 which will contribute further to the Commission's ability to assure protection of the State's waters.

In addition to the above, the Michigan Department of Public Health through its Waste Water Control Section, expends $130,000 and approximately 12 man years on pollution control.

Minnesota

The Minnesota Pollution Control Agency has planned a program of expansion and special contracts in Fiscal Year 1969. The Agency has overall responsibility, at the State level, for managing the quality of the waters of Minnesota by controlling the sources of pollution which may adversely affect water quality. Minnesota's program includes several specific activities to improve the water pollution control effort. Effluent standards have been adopted for all waters of the State and more waters are to be monitored on a more frequent basis throughout the State. A systematic program of adopting water use classifications and establishing water quality standards is underway for intrastate waters. The State's criteria for determining priorities for Federal grants for the construction of municipal waste facilities enables better distribution of funds to areas where pollution problems are greatest. The important aspect of efficient plant operation will be improved with the planned use of regional operator training schools, although certification is not mandatory in Minnesota. A bill has been introduced into the current session of the legislature that would require mandatory certification. The Agency's plans to expand its staff and activity in all elements of the water pollution control program is a significant expression of the State's concern.

Currently Minnesota's annual water pollution control budget is $717,476 and approximately 46 man-years are assigned to that effort. The Fiscal Year 1969 budget and the proposed Fiscal Year 1970 budget are significantly higher than previous years, and an increase over present levels of about 12 man-years is projected for Fiscal Year 1970.

Wisconsin

The Wisconsin Department of Natural Resources serves as the central unit of State government to protect, maintain and improve the quality and management of the waters of the State and to organize a comprehensive program for that purpose. Wisconsin's Fiscal Year 1969 program includes many activities which are an expansion of the State's effort. Intrastate water quality standards have been adopted and a system of effluent charges for the control of water pollution is being studied. Plans call for at least annual inspection of all municipal, industrial and State operated sewage treatment plants. The mandatory certification of waste treatment plant operators recently went into effect; and in keeping with that program, the operator training program is being significantly upgraded and expanded. As a step in a program of flood plain and shoreland management, the State is currently overseeing local administration of ordinances and development of flood plain information. The water resources planning activity is also scheduled for expansion to provide plans for each of the State's regions.

In Fiscal Year 1969 Wisconsin's water pollution control budget is $1,879,800 and 68 man-years are assigned to that effort. Projections for Fiscal Year 1970 call for increases which will further expand the State's water pollution control effort.

V. WATER QUALITY CRITERIA

The quality of water in Lake Superior surpasses that of virtually all other major lakes of the United States. The extremely low dissolved and suspended solids, the very cold temperatures, the extreme clarity, and the high oxygen concentration of the water coupled with the size of the lake, makes a unique natural resource that has no equal in the world.

Most of the lake is uniform in nature, including such indices that normally vary seasonally; as for example, temperature and oxygen. For the most part, the dissolved materials present in the water are those that are contributed by natural causes. Present discharges from tributary streams and man-made outfalls are few in number and mostly small in size, therefore as a general rule only limited areas are adversely affected by them. Except for minimal pesticide contamination, the lake is essentially free of synthetic organic chemicals that cause so many problems in other waters. This existing exceptionally high water quality must be preserved.

Water quality standards have been adopted for Lake Superior by the Lake Superior States and approved by the Department of the Interior. The States assigned their highest use categories to Lake Superior (i. e., public water supply, whole body contact recreation, and cold water fishery). The water quality criteria adopted to protect these designated uses were established using the best available knowledge at that time. Hence, the water quality standards for Lake Superior are the most restrictive adopted by the States of Michigan, Minnesota, and Wisconsin, and are among the most stringent standards nationally.

Additional data concerning water quality criteria specific to Lake Superior waters are now available as a result of recently completed research at the FWPCA's National Water Quality Laboratory at Duluth, Minnesota. The National Technical Advisory Committee on Water Quality Criteria (46) issued a report on April 1, 1968 that provides additional information on water quality criteria. These data can be used as a guide to amend the existing water quality standards on Lake Superior. In accordance with the provisions of the Water Quality Act of 1965, it was anticipated that after the initial setting of standards periodic review and revision would be required to take into account changing technology and advances in knowledge of water quality requirements developed through research.

While data on the existing quality of Lake Superior is not abundant, there have been continuous monitoring stations operated at the Duluth water intake and on the St. Mary's River by the FWPCA's water quality monitoring system. From these activities a reasonable picture is available as to the elemental composition of the water for many of the major constituents.

On the basis of the above, water quality criteria can be developed on the open waters of Lake Superior to reflect more appropriately the uniqueness of the lake. These criteria are presented in Table 3. The rationale for these criteria are presented in Appendix C.

TABLE 3

PROPOSED WATER QUALITY CRITERIA FOR THE OPEN WATERS OF LAKE SUPERIOR[1]

(Mg/1 unless otherwise specified)

Parameter	90% Value[2]	Maximum Value[3]
Dissolved Oxygen	>10.0	9.0
Turbidity	0.5 JTU	5.0 JTU
Color – Wavelength A[4]	0.01 absorbance units	0.05 absorbance units
Wavelength B[5]	0.05 absorbance units	0.25 absorbance units
Total Dissolved Solids	65.0	–
Total Coliform Bacteria	10 per 100 ml	1,000 per 100 ml
Fecal Coliform Bacteria	10 per 100 ml	200 per 100 ml
Detergents (MBAS)	0.1	0.4
Phenol	–	0.001
Ammonia Nitrogen	0.05	0.1
Phosphorus	–	0.01
Iron	0.03	0.1
Cadmium	0.002	0.005
Chromium	0.02	0.05
Copper	0.008	0.012
Lead	0.03	0.05
Nickel	0.015	0.03
Zinc	0.01	0.015
Cyanide	0.002	0.004
Hydrogen Sulfide (as total sulfide measured at bottom-water interface)	0.002	0.02
Taste and Odor – Chloroform Extracts	0.03	0.05
Threshold Odor	1.0	3.0
	Mean Value	**Maximum Value**
Temperature (Surface in top meter)		
January, February, March	2°C	5°C
April, May, June	10°C	18°C
July, August, September	18°C	21°C
October, November, December	8°C	15°C
Depths greater than 120 feet: never over 6°C		

pH – Should remain between 6.8 to 8.5 units

Radioactivity – Recommendations for proposed radiological criteria will be deferred pending development of model criteria by Federal Water Pollution Control Administration, Atomic Energy Commission, and U.S. Public Health Service.

General: For nonpersistent wastes discharged directly to Lake Superior, and for other individual chemicals, the 90% value is 1/20 of the 96-hour TL_m value and the maximum value is 1/10 of the 96-hour TL_m value. For persistent complex wastes and other individual materials, the 90% value is 1/100 of the 96-hour TL_m value and the maximum value is 1/20 of the 96-hour TL_m value.

[1] Zones of tributary influence and mixing zones should not exceed a linear distance equal in feet to the cube root of the discharge in mgd x 500. In these zones other standards may be applicable but in no case can the 96-hour TL_m value be exceeded.

[2] 90% of the values obtained at one location must not exceed this value. (For dissolved-oxygen the stated value is a minimum.)

[3] Maximum value not to be exceeded. (For dissolved-oxygen the stated value is a minimum.)

[4] Wavelength A: 3500-8000 angstroms, 10 centimeters light path.

[5] Wavelength B: 2400-3500 angstroms, 10 centimeters light path.

The solitude, peace and quiet beauty found in many areas around Lake Superior refreshes the spirit of those who seek it.

VI. SUMMARY AND CONCLUSIONS

1. Lake Superior is a priceless natural heritage which the present generation holds in trust for posterity, with an obligation to pass it on in the best possible condition.

2. The esthetic value of Lake Superior is of major importance. The lake's deep blue appearance is a significant tourist attraction.

3. Because of the low mineral content of Lake Superior's waters, increases in the range of 2 to 50 parts per billion of heavy metals such as copper, chromium, zinc, and cadmium will have lasting deleterious effects upon the lake.

4. The extreme clarity and cold temperature of the waters of Lake Superior are a necessity to support its present ecology. A reduction in light penetration will significantly alter the types of life therein. The clarity of the lake is extremely susceptible to being reduced by pollutants.

5. The portion of Lake Superior shallow enough to provide suitable fish spawning areas is limited to a small band around the shoreline. This area is most susceptible to the influence of natural and man-made sediments. Deposition on the bottom of fine particles discharged to Lake Superior is a threat to the inshore food producing area and to the incubation of important fish species.

6. Water quality criteria can be established to protect the esthetic value, recreational uses and the unique aquatic life of the lake and yet such that reasonable allowance is made for future municipal and industrial expansion.

7. Lake Superior is an oligotrophic lake. Nutrient values in some area of the lake have been reported at levels approaching those commonly associated with nuisance algal growths. However, other factors, such as temperature, are limiting.

8. Outflow from Lake Superior passes through Lakes Huron, Erie and Ontario. Dissolved chemicals in this outflow contribute to the levels found in these downstream lakes.

9. The discharge of taconite tailings to Lake Superior from the Reserve Mining Company, E.W. Davis Works, has a deleterious effect on the ecology of a portion of the lake by reducing organisms necessary to support fish life.

10. The quantitiy of oxygen normally dissolved in water is one of the more important ingredients necessary for a healthy balanced aquatic life. The discharge of treated and untreated municipal and industrial wastes with high concentrations of biochemical oxygen demand has caused oxygen depletion in the St. Louis River, Duluth - Superior harbor, and Montreal River.

11. Watercraft plying the waters of Lake Superior are contributors of both untreated and inadequately treated wastes in local harbors and in the open lake, and intensify local pollution problems.

12. Oil discharges from industrial plants, commercial ships and careless loading and unloading of cargoes despoil beaches and other recreational areas, coat and hulls of boats and are deleterious to fish and aquatic life.

13. Evidence of bacterial pollution has been reported in the St. Louis River, and Duluth Harbor area in Minnesota; and Superior Harbor area, Ashland inshore area and reaches of the Montreal River in Wisconsin.

14. The maintenance of waterways for commercial and recreational use is a necessary activity. The deposition of polluted dredgings contributes to the degradation in quality of Lake Superior.

15. Adverse effects upon water quality and water uses of streams in the red clay area of northwestern Wisconsin is occurring as a result of land runoff from poor land management practices. The sediment contained in the discharges from streams in this area has an adverse effect on Lake Superior.

16. A persistent pollutant entering directly into the waters of Lake Superior or dissolved in the water that feeds the lake mixes with and becomes an integral part of a significent portion of the lake water.

17. Discharges of wastes originating in Michigan and Wisconsin cause pollution of the interstate Montreal River. Discharges of wastes originating in Minnesota and Wisconsin cause pollution in the interstate St. Louis River and Duluth - Superior harbor. These discharges endanger the health or welfare of persons in States other than those in which such discharges originate. This pollution is subject to abatement under the provisions of the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et. seq.).

We conserve so that our own and future generations will be able to enjoy...

Congressman Wayne N. Aspinall
Colorado

VII. RECOMMENDATIONS

It is recommended that:

1. Water quality criteria as shown in Table 3 (page 44) be included as part of the interstate water quality standards on Lake Superior to reflect more appropriately the uniqueness of the lake.

2. The FWPCA and the States keep the discharge of taconite tailings to Lake Superior from the Reserve Mining Company, E.W. Davis Works, under continuing surveillance and report to the conferees at six month intervals on any findings that interstate pollution is occurring or is likely to occur, and the State of Minnesota is urged to take such regulatory actions as necessary to control the intrastate pollution resulting from these discharges, if any.

3. The FWPCA and the States adjust or modify water quality surveillance plants for the Lake Superior basin to insure that plans are sufficiently sensitive to monitor changes in water quality. The FWPCA and States are requested to report to the conferees within six months concerning their program.

4. Secondary biological waste treatment be provided by all municipalities in the Lake Superior basin. This action is to be accomplished by Janury 1973 or earlier if required by Federal-State water quality standards.

5. Continuous disinfection be provided throughout the year for all municipal waste treatment plant effluents. This action should be accomplished as soon as possible and not later than May 1970.

6. Continuous disinfection be provided for industrial effluents containing pathogenic organisms which indicate the presence of such pathogens. This action should be accomplished as soon as possible and not later than May 1970.

7. Waste treatment be provided by municipalities to achieve at least 80 percent reduction of total phosphorus from each State. This action is to be accomplished by January 1973, or earlier if required by Federal-State water quality standards.

8. Industries not connected to municipal sewer systems provide treatment equivalent to that of municipalities so as not to cause the degradation of Lake Superior water quality. This action is to be accomplished by January 1973 or earlier if required by Federal-State water quality standards.

9. Each State water pollution control agency make necessary corrections to the list in Appendix A of municipal and industrial waste discharges to the Lake Superior basin. In addition, information should be provided on each source to indicate whether it discharges pollutants, including nutrients, that have a deleterious effect on Lake Superior water quality. Detailed action plans for treatment of all wastes having deleterious effects should be developed, where not already completed. Such plans shall identify the principal characteristics of the waste material now being discharged, the quantities, the proposed program for construction or modification of remedial facilities and a timetable for accomplishment, giving target dates in detail. This list shall be presented to the conferees within six months.

10. Unified collection systems serving contiguous urban areas be encouraged.

11. Each of the State's water pollution control agencies accelerate programs to provide for the maximum use of area-wide sewage facilities to discourage the proliferation of small treatment plants in contiguous urbanized areas and foster the replacement of septic tanks with adequate collection and treatment.

12. Each State water pollution control agency list the municipalities or communities having combined sewers. The listing should include a proposed plan for minimizing bypassing so as to utilize to the fullest extent possible the capacity of interceptor sewers for conveying combined flow to treatment facilities. Construction of separate sewers or other remedial action to prevent pollution from this source is to be completed by October 1977.

13. Existing combined sewers be separated in coordination with all urban reconstruction projects except where other techniques can be applied to control pollution from combined sewer overflows. Combined sewers should be prohibited in all new developments.

14. Discharge of treatable industrial wastes to municipal sewer systems be encouraged.

15. The States institute necessary controls to ensure that the concentration of DDT in fish not exceed 1.0 micrograms per gram; DDD not exceed 0.5 micrograms per gram; Dieldrin not exceed 0.1 micrograms per gram and all other chlorinated hydrocarbon insecticides, singly or combined, should not exceed 0.1 micrograms per gram. Limits apply to both muscle and whole body and are expressed on the basis of wet weight of tissue.

16. Uniform State rules and regulations for controlling wastes from watercraft should be adopted. These rules and regulations should generally conform with the rules and regulations approved by the conferees to the Lake Michigan - Four State Enforcement Conference. Commensurate interstate requirements controlling the discharge of wastes from commerical vessels should be the responsibility of the Federal Government.

17. The dumping of polluted dredged material into Lake Superior be prohibited.

18. Programs be developed by appropriate State and Federal agencies to control soil erosion in the basin. The action plan developed by the Red Clay Interagency Committee should become an integral part of the programs conducted by all appropriate agencies, groups and private individuals.

19. The discharge of visible oil from any source be eliminated.

20. The recommendations of this enforcement conference be adopted as part of the States' enforceable water quality standards.

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APPENDIX A

Information contained in the following tables of waste discharges are as currently known to the Federal Water Pollution Control Administration. No interpretation of the adequacy or inadequacy of the existing treatment or the abatement schedule is made.

STATUS OF MUNICIPAL WASTE DISCHARGES

(As of March 1, 1969)

MICHIGAN

COMMUNITY OR DISTRICT	TYPE OF TREATMENT (EXISTING)	WHERE DISCHARGED	ABATEMENT SCHEDULE
Ahmeek	None	Hills Creek	
Allouez Twp.	None	Hills Creek	
Baltic	Primary	Br. of Pilgrim River	
Baraga	Primary	Lake Superior	
Bergland	None	Lake Gogebic	
Bessemer	Secondary	Kallander Creek	
Big Bay	Primary	Lake Independence	
Bruce Crossing	None	Clear Creek	
Calumet	Secondary	Ground waters	
Chatham	None	Slapneck Creek	
Copper City	Primary	Trap Rock River	
Erwin Twp.	Secondary	Ground waters	
Ewen	None	So. Br. of Ontonagon River	
Florida	None	Hammell Creek	
Gay	Primary	Tobacco River	
Houghton - Hancock	Secondary	Portage Lake	
Hubbell	None	Torch Lake	
Ironwood	Secondary	Montreal River	
Ironwood Twp.	Secondary	Welch Creek	
Ishpeming	Primary	Carp River	
Ishpeming Twp. A.	Primary	Carp River	
Ishpeming Twp. B.	Primary	Carp River	
Lake Linden	None	Torch Lake	
L'Anse	Secondary	Linden Creek	
Laurium	Primary	Hammell Creek	
Marenisco	None	Presque Isle River	
Marquette	Primary	Carp River	
Mass-Greenland	None	Flintsteel River	
Mohawk	None	Hills Creek	
Munising	Primary	Anna River	
Negaunee	Secondary	Ditch	
Newberry	Primary	Tahquamenon River	
Ontonagon	Primary	Ontonagon River	
Painesdale	None	Ditches	
Portage Twp.	None	Huron Creek	
Ramsay	None	Black River	
Rockland	None	Rockland Creek	
South Range	Primary	Br. of Pilgrim River	
Trout Creek	None	Trout Creek	
Wakefield	Secondary	Planter Creek	
Watersmeet	Primary	Middle Branch of Ontonagon River	
White Pine	Secondary	Mineral River	

STATUS OF INDUSTRIAL WASTE DISCHARGES

(As of March 1, 1969)

MICHIGAN

INDUSTRY AND LOCATION	TYPE OF TREATMENT (EXISTING)	WHERE DISCHARGED	ABATEMENT SCHEDULE[1]
Bancroft Dairy Marquette	Septic tank	Dead River via Unnamed Creek	E
Royal Oak Charcoal Marquette	Oil and tar separator San. - city sewers	Lake Superior	B
Bosch Brewing Houghton	Hops removed Label screen on bottle washer San. - septic tanks and tile field	Portage Lake	B
Kimberly Clark Munising	Chem. precip. & settling. San. - city sewers	Lake Superior	B
Calumet and Hecla Osceola Mine Calumet	None	Hammel Creek to Torch Lake	B
Cleveland Cliffs Iron Eagle Mills	Seepage Lagoon		A
White Pine Copper White Pine	San. sewage from Tolfrey Shaft	Argentine and Tolfrey Cr.	A
	Chem. precip. and lagoon	Native Cr. and Mineral River - Lake Superior	A
	San. sewage Sec. treat. & CL_2	Mineral River - Lake Superior	
Hoerner-Waldorf, Inc. Huss-Ontonagon Mill Division Ontonagon	Save-all, San. - city sewer	Ontonagon River	E

STATUS OF INDUSTRIAL WASTE DISCHARGES

(As of March 1, 1969)

MICHIGAN
(CONTINUED)

INDUSTRY AND LOCATION	TYPE OF TREATMENT (EXISTING)	WHERE DISCHARGED	ABATEMENT SCHEDULE[1]
Ontonagon Valley Coop. Creamery Bruce Crossing	Haul whey	Clear Creek and Baltimore River	B
Celotex Corporation L'Anse	Spray irrigation	Ground water	A
Superior Packing Ironwood		Ground water	B
Somer's Slaughterhouse Newberry		Ground water	B
Board of Power and Light	Cooling water - None	Lake Superior	A
Marquette	Ash disposal - Lagoon	Lake Superior	
U. P. Generating Co. Marquette	Cooling water - None	Lake Superior	A
	Ash disposal - Lagoon	Dead River	
U. P. Power Co. L'Anse	Cooling water - None	Falls River and Lake Superior	A
Lake Superior Engineering Company Winona	Seepage Lagoon		B
Northern Automatic Elec. Foundry Ishpeming	Cooling and settling ponds	Carp River	B

[1] A - Control adequate
B - Control provided - adequacy not established
C - No control - need not established
D - Control provided - protection unreliable
E - Control inadequate

STATUS OF MUNICIPAL WASTE DISCHARGES

(As of March 1, 1969)

MINNESOTA

COMMUNITY OR DISTRICT	TYPE OF TREATMENT (EXISTING)	WHERE DISCHARGED	ABATEMENT SCHEDULE
Aurora	Secondary	Creek to St. Louis River	
Babbitt	Secondary	Embarrass River	
Biwabik	Secondary	Embarrass Lake	
Buhl	Secondary	Buhl Creek to East Swan River	
Carlton	Primary	St. Louis River	12-18-71
Chisholm	Secondary	Chisholm Creek to East Swan River	
Cloquet	Primary	St. Louis River	11-12-73
Duluth - Main Plant	Primary	St. Louis Bay	6-18-71
Duluth - Fairmont Park	Primary	St. Louis River	6-18-71
Duluth - Gary-New Duluth	Primary	St. Louis River	6-18-71
Duluth - Smithville	Primary	St. Louis River	6-18-71
Eveleth	Secondary	Creek to Elbow Lake	
Floodwood	None	Floodwood River	12-18-71
Franklin	Primary	Mine Cave	
Fraser	Secondary	Creek to Six Mile Lake	
Gilbert	Secondary	Ditch to Horseshoe Lake to Embarrass River	
Grand Marais	Primary	Lake Superior	12-18-71
Hibbing	Secondary	Hibbing Creek to East Swan River	
Hoyt Lakes	Secondary	Lower Partridge Lake	
Iron Junction	Primary	Creek to St. Louis River	
Kelly Lake St. Louis County	Secondary	West Swan River	
Kinney	Primary	Creek to McQuade Lake to W. Two Rivers	
Leonidas	Primary	Creek to St. Louis River	
McKinley	Primary	McKinley Lake and Cr. to Embarrass River	
Meadowlands	Secondary	Cr. to Whiteface River	
Mountain Iron	Secondary	Cr. to West Two Rivers	
Nichols Twp. St. Louis County	Secondary	Creek to Mashkenode Lake	
Proctor	Duluth sewer system, Fairmont Park Plant		
Scalon	Primary	St. Louis River	12-18-71
Silver Bay	Secondary	Lake Superior	6-18-72
Taconite Harbor Cook County	Secondary	Lake Superior	
Thompson Twp. - Esko Corner Carlton County	Secondary	Midway River	
Two Harbors	Primary	Agate Bay - Lake Superior	12-18-71
Virginia	Secondary	East Two Rivers to Three Mile Lake	
Wrenshall	Secondary	Ravine to Silver Brook to St. Louis River	
Nopeming Sanatorium Duluth, Minnesota	Secondary	Ditch to Mission Creek	

STATUS OF INDUSTRIAL WASTE DISCHARGES

(As of March 1, 1969)

MINNESOTA

INDUSTRY AND LOCATION	TYPE OF TREATMENT (EXISTING)	WHERE DISCHARGED	ABATEMENT SCHEDULE
Minnesota Power and Light Co. Duluth	Pneumatic ash system	St. Louis Bay	
Superwood Co. Duluth	Settling pond	Superior Bay	12-18-71
U.S. Steel Co., Duluth Works Duluth	Oil and solids removal pond, spent acid disposal pit	St. Louis Bay	12-18-71[1]
Arrowhead Blacktopping Duluth	Oil trap	Sargent Creek to St. Louis Bay	
R.J. Reynolds Foods, Inc. Duluth	Process waste - Mun. Cooling and retort waste - none	Swamp to St. Louis Bay	
Arrowhead Sand and Gravel Co. Duluth	Tailings basin	Sullivan Creek	
Two Harbors Power Plant Two Harbors		Lake Superior	
Reserve Mining Co. E.W. Davis Works Silver Bay	None	Lake Superior	12-18-71
Erie Mining - Taconite Harbor Power Plant Taconite Harbor	Pneumatic ash system	Lake Superior	
U.S. Customs and Immigration Pigeon River	Secondary	Pigeon River	
Continental Oil Co. Wrenshall	A.P.I. oil separator, oil removal pond, seepage pond, steam strippers, spent caustic recovery aeration ponds	Silver Creek to St. Louis River	
Northwest Paper Co. Cloquet	Screens and flotation save-all, lime sludge ponds, clarifier, sulfite liquor for road binder	St. Louis River	11-12-73

[1]Final date for suspended solids, oil and turbidity reduction. An additional year may be granted for other construction needed.

STATUS OF INDUSTRIAL WASTE DISCHARGES

(As of March 1, 1969)

MINNESOTA
(CONTINUED)

INDUSTRY AND LOCATION	TYPE OF TREATMENT (EXISTING)	WHERE DISCHARGED	ABATEMENT SCHEDULE
Conwed Corporation Cloquet	Fine screens, hot pond settling basin	St. Louis River	11-12-73
Oglebay Norton Co. Fairlane Plant Forbes	Closed tailings basin system Sanitary-secondary	Emergency discharge only to St. Louis River Swamp to St. Louis River	
The Hanna Mining Co. Agnew, Hibbing	Closed tailings basin system		
The Hanna Mining Co. Natl. Steel Pellet Project, Kewatin	Closed tailings basin system		
The Hanna Mining Co. Pierce Group Hibbing	Closed tailings basin system		
Jones and Laughlin Steel Corp. - McKinley McKinley	Closed tailings basin system		
Jones and Laughlin Steel Corporation - Schley Group Gilbert	Closed tailings basin system		
Coons Pacific Co. Coons Pacific Plant Eveleth	Closed tailings basin system		
Pickands Mather and Co. Erie Commercial Hoyt Lakes	Closed tailings basin system		
Pickands Mather and Co. Mahoning Hibbing	Closed tailings basin system		
Rhude and Fryberger Gross - Nelson Eveleth	Closed tailings basin system		
Rhude and Fryberger Hull - Rust Hibbing	Closed tailings basin system		
U.S. Steel Corp. Minntac Mountain Iron	Closed tailings basin system		
U.S. Steel Corp. Rochleau Group Virginia	Closed tailings basin system		
U.S. Steel Corp. Sherman Group Chisholm	Closed tailings basin system		

STATUS OF MUNICIPAL WASTE DISCHARGES

(As of March 1, 1969)

WISCONSIN

COMMUNITY OR DISTRICT	TYPE OF TREATMENT (EXISTING)	WHERE DISCHARGED	ABATEMENT SCHEDULE
Ashland	Primary	Lake Superior	10-1-70
Bayfield	Primary	Lake Superior	10-1-70
Hurley	Primary	Montreal River	10-1-70
Knight, Tn. of	Primary	Iron Belt Trib.	10-31-69
Iron River	Primary	Iron River	10-31-69
Mellen	Primary	Bad River	10-1-70
Montreal	Primary	West Fk. Montreal River	10-1-70
Pence	Primary	Pence Tributary	10-31-69
Port Wing, Tn. of	Lagoon	Tributary of Flag River	
Saxon	None	Swamp of Vaughn Cr.	10-31-69
Superior	Primary	Lake Superior	10-1-70
Superior Village	Secondary	Pokegama River	
Washburn	Primary	Lake Superior	10-1-70
Ondassagon School Ashland, Wisconsin		Whittlesey Creek	9-1-69
Pureair Sanatorium Bayfield, Wisconsin		Drainage Course	10-31-68

STATUS OF INDUSTRIAL WASTE DISCHARGES

(As of March 1, 1969)

WISCONSIN
(CONTINUED)

INDUSTRY AND LOCATION	TYPE OF TREATMENT (EXISTING)	WHERE DISCHARGED	ABATEMENT SCHEDULE
Twin Ports Dairy Benoit	None	South Fork Fish Creek	10-31-68
Martens Dairy Cornucopia	None	Siskiwit River	10-31-68
Fuhrman South Shore Dairy Iron River	Septic tank, hauling	No discharge	10-31-68
Great Northern Allouez Superior	Separator	Bluff Creek to Lake Superior	10-31-68
Koppers Superior	Lagoon	No discharge	
Murphy Oil Superior	Separator & lagoons	Newton Creek	10-31-70
Soo Line Railroad Superior	None	Soo Line Drainage to Lake Superior	10-31-68
Great Northern Railroad Superior	Separator & lagoons	Great Northern Drainage to Lake Superior	10-31-68
Union Tank Car Superior	Septic tanks	No discharge	
Superior Fiber Products Superior	Chemical and screening	Lake Superior	10-1-70
Mason Milk Products Mason	Septic tank and lagoon	No discharge	
Andersonville Coop Ashland	None	Little Beartrap Creek	10-31-68
American Can Ashland	Chemical treatment & Clarification	Lake Superior	10-1-70
Lake Superior District Power Company Ashland	None	Lake Superior	
Moquah Cheese Moquah	Hauling	Moquah Cheese Factory tributary	
Bodin Fisheries Bayfield	Sanitary to Bayfield	Lake Superior	10-31-68
E.I. duPont de Nemours Barksdale	Irrigation	Boyd Creek to Lake Superior	9-1-70

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

LEGEND: S - Sanitary Wastes; I - Industrial Wastes; G - Ground or Subsurface Discharge; P- Persons
Treatment Provided: ST - Septic Tank; DF - Drain Field; Sec. - Secondary Treatment; Pri. - Primary Treatment; Cl_2 - Chlorination (effluent)
Ratings: A- Adequate treatment; B - Inadequate treatment, abatement program progressing; C - Inadequate treatment, no action taken; D - Adequacy uncertain

* Pit or vault toilets
** Schedule unmanning and automation data
*** Estimated maximum

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MICHIGAN					
U.S. Coast Guard					
Grand Marais Station Grand Marais (Alger Co.)	.70 S	G	ST, DF	A	
Whitefish Point Light Station Whitefish Point (Chippewa Co.)	11 P - S	G	ST, DF	A	
Keweenaw Lower Entrance Light Station (Houghton Co.)	11 P - S	Lake Superior	Sec, Cl_2	A	Treatment facilities installed in 1964
Portage Station Hancock (Houghton Co.)	32 P - S	G	ST, DF	A	New treatment facilities installed 1967
Manitou Island Light Station (Keweenaw Co.)	5 P - S	G	ST, DF	A	New drain field installed in 1964
Passage Island Light Station (Keweenaw Co.)	5 P - S	Lake Superior	ST	B	** 1976
Rock of Ages Light Station (Keweenaw Co.)	5 P - S	Lake Superior	None	B	** 1972 The Coast Guard has submitted FY 70 project for installing incineration type toilet as an interim measure pending unmanning and automation. (Est. Cost - $1,000)
Eagle Harbor Light Station Eagle Harbor (Keweenaw Co.)	7 P - S	Lake Superior	Sec, Cl_2	A	Treatment facilities installed in June 1964
Huron Island Light Station West Huron Island (Marquette Co.)	5 P - S	Lake Superior	Sec, Cl_2	A	Treatment facilities installed in June 1964

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rat-ing	Remarks
MICHIGAN					
Department of Agriculture - Forest Service - Hiawatha National Forest (C - Campgrounds) (P - Picnic Sites)					
AuTrain Lake Picnic Area (Alger Co.) (10 P)	50 P - S	G	None		*
Bay Furnace Campground (Alger Co.) (24 C)	120 P - S	G	None		*
Bay View Campground (Chippewa Co.) (24 C)	120 P - S ***	G	None		*
Big Pine Picnic Area (Chippewa Co.) (14 P)	70 P - S	G	None		*
Monacle Lake Camp, Picnic Ground (Chippewa Co.) (59 C, 12 P)	355 P - S	G	None		*
Three Lakes Camp, Picnic Ground (Chippewa Co.) (48 C, 6 P)	270 P - S	G	None		*
Raco Ranger Dwelling and Office Raco (Chippewa Co.)	0.3 S	G	ST, DF	A	
Upper Michigan Experimental Forest, Dukes (Marquette Co.)	0.3 S	G	ST, DF	A	
Dukes Warehouse One, Dukes (Marquette Co.)	0.03 S	G	ST, DF	A	
Ottawa National Forest					
Sturgeon River Campground (Baraga Co.) (9 C)	45 P - S	G	None		*
Bobcat Lake Camp, Picnic Ground (Gogebic Co.) (12 C, 11 P)	115 P - S	G	None		*
Burned Dam Campground (Gogebic Co.) (6 C)	30 P - S	G	None		*

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MICHIGAN					
Department of Agriculture - Forest Service - Ottawa National Forest, Cont'd.					
Clark-Helen Day Use Area -	150 P - S	G	None		* Plans call for construction of sewer system, sewage lagoon and spray irrigation system concurrent with site development
Sylvania Campground and Recreation Area (Gogebic Co.)	24.0 - S (future)	G			
Ojibway Job Corps Center Marenisco (Gogebic Co.)	15.0 - S	Wellington Cr. (Presque Isle R.)	Sec., Polishing Lagoon, Cl_2 (91% BOD removal)	A	2 - 17,000 gpd extended aeration package sewage treatment plants; 60 to 90-day lagoon.
Taylor Lake Campground (Gogebic Co.)	105 P - S	G	None		*
Marion Lake Campground (Gogebic Co.)	220 P - S	G	None		*
Henry Lake Campground (Gogebic Co.) (11 C)	55 P - S	G	None		*
Imp Lake Camp, Picnic Ground (Gogebic Co.) (22 C, 8 P)	150 P - S	G	None		*
Langford Lake Camp, Picnic Ground (Gogebic Co.) (11 C, 6 P)	85 P - S	G	None		*
Matchwood Tower Campground (Gogebic Co.) (5 C)	25 P - S	G	None		*
Moosehead Lake Campground (Gogebic Co.) (13 C)	65 P - S	G	None		*
Pomeroy Lake East Picnic Ground (Gogebic Co.) (3 P)	15 P - S	G	None		*

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MICHIGAN					
Department of Agriculture - Forest Service - Ottawa National Forest, Cont'd.					
Pomery Lake North Campground (Gogebic Co.) (19 C)	95 P - S	G	None		*
Pomeroy Lake, West Picnic Ground (Gogebic Co.) (2 P)	10 P - S	G	None		*
Potawatomi and Gorge Falls Picnic Ground (Gogebic Co.) (8P)	40 P - S	G	None		*
Bob Lake Camp, Picnic Ground (Houghton Co.) (17 C, 9P)	130 P - S	G	None		*
Lower Dam Campground (Houghton Co.) (7 C)	35 P - S	G	None		*
Sparrow Rapid Campground (Houghton Co.) (6 C)	30 P - S	G	None		*
Kenton Dwelling Nos. 1, 2 & 3 (Houghton Co.)	1.2 S	G	ST, DF	B	The Forest Service has developed preliminary plans to connect the dwellings sanitary wastes to the Kenton Ranger Station sewage treatment facilities. These plans have been reviewed and approved by FWPCA and State of Mich. (Est. Cost - $20,000.)
Kenton Ranger Station (Houghton Co.)	.8 S	Ontonagon Riv. (Lake Superior)	Sec., sand filter, Cl_2		2,000 gpd package treatment plant, sand filter trench, chlorine contact tank, & chlorination facilities installed in 1966

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rat-ing	Remarks
MICHIGAN					
Department of Agriculture - Forest Service - Ottawa National Forest, Cont'd.					
Lake Ste. Kathryn Camp & Picnic Ground (Iron Co.) (35 C, 2P)	185 P - S	G	None		*
Norway Lake Camp, Picnic Ground (Iron Co.) (28 C, 15 P)	215 P - S	G	None		*
Perch Lake Campground (Iron Co.) (20 C)	100 P - S	G	None		*
Perch River Picnic Ground (Iron Co.) (4 P)	20 P - S	G	None		*
Tepee Lake Camp, Picnic Ground (Iron Co.) (17 C, 10 P)	135 P - S	G	None		*
Courtney Lake Camp, Picnic Ground (Ontonagon Co.) (16 C, 15 P)	155 P - S	G	None		*
Steusser Lake Picnic Ground (Ontonagon Co.)	55 P - S	G	None		*
Paulding Pond Camp, Picnic Ground (Ontonagon Co.) (4 C, 2 P)	30 P - S	G	None		*
Robins Pond Campground (Ontonagon Co.) (4 C)	20 P - S	G	None		*
Black River Campground (Ontonagon Co.) (55 P) (Boat docking facilities)	12.0 S	G	ST	B	The Forest Service has submitted FY 71 project for replacing septic tank with aerated lagoon and spray irrigation system. FWPCA and State have approved engineering report and preliminary plans. Est. Cost $280,000

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MICHIGAN					
Department of Agriculture - Forest Service - Ottawa National Forest, Cont'd.					
Bergland Dwelling No. 1 Bergland (Ontonagon Co.)	.24 S	G	ST, DF	A	
Bergland Dwelling No. 2 Bergland (Ontonagon Co.)	.20 S	G	ST, DF	A	
Bergland Ranger Station Office Bergland (Ontonagon Co.)	.20 S	G	ST	B	The Forest Service has submitted FY 71 project for replacing existing septic tank and installing tile field (Est. Cost $1,000); construction to start in spring 1969. Est. completion date June 30, 1969

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer system.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MICHIGAN					
U.S. Army					
Lucas Camp Target Range, Raco (Chippewa Co.)	25 P - S	G	None		*
U.S. Air Force					
Calumet Air Force Station Ahmeek (Keweenaw Co.)	32.0 S	Ditch to Creek to Lake Superior	Sec, Cl_2		Contact stabilization package sewage treatment plant (30,000 gpd) being installed to supplement the exist. overload 6,000 gpd plant. The State will require nutrient reduction by 1972. Const. completion - May 1969.
K. I. Sawyer Air Force Base Republic (Marquette Co.)	668.0 S	Silver Lead Creek (Trib. to L. Sup.)	Sec. - Effluent: BOD - 84 mg/1 64% removal S.S. - 47 mg/1 73% removal	B	The existing treatment plant is hydraulically overloaded and has been cited by Michigan Dept. of Health and Michigan Water Resources Comission as contributing to the pollution of Silver Lead Creek, which waters the State has designated as a trout stream. The Air Force, in 1965 developed a preliminary set of plans for the remedial measures necessary (Cont'd on page 70)

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MICHIGAN U.S. Air Force - Cont'd. K. I. Sawyer Air Force Base Republic (Marquette Co.)					to meet the State requirements. However, due to budget limitations and the more restrictive effluent standards imposed by the State (Min. 80% phosphate removal and 5-day BOD, Max. 65 lbs./day), the Air Force is making revisions to the original design to provide the necessary facilities. The State's compliance date for the above work is 1972. Contract was let on Oct. 21, 1968 for limited modification and improvements to existing primary & secondary treatment units (sludge handling and digestion improvements, weir replacement, new laboratory, oil skimmer, chlorine bldg. chlorine contact, new filter media). Cost $233,000. Est. completion date-Nov. 1969. Tertiary treatment project has not yet been programmed.

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(as of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MICHIGAN					
U.S. Air Force - Cont'd.					
K. I. Sawyer Air Force Base, Cont'd. Republic (Marquette Co.)	.5 S .11 I	G G	ST, DF Holding and settling tanks with oil skimming devices and lagoon	A B	The Air Force has submitted FY 70 project for connecting the industrial waste discharge to the Base sanitary sewer system. This work cannot be accomplished, however, until the implementation of the above plans. Est. Cost $59,000.
Dept. of the Interior - Bur. of Sports Fisheries & Wildlife					
Pendills Creek National Fish Hatchery, Brimley (Chippewa Co.)	5,750 I	Pendills Creek to Lake Superior	None	D	Fish hatchery effluent from fish rearing tanks.
	0.7 S	G	ST, DF	A	
Hiawatha Forest Fish Hatchery Raco (Chippewa Co.)	4,220 I	Sullivans Creek to Lake Superior	None	D	Fish hatchery effluent from fish rearing tanks.
	0.15 S	G	ST, DF	A	
Dept. of the Interior - National Park Service - Isle Royale National Park					
Rock Harbor Lodge (Keweenaw Co.)	1.8 S	G	ST, DF	A	
Mott Island Headquarters (Keweenaw Co.)	0.8 S	G	ST, DF	A	
Windigo Lodge (Keweenaw Co.)	1.0 S	G	ST, DF	A	
CP Siskiwit Campground (Keweenaw Co.)	1 P - S	G	None		*

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MICHIGAN					
Dept. of the Interior - National Park Service - Isle Royale National Park Cont'd					
Beaver Island (Keweenaw Co.)	1 P - S	G	None		*
Belle Island Campground (Keweenaw Co.)	1 P - S	G	None		*
Birch Island (Keweenaw Co.)	1 P - S	G	None		*
Washington Creek Campground (Keweenaw Co.)	3 P - S	G	None		*
Todd Harbor Campground (Keweenaw Co.)	1 P - S	G	None		*
Tobin Harbor Campground (Keweenaw Co.)	3 P - S	G	None		*
Moskey Basin Campground (Keweenaw Co.)	2 P - S	G	None		*
Rock Harbor Campground (Keweenaw Co.)	1 P - S	G	None		*
Merritt's Lane Campground (Keweenaw Co.)	1 P - S	G	None		*
Malone Bay Campground (Keweenaw Co.)	3 P - S	G	None		*
McCargo Cove Campground (Keweenaw Co.)	2 P - S	G	None		*
Grace Island Campground (Keweenaw Co.)	1 P - S	G	None		*
Duncan Narrows Campground (Keweenaw Co.)	1 P - S	G	None		*
Duncan Bay Campground (Keweenaw Co.)	1 P - S	G	None		*
Daisy Farm Campground (Keweenaw Co.)	4 P - S	G	None		*
Chippewa Harbor Campground (Keweenaw County)	2 P - S	G	None		*
Caribou Island (Keweenaw Co.)	1 P - S	G	None		*

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERICR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MINNESOTA					
U.S. Coast Guard					
North Superior Station Grand Marais (Cook Co.)	9 P - S	G	ST, DF	A	
Split Rock Light Station (Lake Co.)	8 P - S	G	ST, DF	A	
Duluth Light Station Duluth (St. Louis Co.)	4 P - S	Lake Superior	None	B	** 1977. The Coast Guard has submitted FY 70 project for installing incineration type toilets as an interim measure prior to to unmanning automation. (Est. Cost $1,500.)
Department of Agriculture - Forest Service Superior National Forest					
Sawbill Lake Camp, Picnic Ground (Cook Co.) (50 C, 2 P)	260 P - S	G	None		*
Temperance River Camp Ground (Cook Co.) (8 C)	40 P - S	G	None		*
Ox-Bow Campground (Cook Co.) (3 C)	15 P - S	G	None		*
Baker Lake Campground (Cook Co.) (4 C)	20 P - S	G	None		*
Crescent Lake Campground (Cook Co.) (43 C)	215 P - S	G	None		*
Bouder Lake Picnic Ground (Cook Co.) (2 P)	10 P - S	G	None		* The Forest Service has requested that this picnic ground be discontinued.
Lichen Lake Picnic Ground (Cook Co.) (1 P)	5 P - S	G	None		* The Forest Service has requested that this picnic ground be discontinued.

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MINNESOTA					
Department of Agriculture - Forest Service - Superior National Forest, Cont'd.					
Upper Poplar River Camp Ground (Cook Co.) (4 C)	20 P - S	G	None		*
Pike Lake Picnic Ground (Cook Co.) (5 P)	25 P - S	G	None		*
Upper Cascade River Picnic Ground (Cook Co.) (2 P)	10 P - S	G	None		*
Two Island Lake Campground (Cook Co.) (39 C)	195 P - S	G	None		*
Devil Track Lake Campground (Cook Co.) (18 C)	90 P - S	G	None		*
East Bearskin Campground (Cook Co.) (47 C)	235 P - S	G	None		*
Flour Lake Campground (Cook Co.) (44 C)	220 P - S	G	None		*
Kimball Lake Campground (Cook Co.) (7 C)	35 P - S	G	None		*
Tofte Administrative Site (Cook Co.)	17 P - S (75 P in future)	G	ST, DF	B	The Forest Serv- has awarded a contract for the construction of secondary treatment plus sand filtration and chlorination facilities. Contract awarded Jan. 1969. Est. completion date - Aug. 1969. Cost - $45,000.
Knife River Administration, Two Harbors (Lake Co.)	-	G	ST, DF	A	The Forest Service no longer utilizes these facilities for other than storage.
Knife River Nursery Dwelling, Two Harbors (Lake Co.)	5 P - S G	G	ST, DF	A	

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MINNESOTA					
Department of Agriculture - Forest Service - Superior National Forest, Cont'd.					
White Pine Picnic Ground (Lake Co.) (3 P)	15 P - S	G	None		*
Nine Mile Lake Campground (Lake Co.) (19 C)	95 P - S	G	None		*
Norway Point Picnic Ground (St. Louis Co.) (6 P)	30 P - S	G	None		*
White Face Reservoir Camp, Picnic Ground (St. Louis Co.)(59 C, 30 P)	445 P - S (10,000 gpd) (future)	G	None	B	* Plans call for the construction of a sewer system, aerated lagoon and spray irrigation systems with disinfection during FY 72. Est. Cost $72,000.
Bird Lake Picnic Ground (St. Louis Co.) (3 P)	15 P - S	G	None		*
Cadotte Lake Picnic Ground (St. Louis Co.) (27 P)	135 P - S	G	None		*
Salo Lake Picnic Ground (St. Louis Co.) (3 P)	15 P - S	G	None		*
Mesaba Dwelling (St. Louis Co.)	3 P - S	G	None		*
Eveleth Nursery Administration and Nursery Eveleth (St. Louis Co.)	.8 S	G	Sec.	A	Package extended aeration plant and tile drain field
U.S. Army (Corps of Engineers)					
U.S. Vessel Yard Duluth (St. Louis Co.)	.2 S	G	ST, DF	A	Future plans call for connections to the municipal sewer system by FY 1970. Est. Cost - $500.

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rat-ing	Remarks
MINNESOTA					
U.S. Air Force					
Finland Air Force Station Finland (Lake Co.)	35.0 S	Surface drainage to Trib. of Baptism R. thence Lake Superior	ST, sand filter	B	40,000 gpd contact stabilization package sewage treatment plant with chlorination under construction; 30% completed; est. completion date May 1969
Duluth Air Force Missile Site Duluth (St. Louis Co.)	10.0 S	Roadside ditch	Sec.	C	Extended aeration package plant
Duluth Air National Guard Duluth (St. Louis Co.)	12.0 S	Miller's Creek	ST, DF	B	The Air Force has submitted a FY 69 project to connect their sewage disposal facilities to the Duluth Municipal sewer system. (Est. Cost $170,000)
Department of the Interior - National Park Service					
Grand Portage Stockade Grand Portage (Cook Co.)	3.0 S	G	ST, DF	D	
Department of the Interior - Bureau of Indian Affairs					
MA Grand Portage Grand Portage (Cook Co.)	0.40 S	G	ST, DF	A	

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
MINNESOTA					
Department of Justice Immigration and Naturalization Service					
Border Patrol Station Grand Marais (Cook Co.)	2.0 S	Ground and Pigeon River	ST, Built up sand filter	A	Recently completed the installation of new lift station, septic tanks and sand gravel filter, the effluent from which, if any, is chlorinated and discharged to the Pigeon River.
WISCONSIN					
U.S. Coast Guard					
Bayfield Station Bayfield (Bayfield Co.)	11 P - S	None	Incinerator type toilet	A	New facilities to be constructed with discharge to the Bayfield Municipal Sewer System. Scheduled completion date 1971. Est. Cost $4,000.
Devils Island Light Station (Bayfield Co.)	5 P - S	G	ST, DF	A	
Superior Entry South Breakwater Light Station, Superior (Douglas Co.)	11 P - S	Allouez Bay	ST, DF	A	** 1973
Department of Agriculture - Forest Service Chequamegon National Forest (C - Campgrounds; P - Picnic Sites)					
Bad River Picnic Ground (Ashland Co.) (3 P)	15 P - S	G	None		*

STATUS OF WASTE WATER DISPOSAL AT FEDERAL INSTALLATIONS
LAKE SUPERIOR DRAINAGE BASIN

(As of March 26, 1969)

(This inventory does not include installations connected to municipal sewer systems.)

Installation (Name & Location)	Volume & Type of Wastes (1,000 GPD)	Receiving Waters Drainage Basin	Treatment Provided	Rating	Remarks
WISCONSIN					
Department of Agriculture - Forest Service Chequamegon National Forest (C - Camprgounds; P - Picnic Sites)					
Beaver Lake Campground (Ashland Co.) (11 C)	55 P - S	G	None		*
Lake Three Campground (Ashland Co.) (8 C)	40 P - S	G	None		*
Potter Lake Picnic Ground (Ashland Co.) (2 P)	10 P - S	G	None		*
Pigeon Lake Campground (Bayfield Co.)	2.0 S	G	None		*
Two Lakes Campground (Bayfield Co.) (98 C)	13.0 S	G	None	B	A project has been submitted to provide a water-borne system with aerated lagoon, irrigation and disinfection. Cost estimate: FY 71 - $20,000 design FY 72 - $240,000 construction (Prelim. plans completed)
Drummond Lake Picnic Ground (Bayfield Co.) (6 P)	30 P - S	G	None		*
Lake Owen Picnic Ground (Bayfield Co.) (18 P)	90 P - S	G	None		*
Lake Owen Outlet Picnic Ground (Bayfield Co.) (4 P)	20 P - S	G	None		*
Wanoka Lake Campground (Bayfield Co.) (20 C)	100 P - S	G	None		*
Long Lake Picnic Ground (Bayfield Co.) (21 P)	105 P - S	G	None		*

STATUS OF WASTE TREATMENT AT FEDERAL INSTALLATIONS
LOCATED IN THE LAKE SUPERIOR DRAINAGE BASIN

Installation Name & Location (Berth)	Compliment	Area of Operation	Treatment Provided	Rating	Remarks
Vessels					
U.S. Coast Guard	47	Lake Superior	None	D	Installation of adequate waste treatment facility is contingent upon development of suitable shipboard operational plant by the Coast Guard
USCGC Woodrush					
National Park Service					
M.V. Ranger III (165')	138	Lake Superior	Holding Tank	A	Discharges into the Houghton-Hancock Municipal Sanitary Sewer System. Depending on fund approval, eventual plans call for unloading into marine facilities at Isle Royale.
Tug J.E. Colombe (45 ft.)	2	Lake Superior	Holding Tank	A	"
M.V. Conrad L. (26 ft.)	2	Lake Superior	Holding Tank	A	"
M.V. Demray (26 ft.)	2	Lake Superior	Holding Tank	A	"
M.V. Louis J. (26 ft.)	2	Lake Superior	Holding Tank	A	"
M.V. C.M. Gothe (26 ft.)	2	Lake Superior	Holding Tank	A	"
U.S. Army (Corps of Engineers)					
Derrick Boat DK 20	5	Lake Superior	Macerator Chlorinator	B	Study is being conducted by Corps of Engineers to develop a suitable package aeration unit for this type of vessel.
Derrick Boat - Coleman	11	Lake Superior	"	B	"
Dredge - Gaillard	27	Lake Superior	"	B	"
Tow Boat - Marquette	8	Lake Superior	"	B	"
Tow Boat - Superior	9	Lake Superior	"	B	"
Tow Boat - Duluth	3	Lake Superior	"	B	"

APPENDIX B

LAKE SUPERIOR OPEN WATERS*
WATER QUALITY CRITERIA AND DESIGNATED USES
MICHIGAN, MINNESOTA, WISCONSIN

STATE	DESIGNATED USES	COLIFORM GROUP	DISSOLVED OXYGEN	SUSPENDED, COLLOIDAL AND SETTLEABLE MATERIALS	FLOATING MATERIAL, RESIDUES, DEBRIS AND MATERIAL OF UNNATURAL ORIGIN	TOXIC AND DELETERIOUS SUBSTANCES
MICHIGAN	Domestic Water Supply Industrial Water Supply Recreation: – Whole Body Contact – Partial Body Contact Fish, Wildlife and Other Aquatic Life: – Intolerant Fish Cold Water Species – Intolerant Fish Warm Water Species Agricultural Commercial	The average of any series of 10 consecutive samples shall not exceed 1000 organisms per 100 ml nor shall 20% of samples exceed 5000/100 ml Fecal coliforms for the samples $\ngtr$ 100/100 ml	Cold Water Intolerant Species $\nless$ 6 mg/1 at any time Warm Water Intolerant Species Avg. Daily Value $\nless$ 5 mg/1 Any Single Value $\nless$ 4 mg/1	No objectionable unnatural turbidity, color, or deposits in quantities sufficient to interfere with designated use	No evidence of such material except of natural origin No visible film of oil or globules of grease	Conform to current USPHS Drinking Water Standards, except Cyanide. $\ngtr$ 0.2 mg/1 Chromium· $\ngtr$ 0.05 mg/1 Phenols· Mo. Avg. $\ngtr$ 0.002 mg/1 Single Value $\ngtr$ 0.005 mg/1 Not to exceed 1/10 of the 96-hour TL_m obtained from continuous flow bioassays where the dilution water and toxicant are continuously renewed except that other application factors may be used in specific cases when justified on the basis of available evidence and approved by the appropriate agency
MINNESOTA	Domestic Consumption (IB) Fisheries and Recreation (2A) Industrial Consumption (3A)	$\ngtr$ 50 MPN/100 ml	Oct-May $\nless$ 7.0 mg/1 Jun-Sep $\nless$ 5.0 mg/1	Turbidity $\ngtr$ 5.0 units No discharge from unnatural sources so as to cause any nuisance conditions	Oil $\ngtr$ Trace No discharge from unnatural sources so as to cause any nuisance conditions	[$\ngtr$ - mg/1] Arsenic 0.01 Barium 1.0 Cadmium 0.01 CCE 0.2 Chromium Trace Copper Trace Cyanide Trace Fluorides 1.5 Lead 0.05 Manganese 0.05 Nitrates 45.0 Selenium 0.01 Silver 0.05 Zinc 5.0
WISCONSIN	Public Water Supply Industrial and Cooling Water Commercial Shipping Recreation: – Whole Body Contact Beach areas Fish and Aquatic Life Trout Waste Assimilation	Arith. Avg. $\ngtr$ 1000/100 ml Max. $\ngtr$ 2500/100 ml during recreation season	$\nless$ 80% Saturation nor $\nless$ 5 mg/1 at any time $\ngtr$ 1 mg/1 change	Substances that will cause objectionable deposits in the bed or on the shore of a body of water shall not be present in such amounts as to create a nuisance	Floating or submerged debris, oil, scum or other material shall not be present in such amounts as to create a nuisance	Substances in concentrations or combinations which are toxic or harmful to humans shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts, which by bioassay and other appropriate tests, indicate acute or chronic levels harmful to animal, plant or aquatic life

*Criteria and Uses as of March 1, 1969

$>$ Greater Than $\ngtr$ Not Greater Than
$<$ Less Than $\nless$ Not Less Than

Where designated uses have different criteria the most stringent criteria are listed.

TOTAL DISSOLVED SOLIDS	NUTRIENTS	TASTE AND ODOR PRODUCING SUBSTANCES	TEMPERATURE	pH	RADIOACTIVE MATERIALS
Total Dissolved Solids: $\ngtr$ 200 mg/1 Chlorides: Mo. Avg. $\ngtr$ 50 mg/1	Nutrients originating from industrial, Municipal or domestic animal sources shall be limited to the extent necessary to prevent adverse effects on water treatment processes or the stimulation of growth of algae, weeds and slimes which are or may become injurious to the designated use	Concentrations of substances of unnatural origin shall be less than those which are or may become injurious to the designated use Phenols: Mo. Avg. $\ngtr$ 0.002 mg/1 Max. Concentration for a Single Value $\ngtr$ 0.005 mg/1	Intolerant Fish Cold Water Species 70°F Maximum $\ngtr$ 10°F Increase Intolerant Fish Warm Water Species 85°F Maximum $\ngtr$ 15°F Increase when ambient temperature is less than 35°F $\ngtr$ 10°F Increase when ambient temperature ranges from 36°F to natural maximum See Footnote Below[1]	Range of 6.5 - 8.8 $\ngtr$ 0.5 unit change within range	$\ngtr$ 1000 pc/l of gross beta activity in absence of Sr-90 and alpha emitters If this limit is exceeded the specific radionuclides present must be identified by complete analysis in order to establish the fact that the concentration of nuclides will not produce exposure above recommended limits established by the Federal Radiation Council
Total Dissolved Solids: $\ngtr$ 500 mg/1 Chlorides: $\ngtr$ 50 mg/1 Sulfates: $\ngtr$ 250 mg/1 Hardness: $\ngtr$ 50 mg/1	No discharge from unnatural sources so as to cause any nuisance conditions	Threshold Odor Number $\ngtr$ 3 Phenols: $\ngtr$ 0.001 mg/1	No Material Increase	Within range of 6.5 - 8.5	Gross beta concentration not to exceed 1000 pc/1 in known absence of alpha emitters and Sr-90 Also: Not to exceed the lowest concentrations permitted to be discharged to an uncontrolled environment as prescribed by the appropriate authority having control over their use
Mo. Avg. $\ngtr$ 500 mg/1 Max. $\ngtr$ 750 mg/1 at any time	Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to create a nuisance	Materials producing color, odor, taste or unsightliness shall not be present in such amounts as to create a nuisance	84°F Max. Change from natural unpolluted background $\ngtr$ 5°F Rate of Change $\ngtr$ 2°F/hour	Within range of 6.0 - 9.0 $\ngtr$ 0.5 unit change if natural values are above 8.5 or below 6.5	Intake water supply will be such that by appropriate treatment and adequate safeguards it will meet PHS Drinking Water Standards, 1962

[1]For the Great Lakes and connecting waters no heat load in sufficient quantity to create conditions which are or may become injurious to the public health, safety, or welfare; or which are or may become injurious to domestic, commercial, industrial, agricultural, recreational or other uses which are being or may be made of such waters, or which are or may become injurious to the value or utility of riparian lands, or which are or may become injurious to livestock, wild animals, birds, fish or aquatic life or the growth or propagation thereof.

APPENDIX C

INDEX TO APPENDIX C

DISSOLVED OXYGEN

I. BIOLOGICAL EFFECTS. A continuous supply of oxygen is required for the normal metabolism of fish and most of their food organisms. Oxygen is used also in the respiration of plants and by bacteria. Oxygen enters the water chiefly by diffusion from the air and by the photosynthetic activity of plants. In general a balance is maintained between addition and removal, but because oxygen is not very soluble the water's capacity is small, so that any interference with the influx from the air or production by plants or any sudden increase in utilization (as, for example, in the bacterial oxidation of sewage wastes, etc.) soon lowers it to critical levels.

The oxygen concentration needed for maintenance varies widely with species, and there is evidence that highly desirable fish species in Lake Superior (coregonids, salmonids) require relatively high concentrations. There are indications, also, that several of the important food organisms (gammarids and shrimp) are even less tolerant of oxygen deficiencies. Within any one species the requirement varies with temperature, and especially with life-history stage, the eggs and early fry being more sensitive than the adults to oxygen lack. For such cold-water fish as salmonids a minimum of 6 mg/1 has been recommended for good growth and general well-being of adults and their associated food organisms, and of 7 mg/1 for eggs and fry.

II. SPECIAL CONSIDERATIONS. In addition to providing for growth, activity, reproduction and the like, the oxygen concentration must be high enough to protect against adverse conditions that may be encountered. For example, toxicants that enter through the gills become more toxic as the oxygen concentration is decreased, because the fish must pass more water over the gills to get enough oxygen, and this brings more toxicant against the gill surface. Because the low salt content of Lake Superior water permits such agents as heavy metals to be more toxic than they would be in harder waters, it is especially important that the oxygen concentration be maintained high enough to counteract this hazard.

Little is known about the requirements of the adult stages of the important species of fish and food organisms under the environmental conditions of the bulk of Lake Superior, and even less about those of the more sensitive developmental stages. Further, little seems to be known about the oxygen concentration in various parts of the lake, especially at the bottom where the eggs and early stages of many species must live. Evidently the lake oxygen concentrations that have entered into maintaining the recorded levels at Duluth and Sault Ste. Marie so far have been high enough to maintain the aquatic population, and these should serve as guidelines until we have more information.

It is important to recognize that a reduction in oxygen from existing concentrations would serve as a warning of organic decomposition with subsequent release of poisonous materials such as hydrogen sulfide and ammonia.

III. EXISTING CONDITIONS. The gross range of dissolved oxygen concentrations over the period 1958-1968 was between 9.4 and 14.6 mg/1 at Duluth, and 8.4 and 16.4 mg/1 at Sault Ste. Marie, with means of 12.6 and 12.2 mg/1, respectively.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The dissolved oxygen concentration of the open water of the lake shall not be less than 9 mg/1, at any time or any place in that habitat and 90% of the values should be greater than 10 mg/1. For habitats occupied primarily by warmer water fish (e.g., perch and walleye in the shallower bays) the criteria shall be not less than 5 mg/1 at any time or place in that habitat.

V. REFERENCES.

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2. Doudoroff, P. and C.E. Warren, 1962. Biological Problems in Water Pollution. Public Health Service; Third Seminar: pp. 145-155. Dissolved Oxygen Requirements of Fishes.
3. Ellis, M.M. 1937. Bulletin U.S. Bureau of Fisheries, Volume 48:365-437. Detection and Measurement of Stream Pollution.
4. Smith, L. L. et al, 1956. Sewage & Industrial Wastes 28:678-690. Aquatic Life Water Quality Criteria: Second Progress Report.
5. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D.C., April 1968.

TURBIDITY AND COLOR

I. BIOLOGICAL EFFECTS. Ecologically, the quality of the light, the intensity and the duration impinging on a given surface area controls the ecosystem through its influence on primary production. Light is the ultimate source of energy, without which life could not exist. Many structural and behavorial characteristics of organisms are directly influenced by light, therefore making it a vital factor as well as a limiting one at both the maximum and minimum levels.

Reduction of light presents a more serious problem in the aquatic environment than in the terrestrial. Light diminishes rapidly even in clear water, and changes in spectral composition and in other respects. Any extraneous material which is introduced to water, whether it be dissolved or suspended, will diminish the light intensity and possibly change the light quality. In short, suspended or dissolved solids absorb light energy, and this absorption will decrease that light energy available for primary production.

Production takes place in the water at a depth to which light penetrates so that in deep water lakes the light-penetrated "surface water" provides the major source of production for the entire depth. Effects of turbidity on desirable fish in Lake Superior would first appears as indirect ones on food supply.

II. CHEMICAL EFFECTS. Increases in turbidity require an increase in the available chlorine necessary for chlorination.[1] Further, an increase in turbidity makes phosphate and radioactivity removal harder to accomplish.[2] Turbidity produces in Lake Superior "colored water" which is not esthetically pleasing.[3]

III. SPECIAL CONSIDERATIONS. Since Lake Superior is deep (average depth about 600 feet) and cold (average temperature $<42°F$) primary production is already hindered. If light energy is removed because of turbidity or color, further stress would be placed on the lake's primary production. A combination of all these adverse conditions (extreme depth, low temperature, and light absorption) could render the lake practically sterile. Since the lake's depth cannot be controlled, and the cold temperature is required for the natural fish, it is most imperative that turbidity and color be removed from effluents being discharged into the lake.

IV. EXISTING CONDITIONS. Twenty-year averages of turbidity measurements taken daily at the Duluth Water Treatment Plant (Lakewood Pumping Station) show the mean turbidity of Lake Superior at this station to be about 0.3 JTU.

V. RECOMMENDED CRITERIA FOR LAKE SUPERIOR.

Turbidity: Less than 0.5 JTU (measured by dilution of standard solutions for JTU) for 90% of the time. Not to exceed 5.0 JTU as a maximum.

Color: Less than 0.010 absorbance units (10 cm path length) over wave length range 3500-8000 A°, and less than 0.050 absorbance units (10 cm path length) over the wave length range 2400-3500 A° for 90% of the time. Not to exceed five times these values as a maximum.

VI. REFERENCES.

1. Felsen, D. and Taras, M. J. Journal American Water Works Association, 42, 455 (1950).
2. Eliassen, R. et al. Journal American Water Works Association, 43 621 (1951).
3. Odum, E.P. Fundamentals of Ecology, p. 106. W. B. Saunders and Co., Philadelphia, 1959.
4. Clarke, G. L. Elements of Ecology, p. 185, John Wiley and Sons, Inc., New York. 1954.

TOTAL DISSOLVED SOLIDS

I. GENERAL CONSIDERATIONS. The quantity of dissolved solids by itself is not especially important in assessing water quality. More important are the kinds of dissolved solids that are present, and in some cases, the ratio of one to another. Only when the total exceeds many times the existing values in the lake, would there be any direct impairment.

Dissolved solids measurements do, however, provide a good index of the aging rate of the lake. Such correlations have been established in Lake Erie, as an example. For this reason, dissolved solids should be kept close to the present level to avoid undesirable aging effects.

II. EXISTING CONDITIONS. No data is available for St. Mary's River, but rarely is 60 mg/1 reached at Duluth.

III. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. Ninety percent of the values should not exceed 65 mg/1.

IV. REFERENCES.

1. A Plan for Water Pollution Control - Lake Erie Report. U. S. Department of the Interior, Federal Water Pollution Control Administration. August 1968.

BACTERIA

I. GENERAL CONSIDERATIONS. The presence of bacteria in water was recognized early as an indicator of degraded water quality. The coliform bacterial count has been most widely used as an index of sewage contamination and possible accompanying hazard of human pathogens. Some waters have a high count even though there is little or no sewage contamination as coliform bacteria enter waterways from sources other than man, such as land runoff from agricultural lands.

The cold temperature, extreme water clarity (permitting deep penetration of sunlight) and sparsely populated watershed result in very low counts. The average total coliform value at Duluth is 3.68/100 ml and 7.81/100 ml at the St. Mary's River.

II. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The maximum total coliform count should not exceed 1000/100 ml and 90% of the counts should be less than 10/100 ml at any location. The maximum fecal coliform count should not exceed 200/100 ml and 90% of the counts should be less than 10/100 ml at any location.

III. REFERENCES.

1. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D. C., April 1968.
2. Sanitary Significance of Fecal Coliforms in the Environment. U. S. Department of the Interior, Federal Water Pollution Control Administration, Publication WP-20-3.
3. The Bacteria, Volume II. Gunsalus and Stanier, Academic Press. 1961.
4. Pollutional Effects of Pulp and Paper Mill Wastes in Puget Sound. U. S. Department of the Interior, Federal Water Pollution Control Administration, March 1967.
5. Proceeding-Eleventh Conference on Great Lakes Research - 1968. International Association for Great Lakes Research.
6. Microbiology for Sanitary Engineers. McKinney, Rose E. McGraw-Hill, 1962, pp. 152.

DETERGENTS (MBAS)

I. BIOLOGICAL EFFECTS. Detergents, because of their ubiquitous usage, are wisespread in waterways. In 1965, the United States detergent manufacturers changed over from the "hard" tetrapropylene alkyl benzene surfactants. With present detergent formulations, the LAS surfactant is the primary toxic component and has been demonstrated to be two to four times more toxic than the old ABS compound. However, the removal of LAS by biodegradation is accompanied by a reduction in toxicity without the accumulation of toxic intermediates.

Most of the published detergent toxicity data for fish and other aquatic life is for old ABS formulations, while LAS toxicity information exists primarily for fish. Short-term studies by a number of investigators with LAS have shown that the lethal concentrations (96 hour TL_m values) for certain fish species range from 0.6 to 6.4 mg/1. A long-term study with fathead minnows indicated that the maximum acceptable concentration of LAS is 0.6 mg/1. Unpublished experiments of one to three months duration at the National Water Quality Laboratory have shown that the 30 day lethal value for smallmouth bass and northern pike fry is between 0.5 to 0.6 mg/1, and the threshold concentration of LAS for an amphipod and operculate snail is approximately 1.0 to 1.7 mg/1, and for a pulmonate snail greater than 2.0 mg/1.

II. SPECIAL CONSIDERATIONS. The methylene blue method is used for quantitatively measuring surfactants, but doen not differentiate between the now existing levels of ABS and LAS occurring in natural waters or certain natural substances. Therefore, it has been proposed and generally accepted that these anionic substances be reported as methylene blue active substances (MBAS).

The Public Health Service Drinking Water Standards, 1962, limits ABS in drinking water to 0.5 mg/1 since higher concentrations may cause undesirable tastes and foaming. A similar LAS standard has not yet been adopted. An important secondary effect related to a detergent standard is that polyphosphates comprise a large percentage of powdered detergent formulations and furnish nutrients to receiving waters, and may promote nuisance conditions (e.g. algal blooms).

III. EXISTING CONDITIONS. Available information on surfactant concentrations in Lake Superior indicates a range from 0.01 - 0.05 mg/1.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The maximum concentration for Lake Superior should be 0.4 mg/1 MBAS and 90% of the measurements less than 0.1 mg/1 MBAS at any single location.

V. REFERENCES.

1. Thatcher, Thomas O., and Joseph F. Santner, 1966. Acute Toxicity of LAS to Various Fish Species. Proceedings 21st Purdue Industrial Waste Conference, Engineering Extension Series No. 121., 50(2): 996-1002.
2. Pickering, Quentin H. 1966. Acute Toxicity of Alkyl Benzene Sulfonate to the Eggs of the Fathead Minnow, Pimephales promelas. Air and Water Pollution Journal, 10: 385-391.
3. Pickering, Quentin H. and Thomas O. Thatcher. 1968. The Chronic Toxicity of Linear Alkylate Sulfonates to the Fathead Minnow (Pimephales promelas, Raf.). Submitted to Journal Water Pollution Control Federation for publication.
4. Swisher, R.D., J.T. O'Rourke, and H.D. Tomlinson. 1964 Fish Bioassays of Linear Alkylate Sulfonates (LAS) and Intermediate Biodegradation Products. Journal of American Oil Chemical Society, 41: 746-752.
5. Marchetti, R. 1965. Critical Review of the Effects of Synthetic Detergents on Aquatic Life. Stud. Rev. Gen. Fish. Coun. Medit., No. 26, 32 pp.

PHENOLS AND PHENOLIC COMPOUNDS

I. BIOLOGICAL EFFECTS. Phenols and substituted phenols are toxic to trout and other fish at concentrations of 0.1 to 10 mg/l. Studies of long term effects at lower concentrations have not been made.

Phenolic compounds, particularly the chlorophenols, cause unpleasant odors and flavors in fish from waters containing as little as 0.0001 mg/l. Most phenols are biodegradable, but at concentrations of a few mg/l or less cause nuisance slime and mold growths on rocks, etc.

II. SPECIAL CONSIDERATIONS. Phenols in drinking water are detectable by disagreeable taste and odor at concentrations of 0.001 to 0.01 mg/l, thus the U.S. Public Health Service Drinking Water Standard has been set at 0.001 mg/l. Current waste treatment practices (tertiary treatment) are highly efficient at removal of phenols; however, post-chlorination of the waste increases the proportion of taste and odor causing chlorophenols.

III. EXISTING CONDITIONS. Phenol as such is not routinely measured in Lake Superior. However, data from Duluth and the St. Mary's River indicate that total aromatics (including phenols) average less than 0.001 mg/l.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. Based on the potential for causing taste and odor problems in drinking water and in commercial fish, the recommended criteria for phenols in Lake Superior is a maximum concentration of 0.001 mg/l.

V. REFERENCES.

1. Brown, V.M., Jordan, D.H.M., and Tiller, B.A., 1967. The Effect of Temperature on the Toxicity of Phenol to Rainbow Trout in Hard Water. Water Research 1:587-594.
2. Pickering, Q.H., and Henderson, C., 1966. Acute Toxicity of Some Important Petrochemicals to Fish. Journal Water Pollution Control Federation 38 (9): 1419-1429.
3. Ryckman, D.W., Prabhakara Rao, A.V.S., and Buzzel, J.C., Jr. Behavior of Organic Chemicals in the Aquatic Environment: A Literature Critique. Published by the Manufacturers Chemists Association, Washington, D.C., Summer 1966.
4. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D.C., April 1968.

AMMONIA

I. BIOLOGICAL EFFECTS. Ammonia is a normal product of animal metabolism and the major nitrogenous excretion of fish and other freshwater animals. It enters water naturally also by microbial decomposition of decaying plant and animal material, in rain water and, under certain conditions, by the degradation of dissolved nitrites and nitrates. In addition, it enters water as a component of sewage, fertilizers, and numerous industrial wastes. Conversely, it serves as a nutrient for some of the algae. Its concentration is unlikely to remain constant in a normal aquatic environment, but tends to be decreased by conversion to nitrite and nitrate. Because of its many possible sources and fates, the ammonia content of natural unpolluted waters is highly variable, and has been reported to range from 0.0 to about 4.0 mg/1, although usually less than 0.2 mg/1.

The experimental work to date on ammonia toxicity does not provide clear guidelines, partly because the distinction has not always been made between the highly toxic ammonia molecule and the less toxic ammonium ion, and partly because the experiments have been too crude to be related to long-term effects. A concentration of 1.5 mg/1 has been reported as "not harmful to fish", but it has also been reported, however, that 1 mg/1 and even 0.3 mg/1 can affect the oxygen carrying capacity of the blood. Its effects on important fish food organisms of the lake are not known.

II. SPECIAL CONSIDERATION. The higher the pH the greater the proportion of toxic molecular ammonia relative to ammonium ion, the toxicity of ammonium compounds increasing by 200% or more between pH 7.4 and 8.0. Over the period 1958-1968 the pH of Lake Superior water at Duluth has ranged between 7.3 and 8.5, with a mean of 7.72, which is in a critical range for ammonia. Further, because of its low salt concentration Lake Superior water is poorly buffered against changes in pH. For these reasons the standard for ammonia must be extremely conservative to be safe for aquatic life.

III. EXISTING CONDITIONS. Over the period 1959-1966 at Sault Ste. Marie, and 1958-1965 at Duluth, the reported ammonia concentrations ranged between 0.0 and 0.1 mg/1 as ammonia nitrogen, with means of 0.071 and 0.0024 mg/1, respectively.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. Since the values so far recorded seem not to have had an adverse effect, since the ammonia concentration is highly labile, and since ammonia is most toxic at high pH ranges, the recommended criteria is a maximum of 0.1 mg/1, expressed as ammonia nitrogen, and 90% of the values should be less than 0.05 mg/1.

V. PERTINENT REFERENCES.

1. Doudoroff, P., and Katz, M., 1950 22:1432-1458. Critical Review of Literature on the Toxicity of Industrial Wastes and their Components to Fish. I. Alkalies, Acids and Inorganic Gases. Sewage and Industrial Wastes.
2. Ellis, M. M. 1937. Bulletin U. S. Bureau of Fisheries. Detection and Measurement of Stream Pollution. Vol. 48: 365-437.
3. Goldstein, L., Forster, R. P. and Fanelli, G. M., Jr. 1964. Gill Blood Flow and Ammonia Excretion in the Marine Teleost, *Myoxocephalus scorpius*. Comp. Biochem. Physiol. 12: 489-499.
4. Lloyd, R. 1961. Effect of Dissolved Oxygen Concentrations on the Toxicity of Several Poisons to Rainbow Trout. Journal Experimental Biology. 38: 447-456.

PHOSPHORUS

I. BIOLOGICAL EFFECTS. Phosphorus is an essential nutrient which frequently occurs in minute quantities in natural waters and can thereby be limiting to the growth of aquatic plants. When present in excess, however, under favorable environmental conditions, it is instrumental in producing heavy and undesirable growths of both algae and rooted aquatic plants. Results obtained by various workers (e.g., Sawyer, 1947; Chu, 1943; Strickland, 1965; and Sylvester, 1961) indicate that phosphorus does not become limiting to algae until concentrations as low as 0.01 mg/l or less of soluble phosphorus are reached.

II. SPECIAL CONSIDERATIONS. Phosphorus, in increased quantities, is commonly associated with accelerated lake eutrophication. The degree to which aquatic plant growth is stimulated by phosphorus is variable, and will depend on the occurrence of other essential nutrients, temperature, light, etc. Phosphorus is, however, a substance which is essential to plant growth, one which is frequently limiting, and one which is much more amenable to control than many other nutrients. Nitrogen, for example, is difficult to control because some forms of algae are able to fix atmospheric nitrogen.

III. EXISTING CONDITIONS. Data on phosphorus distribution in Lake Superior are scarce. A synthesis of data published by Putnam and Olson (1960) and by Beeton, et al. (1959), indicate average distribution of total phosphorus, as mg/l Phosphorus, for all depths, to be as follows:

West End (West of Apostle Islands)	0.009
Apostle Islands Region	0.014
Open Lake, Apostle Islands to Keweenaw Peninsula	0.010
Keweenaw Bay	0.011
Coastal Waters off Marquette and Munising	0.010
Open Lake, East End	0.005
Whitefish Bay	0.008

The average for the entire lake is 0.0096 mg/l.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The total phosphorus levels should not be permitted to exceed existing values. Where background data are not available the maximum value should not exceed 0.01 mg/l total phosphorus.

V. REFERENCES.

1. Beeton, A.M., J.H. Johnson, and Stanford H. Smith, 1959. Lake Superior Limnological Data. U.S. Fish and Wildlife Service. Special Scientific Report – Fisheries No. 297, Washington, D.C., 177 p.

2. Chu, S.P., 1943. The Influence of the Mineral Composition of the Medium on the Growth of Planktonic Algae. Part II. The Influence of the Concentration of Inorganic Nitrogen and Phosphate Phosphorus. J. Ecology 31:109.

3. Putnam, H.D., and T.A. Olson. An Investigation of Nutrients in Western Lake Superior. School of Public Health, University of Minnesota, Duluth, for the Minnesota Water Pollution Control Commission, 1960.

4. Putnam, H.D., and T.A. Olson, 1966. Primary Productivity at a Fixed Station in Western Lake Superior. Proceedings, Ninth Conf. on Great Lakes Res., Inst. of Sci. and Tech., University of Mich., Ann Arbor, p. 119-128.

5. Sawyer, C.N., 1947. Fertilization of Lakes by Agricultural and Urban Drainage. J. NEWWA, 61:109.

6. Strickland, J.D.H., 1965. Production of Organic Matter in the Primary Stages of the Marine Food Chain. Chemical Oceanography (J.P. Riley and D. Skirrow, eds.), Academic Press, New York.

7. Sylvester, R.O., 1961. Nutrient Content of Drainage Water from Forested, Urban, and Agricultural Areas. Algae and Metropolitan Wastes, Public Health Service, SEC TR W61-3, 80, U.S. Govt. Print. Off., Washington, D.C.

IRON

I. BIOLOGICAL EFFECTS. Iron causes problems of taste, color and odor in water supplies and may stimulate the growth of bacteria and other lower plant life. It will discolor shore areas and may coat water conduits. Concentrations in excess of 0.3 mg/l cause taste problems and stain laundry. Lesser concentrations in combination with manganese often result in undesirable growths.

II. SPECIAL CONSIDERATIONS. Iron solubility is highly pH dependent. In more desirable pH values of 6.5 to 8.5 it occurs in the oxidized state and is rather insoluble and usually settles. Introductions of iron may result in an increase in settleable solids content in this way. Iron will redissolve in hypolimnionic waters under certain conditions and then may cause taste and odor problems.

III. EXISTING CONDITIONS. The ten year average concentration at Duluth is 0.023 mg/l and 0.019 mg/l at the St. Mary's River. The high value recorded is 0.168 mg/l. Highest readings occurred during the last several years.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The maximum value should be 0.1 mg/l and 90% of the values should be less than 0.03 mg/l at any single location.

V. REFERENCES.

1. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D.C. April 1968.

2. U.S. Department of Health, Education and Welfare, 1962, Public Health Service Drinking Water Standards, PHS Publication No. 956.

3. Water Quality Criteria, California State Water Quality Control Board, Sacramento, California, Publication 3-A, 1963. pp. 215

CADMIUM

I. BIOLOGICAL EFFECTS. Cadmium occurs in small amounts in naturally occurring zinc ores reflecting its close chemical relationship to zinc but in natural waters occurs in only trace amounts. Cadmium is a nonessential, nonbeneficial element. It is a heavy metal that accumulates in animal tissues and has a high pollution potential because of its high toxicity and cumulative effects.

In the U.S. Public Health Service Drinking Water Standards, cadmium in excess of 0.010 mg/l constitutes grounds for rejection of the supply. Long term toxicity studies conducted at the Federal Water Pollution Control Administration's Newtown Fish Toxicology Laboratory have shown slow accumulative mortality in young fish and that newly hatched fry are extremely sensitive to cadmium. These chronic studies conducted in hard water (in which cadmium is less toxic than in Lake Superior) gave a "safe" concentration of 0.037 mg/l. The test concentration of 0.057 mg/l was lethal to newly hatched fry.

II. SPECIAL CONSIDERATION. The toxicity of cadmium, like the other heavy metals, is influenced by water quality characteristics, such as pH and hardness. Acute toxicity studies indicate that the lethal concentration of cadmium in softer water is 1 mg/l.

III. EXISTING CONDITIONS. According to Kopp and Kroner, of 66 samples in the Western Great Lakes Basin the frequency of detection (0.45 millipores filtered samples) was 3%. They did not detect cadmium in Lake Superior.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The recommended criteria for cadmium in Lake Superior is a maximum value of 0.005 mg/l and 90% of the measurements less than 0.002 mg/l at a single location.

V. REFERENCES.

1. Pickering, Q.H., and Gast, M. The Chronic Toxicity of Cadmium to the Fathead Minnow (Pimephales promelas) (In preparation).

2. Pickering, Q.H., and Henderson, C. Acute Toxicity of Some Heavy Metals to Different Species of Warm Water Fishes, Proceedings 19th Industrial Waste Conference. Purdue University. 1965.

CHROMIUM

I. BIOLOGICAL EFFECTS. In the U.S. Public Health Service Drinking Water Standards the presence of hexavalent chromium in excess of 0.05 mg/l shall constitute grounds for rejection of the supply. Chromium is not known to be either an essential or beneficial element in animals. There is accumulation of chromium in many animals and when inhaled, chromium is a known cancerigenic agent for man. Trivalent chromium is not of concern in drinking water supplies at present.

In long-term tests conducted at the Federal Water Pollution Control Administration's Newtown Fish Toxicology Laboratory, in a hard water, 1 mg/l of hexavalent chromium was found to be a "safe" concentration for survival and reproduction of the fathead minnow. The lethal value in a similar water (200 mg/l hardness) was 33 mg/l. In a soft water, low pH bioassay the lethal value for the fathead minnow was 17 mg/l.

Bioassays conducted with four species gave lethal values of hexavalent chromium that ranged from 17 to 118 mg/l. Thus it appears that there is a great range of sensitivity of various fish species. Hexavalent chromium appears to be more toxic to some invertebrates; 0.05 mg/l is lethal to Daphnia, a very important animal in Lake Superior. In acute bioassays trivalent chromium is more toxic in soft water than hexavalent chromium. The chronic studies indicated that their toxicity is not greatly different.

II. Special Considerations. Hexavalent chromium is very soluble in water while trivalent chromium is much less soluble, especially in hard water. Many variables influence the toxicity of chromium. Trama and Benoit have shown that the toxicity of hexavalent chromium is dependent on pH; it is more toxic under conditions of low pH. The toxicity of trivalent chromium is dependent on concentration, pH, hardness, and equilibrium state.

III. EXISTING CONDITIONS. Hexavalent chromium concentrations found in Lake Superior at Duluth had a frequency of detection of 40%. In these samples of positive occurrence the mean concentration was 9 μg/l and the maximum was 20 μg/l. At St. Mary's River hexavalent chromium was found in 17% of the samples with a mean of 3 μg/l and a maximum of 7 μg/l. Data are not available for trivalent chromium concentrations.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The recommended criteria for total chromium is a maximum of 0.050 mg/l and 90% of the values should be less than 0.02 mg/l at any single location.

V. REFERENCES.

1. Pickering, Q. P., and Henderson, C. Acute Toxicity of Some Heavy Metals to Different Species of Warmwater Fishes, Proceedings 19th Industrial Waste Conference, Purdue University, 1965.

2. Trama, F. B., and Benoit, R. J. Toxicity of Hexavalent Chromium to Bluegills, Journal Water Pollution Control Federation, Volume 32, 1960.

COPPER

I. BIOLOGICAL EFFECTS. Copper is one of the more toxic of the heavy metals to many desirable aquatic organisms. It is also an essential trace element and is often added to the foods of both aquatic and terrestrial animals. It is commonly used to control algal growths in water supplies. The permissible concentration in public water supplies is 1 mg/l and the desirable concentration is virtually absent.

Experiments with trout, perch, sunfish, freshwater shrimp, Daphnia, snails, and clams establish the maximum no-effect concentrations in Lake Superior water to be between 0.01 and 0.05 mg/l. Trout, shrimp, and Daphnia, all important in Lake Superior, are among the most sensitive. To some animals, copper concentrations that kill are substantially higher than concentrations that retard growth and inhibit reproduction. Experimentation has shown that concentrations 1/10 to 1/30 of the lethal concentrations inhibit reproduction.

II. SPECIAL CONSIDERATION. Both pH and the calcium-magnesium content of water affects copper toxicity to aquatic organisms. The lethal concentrations are more affected by these characteristics than are the no-effect concentrations. Lake Superior water has low concentrations of calcium and magnesium and therefore copper is more toxic in it than in most other natural waters of the United States. For this reason, stringent criteria are needed.

III. EXISTING CONDITIONS. Five year average concentrations of copper at Duluth and the St. Mary's River are 0.003 and 0.005 mg/l, respectively. Some values have been reported as high as 0.02 mg/l, but nearly all are less than 0.01 mg/l. Except near sources of copper introduction, concentrations do not vary greatly.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The criteria for Lake Superior should be a maximum of 0.012 mg/l and 90% of the measurements should be less than 0.008 mg/l at any single location.

V. REFERENCES.

1. Sprague, J. B., Lethal Concentrations of Copper and Zinc for Young Atlantic Salmon, Journal of Fisheries Research Board, Canada, 21 (1), 1964.

2. Mount, Donald I. Chronic Toxicity of Copper to Fathead Minnows (Pimephales Promelas, Rafinesque). Water Research, 2:215-223, 1968.

3. Grande, Magne., Effect of Copper and Zinc on Salmonid Fishes, Third International Conference on Water Pollution Research, Section 1, Paper No. 5.

4. Sprague, J. B., Avoidance of Copper-Zinc Solutions by Young Salmon in the Laboratory. Journal Water Pollution Control Federation. Vol. 36 (8): 990-1004, 1964.

5. (Personal communication, National Water Quality Laboratory Staff.) Acute and Chronic Effects of Cu^{+2} on Fish and Invertebrates in Lake Superior Water, 1969.

LEAD

I. BIOLOGICAL EFFECTS. Lead is quite poisonous to aquatic organisms, concentrations of 0.1 mg/l having killed fish in soft water. In water more like that of Lake Superior, however, short term (a few hours to a few days) mortality test values of from 5 to 50 mg/l of lead have often been obtained.

The few longer term (up to six months), nonlethal exposures to lead in water have demonstrated that accumulations in various parts of the body result from continuous uptake of lead by the fish. Such accumulations in mammals have led to toxic effects and death after long periods of time, even many years. On the basis of available information on fish, similar results would be expected.

Daphnia in Lake Superior water are killed in a few days by an 0.5 mg/l concentration; mayflies, stoneflies, and caddisflies are killed at 16 to 64 mg/l concentrations.

II. SPECIFIC CONSIDERATIONS: Because of lead's low solubility in comparison with many other metal salts, pH and calcium-magnesium content of water are particularly important in determining its toxicity. High lead concentrations are particularly significant in the soft water of Lake Superior.

III. EXISTING CONDITIONS. The average concentration of lead in filtered water at the St. Mary's River over the five year period ending September 30, 1967 was 0.006 mg/l. Two filtered samples taken at Duluth during this period contained 0.007 and 0.02 mg/l. The average of 20 unfiltered samples taken at scattered sites in Lake Superior during 1967 is 0.027 mg/l. This figure excludes one very high and probably incorrect value of 0.306 mg/l that was found in a sample taken near the center of the lake.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The Public Health Service Drinking Water Standard of 0.05 mg/l should never be exceeded and 90% of the measurements should be less than 0.03 mg/l at any single location.

V. REFERENCES.

1. McKee, J.E., and Wolf, H.W., Water Quality Criteria, Publication No. 3-A, California State Water Quality Control Board, Second Edition, 1963.

2. Pickering, Q.H., and Henderson, C., 1966. The Acute Toxicity of Some Heavy Metals to Different Species of Warmwater Fishes. Air-Water Pollution International Journal 10:453-463.

3. Warnick, S.F., and Bell, H.L., 1969. The Acute Toxicity of Some Heavy Metals to Different Species of Aquatic Insects. Journal of Water Pollution Control Federation. 41:280-284.

4. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D.C. April 1968.

5. U.S. Department of Health, Education and Welfare, 1962, Public Health Service Drinking Water Standards, PHS Publication No. 956.

NICKEL

I. BIOLOGICAL EFFECTS. The U.S. Public Health Service Drinking Water Standards do not place any concentration limits on nickel. It is a nonessential element, and its toxicity to mammals appears to be very low. However, nickel may be very toxic to some plants.

The lethal concentration of nickel in soft water (20 mg/l hardness) to the fathead minnow is about 5 mg/l and in hard water (360 mg/l hardness) it is about 43 mg/l. With continuous-flow testing the lethal concentration is 20 mg/l in water of 200 mg/l hardness. Using these data, the estimated lethal concentration in Lake Superior water (44 mg/l hardness) would be 7 mg/l of nickel. Some Lake Superior fish are more sensitive, however.

In a long-term bioassay conducted with a water of 200 mg/l hardness at the Federal Water Pollution Control Administration's Newtown Fish Toxicology Laboratory, the "safe" concentration was 0.4 mg/l nickel. At this concentration the fathead minnow lived, grew, and reproduced.

II. SPECIAL CONSIDERATIONS. Certain environmental variables affect toxicity of nickel, but toxicity is not affected by hardness as much as for other metals. Various types of aquatic life differ considerably in sensitivity to nickel.

III. EXISTING CONDITIONS. Concentrations of nickel in the Western Great Lakes Basin were found in 9% of the samples. In the samples with positive occurrence, the mean concentration was 0.01 mg/1 and the maximum concentration was 0.028 mg/l. Nickel was not detected at Duluth.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. Nickel should not exceed a maximum of 0.03 mg/l and 90% of the values should be less than 0.015 mg/l at a single location.

V. REFERENCES.

1. Pickering, Q.P. and Henderson, C., Acute Toxicity of Some Heavy Metals to Different Species of Warmwater Fishes, Proceedings 19th Industrial Waste Conference, Purdue University, 1965.

ZINC

I. BIOLOGICAL EFFECTS. Zinc is one of several heavy metals occurring almost universally in surface waters. These natural levels of zinc vary greatly and are influenced by minerals in soils and characteristics of the water itself. Zinc is an essential trace metal for aquatic life, yet inhibits fish production at quite low concentrations.

Long-term tests with the fathead minnow in which the fish were continuously exposed to a series of zinc concentrations during the entire life cycle indicate that concentrations significantly inhibiting reproduction are much lower than the lethal concentrations or those that have demonstrated some histological or physiological changes. These studies were conducted in water with higher calcium, magnesium and pH than that found in Lake Superior water and therefore zinc was less toxic under the test conditions. A decrease in reproduction occurred at a zinc concentration of 0.045 mg/l in hard water. Since the test was conducted in a harder water than that of Lake Superior and the toxicity of zinc increases as the calcium-magnesium level decreases, the safe level in Lake Superior is lower than 0.045 mg/l. Zinc partially reduces reproduction over a wide range of concentrations and there is no sharp threshold.

II. SPECIAL CONSIDERATIONS. Many environmental variables affect the toxicity of zinc. Principal examples would be the calcium-magnesium content of the water, pH, temperature, and differential sensitivity of aquatic species. Such factors prohibit the selection of a single criterion for all freshwater environments.

III. EXISTING CONDITIONS. The mean zinc concentration in water taken at the Duluth, Minnesota, water treatment plant was 0.009 mg/l and at the St. Mary's River, 0.020 mg/l. The current permissible level of zind in public water supplies is 5 mg/l. The high values recorded in St. Mary's River are of concern.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. Zinc concentrations should not exceed 0.015 mg/l and 90% of the values should be less than 0.010 mg/l.

V. REFERENCES.

1. Brungs, W. A. Chronic Toxicity of Zinc to the Fathead Minnow (Pimephales Promelas, Rafinesque). Transcription American Fisheries Society, April 1969.

2. Mount, D. I. The Effect of Total Hardness and pH on Acute Toxicity of Zinc to Fish. Air and Water Pollution International Journal, 10:49-56 (1966).

3. Skidmore, J. F. Toxicity of Zinc Compounds to Aquatic Animals, with Special Reference to Fish. The Quarterly Review of Biology, 10 (3): 227 (Sept. 1964).

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CYANIDE

I. BIOLOGICAL EFFECTS. Cyanide is a highly poisonous chemical and occurs principally from industrial processes. It combines with hemoglobin in blood, forming a rather stable complex, and reduces the oxygen-carrying capacity of the blood. It is poorly removed by normal water treatment processes.

Experiments with trout and bluegills resulted in total kill at 0.05 mg/l and other adverse effects as low as 0.005 mg/l.

The U.S. Public Health Service Drinking Water Standard is 0.2 mg/l and the desirable concentration is virtually zero.

II. SPECIAL CONSIDERATIONS. Cyanide toxicity to aquatic life forms is highly pH dependent. Undissociated hydrocyanic acid is most toxic and this is present in the largest proportion at low pH values. It combines readily with heavy metals and may be more or less toxic than the uncombined form, depending on the particular complex.

III. EXISTING CONDITIONS. Average concentrations at both Duluth and the St. Mary's River are less than 0.001 mg/1.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The maximum concentration should not exceed 0.004 mg/l and 90% of the values should be less than 0.002 mg/l at any location.

V. REFERENCES.

1. Biology of Water Pollution, U.S. Department of the Interior, Federal Water Pollution Control Administration, 1967.

2. U.S. Department of Health, Education and Welfare, 1962, Public Health Service Drinking Water Standards, PHS Publication No. 956.

3. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D.C. April, 1968.

4. Cairns, John. Notulae Naturae, #361, July 30, 1963.

5. Doudoroff, P. Transactions of the American Fishery Society, Vol. 95, No 1, Jan. 1966.

HYDROGEN SULFIDE

I. BIOLOGICAL EFFECTS. Sulfides in water are the result of natural processes of decomposition in enriched waters, sewage, and industrial wastes such as those from oil refineries, tanneries, pulp and paper mills[1] chemical plants, and gas manufacturing facilities. Sulfides are produced by the action of anerobic organisms on sulfates and organic sulphur compounds. Hydrogen sulfide contributes to taste and odor of water supples that can be detected by man at 0.005 - 0.010 mg/1[2] and taints flesh of aquatic organisms.

Experiments with eggs and fry of trout, walleye, northern pike, suckers, and immature blue gills and fathead minnows indicate lethal concentrations of undissociated hydrogen sulfide to vary between 0.008 - 0.058 mg/1[2]. Trout fry are killed in three days at 0.020 mg/1 at high oxygen levels. Freshwater shrimp are more sensitive than fish fry.

II. SPECIAL CONSIDERATION. Hydrogen sulfide decays exponentially with a half life of one hour in oxygenated water.[3] However, it can be evolved into oxygenated water from organic deposits and can be found at lethal concentrations at the bottom-water interface.[1] The toxicity of an effluent may bear no relation to its potential toxicity in organic deposits. Fish eggs, fry, and food organisms are most susceptible. Since most species of sport and commercial value in Lake Superior spawn at depths of 100 fathoms or less,[4] it is important that good water quality be maintained to this depth at the bottom-water interface.

Fish fry are more sensitive to hydrogen sulfide at low oxygen concentrations.[2] The toxicity of sulfide increases markedly with a decrease in pH because there is more undissociated hydrogen sulfide present.

III. EXISTING CONDITIONS. No measurements of dissolved sulfide have been recorded for Lake Superior, however, it is unlikely that any accumulation has occurred since high oxygen levels are found even at 250 meters.

IV. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The recommended criteria is a maximum of 0.02 mg/1 and 90% of the values less than 0.002 mg/1 as total sulfide measured at the bottom-water interface.

V. LITERATURE CITED.

1. Colby, Peter J., and Smith, Lloyd L., Jr., 1967. Survival of Walleye Eggs and Fry on Paper Fiber Sludge Deposits in Rainy River, Minnesota. Transactions American Fisheries Society 96 (3) 278-296.
2. Unpublished Data, Department Entomology Fish and Wildlife, University of Minnesota, St. Paul.
3. Hayes, F. R., Reid, B. L. and Cammeron, M. L. 1958. Lake Water and Sediment. II. Oxidation-Reduction Relations at Mud-water Interface. Limnology and Oceagrophy 3: 308-317.
4. Unpublished Data, Bureau of Commercial Fisheries, Ashland, Wisconsin.
5. Longwell, J. and Pentelow, F.T.K. 1935. The Effect of Sewage on Brown Trout (Salmo trutta L.) Journal Exp. Biology 12: 1-12.

TASTE AND ODOR

1. GENERAL CONSIDERATIONS. Tastes and odors affect principally municipal water supplies and beverage industries. In places, tainting of fish flesh occurs and causes impairment of the water for fish production. Great expense is incurred at some treatment plants in other areas of the country because activated carbon treatment is needed to remove tastes and odors.

II. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. Taste and odor do not exist at present in Lake Superior, and in order to avoid expensive treatment in the future, substances causing taste and order should not be permitted. Chloroform extracts should not exceed a maximum of 0.05 mg/1 and 90% of the values should be less than 0.03 mg/1. Threshold odor numbers should not exceed 3 and 90% of them less than 1.

III. REFERENCES.

1. U. S. Department of Health, Education and Welfare, 1962, Public Health Service Drinking Water Standards, PHS Publication No. 956.
2. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D. C. April 1968.
3. Microbiology for Sanitary Engineers. McKinney. 1962.
4. Duluth Municipal Water Supply. Ten Year Composite Log Annual Reports. Duluth, Minnesota. 1968.
5. Quality of Waters, Minnesota - a Compilation - Taste and Odor, 1955 - 1962. State of Minnesota, Department of Conservation, Division of Waters, Bulletin 21, June 1963.

TEMPERATURE

I. GENERAL CONSIDERATIONS. Temperature affects all physical, chemical, and biological processes in Lake Superior. If the normal temperature regime is altered the complete balance of the lake will be changed. An increase in temperature is known to accelerate the aging process of lakes, increase the toxicity of chemicals, lower dissolved oxygen levels, increase algal growths, disrupt delicate biological cycles, and endanger many important sensitive organisms.

Increases in the water temperature of Lake Superior will require more stringent water quality standards for other parameters.

II. BIOLOGICAL EFFECTS. The valuable lake trout, herring and whitefish of Lake Superior require cold water for their survival. Complete mortality of developing embryos is known to occur at 12°C (54°F.). Significant reduction in hatch occurs above 60°C (43°F.) among the coregonid fishes. Most of the important fish in Lake Superior spawn in the fall (Oct., Nov., Dec.) in response to falling temperatures, requiring temperatures of about 10°C (50°F.) or less to initiate the response. Incubation of the eggs which are found on the lake bottom is best below 6°C (43°F.). Optimum incubation occurs at 0.5°C (33°F.) for the lake whitefish (Coregonus clupeaformis) and 2°C (36°F.) or less for the lake herring (C. artedi). Upon hatching in the spring the young fish move into surface waters and at this time exhibit greater temperature tolerance than the incubating eggs. Exposure to temperatures of 15°C (59°F.) will be tolerated by lake herring fry for extended periods without increased mortality rates. Temperature between 18 - 21°C (64-70°F.) will be tolerated for lesser periods but extended exposure to these temperatures increases rate of mortality markedly.

III. SPECIAL CONSIDERATIONS.

A. Heated effluents should not contribute to temperatures of water so as to cause them to serve as barriers to the movement of anadrumous fish to and from their spawning and rearing areas.

B. Discharge of heated effluents should be to the epilimnion, unless a special study indicates a more desirable discharge point, because the important fish species in Lake Superior are deep water dwellers much of the time.

IV. EXISTING CONDITIONS. Lake Superior is a cold clear, oligotrophic lake. It usually does not exhibit well defined temperature stratification until mid-July and even then the stratification is not uniform from area to area and the thermocline is poorly developed. The lake may mix to great depths and homothermous water around 2°C (36°F.) has been found to occur to depths of 600 ft. The deep water remains near 4°C (39°F.) through the year. Yearly average temperatures from Duluth and St. Mary's River are 8.5°C (47°F.) and 7.3°C (45°F.).

Nine year average temperatures at St. Mary's River, given as quarterly averages are:

		Average of Quarterly Mean	Average of Quarterly Maximum
I.	(Jan., Feb., Mar.)	- 0.7° C (33° F)	2.3° C (36° F)
II.	(Apr., May, June)	- 5.5° C (42° F)	14.9° C (59° F)
III.	(July, Aug., Sept.)	- 16.0° C (61° F)	20.4° C (69° F)
IV.	(Oct., Nov., Dec.)	- 7.0° C (45° F)	13.8° C (57° F)

Average temperatures along the North Shore and mid-lake are below these temperatures while averages for areas along the South Shore (Calumet, Marquette, etc.) are similar and occasionally somewhat higher.

These are the maximum values for Lake Superior obtained from the literature as referenced.

I.	(Jan., Feb., Mar.)	-	Mean	1.3° C	(34° F)	Soo (St. Mary's R.)	1965 NWQN
			Max.	2.8° C	(37° F)	Marquette	1954 Beeton
II.	(Apr., May, June)	-	Mean	6.8° C	(44° F)	Soo (St. Mary's R.)	1964 NWQN
			Max.	17.2° C	(63° F)	Calumet	1955 Beeton
III.	(July, Aug., Sept.)	-	Mean	17.9° C	(64° F)	Soo (St. Mary's R.)	1966 NWQN
			Max.	25.0° C	(77° F)	Calumet	1953 Beeton
IV.	(Oct., Nov., Dec.)	-	Mean	7.6° C	(46° F)	Soo (St. Mary's R.)	1963 NWQN
			Max.	13.9° C	(57° F)	Calumet	1953 Beeton

V. RECOMMENDED CRITERIA FOR LAKE SUPERIOR.

A. The recommended quarterly mean and maximum surface[1] water temperatures[2] for Lake Superior that are not to be exceeded are given below:

I.	(Jan., Feb., March):	Mean-	2° C (36°F)
		Maximum-	5° C (41°F)
II.	(April, May, June):	Mean-	10° C (50°F)
		Maximum-	18° C (64°F)
III.	(July, Aug., Sept.):	Mean-	18° C (64°F)
		Maximum-	21° C (70°F)
IV.	(Oct., Nov., Dec.,):	Mean-	8° C (46°F)
		Maximum-	15° C (59°F)

[1]less than 1 meter (3 ft.).
[2]based on continuous temperature monitoring.

B. Water temperatures of 6° C (43°F) shall never be exceeded at depths of 20 fathoms (120 ft.) or greater.

C. The water depth between 3 feet and 120 feet shall be a zone temperature transition.

VI. REFERENCES.

1. Beeton, A.M., Johnson, J.H. and Smith, S.H., 1959. Lake Superior Limnological Data. U. S. Fish and Wildlife Service Special Science Report - Fisheries No. 297, Washington, D. C., 177 pp.
2. Breeder, C. M. Jr., and Rosen, D. E., 1966. Modes of Reproduction in Fishes, American Museum of Natural History, Garden City, New York.
3. Dryer, W.R., 1966. Bathymetric Distribution of Fish in the Apostle Island Region of Lake Superior. Transactions of American Fisheries Society. 95 (3): 248-259.
4. National Water Quality Laboratory: Thermal Studies, 1966-1969. Unpublished Data.
5. National Water Quality Network (1957-1968) Annual Compilation of Data. (Storet Retrival System). U. S. Department of Health, Education and Welfare, Washington, D. C.
6. Price, John W., 1940. Time-temperature Relations in the Incubation of the Whitefish, Coregonus clupeaformis (Mitchill). Journal General Physics (4) 23: 449-468.
7. Ruschmeyer, O.R. and Olson, T.A., 1958. Water Movements and Temperatures of Western Lake Superior. School of Public Health, University of Minnesota, for Minnesota Water Pollution Control Commission, 86 pp.
8. Tait, J. S., 1960. The First Filling of the Swim Bladder in Salmonids. Canadian Journal of Zoology. 38: 179-187.
9. Wells, LaRue, 1966. Seasonal and Depth Distribution of Larval Bloaters (Coregonus hoyi) in Southeastern Lake Michigan. Transactions of American Fisheries Society. 95 (4); 388-396.

pH

I. GENERAL CONSIDERATIONS. Most organisms of esthetic and commercial importance live in water within an extremely narrow pH range. The pH concentration is governed by many inorganic chemicals and biological processes. Excessive additions of domestic or/and industrial wastes result in pH changes and can therefore make water unsuitable for desirable organisms. Thus it is important to control pH which in turn will regulate other water quality parameters.

II. BIOLOGICAL EFFECTS. Rudolfs, et. al. (1953) states that a pH range from 6.5 to 8.4 is tolerated by most fish. Chandler (1940) suggests values between 7.5 to 8.4 to be best for plankton production. Ellis (1937) found that most inland waters having fish have pH values between 6.7 and 8.6. Hart, et. al. (1945) report that only 5% of the waters in the United States supporting a good fish population have pH less than 6.7 whereas 95% have a pH less than 8.3. Parsons (1968) found the greatest number of species of plankton, benthos, and fishes to be in stream sections with a pH of 6.8 and above.

Work with pH at the National Water Quality Laboratory suggests that pH values below 6.0 inhibit or reduce spawning success with fathead minnows, and are lethal to Daphnia magna and new Gammarus pseudolimnaeus.

III. SPECIAL CONSIDERATIONS. Permissible criteria for public water supplies given in Water Quality Criteria (1968) give a range of pH from 6.0 - 8.5.

IV. EXISTING CONDITIONS. Lake Superior is an oligotrophic lake low in total dissolved solids and rather poorly buffered. Beeton (1959) gives pH values ranging from 6.9 to 8.0 in 1953 for samples taken at various depths in the open lake; however, most values were between 7.3 and 7.7. The maximum, minimum and mean pH values in Lake Superior were:

	Lake Superior at Duluth	St. Mary's River at Saulte Ste. Marie
Years	1958 - 1968	1960 - 1968
No. Samples	543	457
Maximum	8.5	8.3
Minimum	7.3	6.8
Mean	7.7	7.8

V. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. The pH in Lake Superior should remain between 6.8 to 8.5.

VI. REFERENCES.

1. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D.C., April 1968.
2. Beeton, A.M., J.H. Johnson, and S.H. Smith, 1959. Lake Superior Limnological Data. U.S. Fish and Wildlife Service Special Science Report -- Fisheries No. 297, Washington, D.C., 177 pp.
3. Chandler, D.C., 1941. Limnological Studies of Western Lake Erie. I. Plankton and Certain Physical-Chemical Data on the Bass Islands Region, from September 1938 to November 1939. Ohio Journal of Science 40, 291.
4. Ellis, M.M., 1937. Detection and Measurement of Stream Pollution (Related principally to fish life). U.S. Department of Commerce, Bureau of Fisheries Bulletin 22.
5. Hart, W.B., P. Doudoroff, and J. Greenbank. 1945. Evaluation of Toxicity of Industrial Wastes, Chemicals and Other Substances to Freshwater Fishes. Water Control Laboratory, Atlantic Refining Company, Philadelphia, Pennsylvania.
6. Parsons, J.D., 1968. The Effects of Acid-Strip-Mine Effluents on the Ecology of a Stream. Arch. Hydrobiol. 65(1):25-50.
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RADIOACTIVITY

I. GENERAL CONSIDERATIONS. There are at present no numerical radiological criteria directly applicable to the open waters of Lake Superior. Releases of radioactive materials to the lake (or otherwise) are regulated, however, by license by the Atomic Energy Commission.[1] Concentration of radionuclides in food and water used in interstate commerce, derived from the lake, are regulated by the U. S. Public Health Service. In addition, State and local regulations limit the concentrations permitted in public drinking waters.

The Federal Water Pollution Control Administration has been working with the Atomic Energy Commission and the U. S. Public Health Service to develop model radiological criteria for water. These criteria will apply to receiving waters, as different from waste effluents which are regulated by the Atomic Energy Commission as noted above. These criteria will be composed of three parts designed for the protection of human health as it may be affected through (1) drinking water, (2) waters used for recreation and other purposes involving potential human contact with or ingestion of water, and (3) waters used for the production or processing of food for human consumption (i. e. fish, shellfish, irrigated crops, milk, etc.).

After a draft of the criteria, developed at staff level through the joint effort of these three Federal agencies, has been reviewed and officially endorsed by each agency, it will be submitted to the Federal Radiation Council, the Conference of State Sanitary Engineers and an appropriate organization of the State radiological health officers for review, comments and hopefully, endorsement. This process may require up to a year to complete.

II. EXISTING CONDITIONS. The 12 year average gross beta radioactivity at Duluth is approximately 9. 5 picocuries/1, including several years of active atmospheric bomb testing (and accompanying fallout). Radioactivity levels since 1965 have averaged less than 3. 5 picocuries/1.

The similar 12 year average for total alpha activity, which includes radium and other naturally occurring radionuclides, is approximately 0. 12 picocuries/1.

Similar averages were obtained at the St. Mary's River station.

III. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. It is recommended that action to establish radiological criteria for Lake Superior be deferred until the model criteria have been fully developed.

IV. REFERENCES.

1. U. S. Atomic Energy Commission, Part 20: Standards for Protection Against Radiation, Federal Register 25 (224): 10914-10924. November 17, 1960.
2. National Committee on Radiation Protection, Report of Ad Hoc Committee, Somatic Radiation Dose for General Population, Science 131:482. February 19, 1960.
3. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposures. Handbook No. 69, National Bureau of Standards, Washington, D. C. 1959.
4. Background Material for the Development of Radiation Protection Standards. Staff Report, Federal Radiation Council, Washington, D. C. July 1964.
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ALL OTHER POLLUTANTS

I. GENERAL CONSIDERATIONS. Application factors provide a rational basis for estimating safe concentrations of pollutants utilizing easily obtained lethal values and are especially useful for establishing safe concentrations of mixed effluents. The procedures to be followed in deriving application factors are discussed on pages 58 and 59 of the Report of the National Technical Advisory Committee on Water Quality Criteria and a brief outline follows.

As the report points out, a great difference usually exists between the toxicant concentration that kills in a few days and the concentration that is just barely safe over one or more entire life cycle periods of continuous exposure to the toxicant. An application factor is composed of the ratio or fraction derived by relating, for a given pollutant, the mortality data from a four day toxicity test to the just safe concentration for the entire life cycle. This factor can subsequently be used to estimate environmental concentrations of this toxicant that are safe for different species of fish or in different water types. One does this by multiplying the application factor for the pollutant by the toxicity data obtained from a four day test with the new species or water type. A different application factor must be calculated for each pollutant.

Thus, application factors are important because they eliminate the necessity of having to expose entire life cycles of all species in all water types. They have varied from 1/7 to 1/500 for different pollutants that have been tested.

II. RECOMMENDED CRITERIA FOR LAKE SUPERIOR. In the absence of specific information, safe concentrations of pollutants should be:

1. For nonpersistent pollutants or those that have noncumulative effects, the environmental concentration should not exceed 1/10 of the 96-hour TL_m level at any time or place, and 90% of the measurements should not exceed 1/20 of the 96-hour TL_m value.
2. For other toxicants the environmental concentrations should not exceed 1/20 and 1/100 of the 96-hour TL_m level under the conditions described in (1) above.
3. Proportional reductions should be made in the permissible concentrations of pollutants when they are known to affect or add to the toxicity of other pollutants present in the water.

III. REFERENCES.

1. Water Quality Criteria, Report of the National Technical Advisory Committee to the Secretary of the Interior, Federal Water Pollution Control Administration, Washington, D. C., April 1968.
2. Mount, D.I., and C.E. Stephan. 1967. A Method for Establishing Acceptable Toxicant Limits for Fish--malathion and the butoxyethanol ester of 2, 4-D. American Fish Society, Trans. 96(2): 185-193.