Water quality and trophic condition of Lake Superior (Wisconsin waters). Report 68 1971

Winter, Donald R.
Madison, Wisconsin: Dept. of Natural Resources, 1971

RESEARCH REPORT 68

WATER QUALITY AND TROPHIC CONDITION OF LAKE SUPERIOR (WISCONSIN WATERS)

By

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Department of Natural Resources

Madison, Wis.

1971

ACKNOWLEDGMENTS

I first wish to thank the Wisconsin Department of Natural Resources for making this study possible. Those within the Department to whom I owe my gratitude include Mr. Lloyd A. Lueschow, Chief, Laboratory Services Section, Division of Environmental Protection, for his suggestions in this stuay; Mr. Orville Weborg, Conservation Warden, who navigated the research vessel in open waters; Mr. Dan Ryan, District Water Pollution Biologist, who assisted me with the field work; and to the Department chemists who performed many of the chemical analyses.

I especially wish to thank Professor J. Magnuson of the University of Wisconsin Department of Zoology and Dr. H. F. Henderson formerly of the University of Wisconsin Department of Zoology, for their guidance in this research project and their thoughtfulness during the course of my graduate studies.

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Edited by Ruth L. Hine

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INTRODUCTION

Lake Superior is a great asset to northern Wisconsin. The lake's large size and generally good water quality make it important for pleasure boating, shipping, commercial and sport fishing, and potable water supplies. The shipping of iron ore and grain is of substantial economic importance to the area. Many goods are received in ports of Lake Superior for dispersal to midcontinent regions. The aesthetic value of Lake Superior cannot be overemphasized. The scenery along much of the Wisconsin shoreline is superb, particularly the rugged cliffs and rock formations of the Bayfield Peninsula. These values, at least in part, stimulated this study to determine present water quality conditions. Water quality and trophic conditions of Wisconsin and boundary waters in Lake Superior were established from field collections made during the summer of 1968.

Lake Superior, the largest of the St. Lawrence Great Lakes, is approximately 610 km long, 260 km wide, and 400 m deep. The surface area is 82,360 square km. Approximately 8,300 square km of northern Wisconsin drain into Lake Superior. This area includes portions of Douglas, Ashland, Bayfield and Iron Counties and extends 160 km from the St. Louis River and the Wisconsin-Minnesota Boundary on the west to the Montreal River and the Wisconsin-Michigan Boundary on the east. The drainage area has an average width of 50 km. Wisconsin river systems tributary to Lake Superior are listed in Table 1 with their respective drainage areas (Schraufnagel et al., 1966).

The Wisconsin shoreline can be divided into three topographic units. A flat elevated plain with deeply eroded ravines and predominately red clay soils characterizes Douglas County, western Bayfield County, a portion of Iron County, and eastern Ashland County. Rugged hills and sandstone outcroppings with poorly defined drainage patterns typify the Bayfield Peninsula. Low flat areas with soils of peat and muck are found at the southwestern end of Chequamegon Bay and in the Kakagon Sloughs.

TABLE 1

Wisconsin River Systems Tributary to Lake Superior (Drainage Areas in Square Km.)

Amnicon	337	Montreal	466
Bad	2,631	Nemadji	458
Bois Brule	479	Poplar	119
Fish	360	St. Louis	199
Flog	184	Sioux	249
Iron	389	Siskiwit	80
Middle	130		

DESIGN & METHODS

Sample Stations

Sampling transects were established prior to the field study with stations located 1, 2.5, and 5 km from shore. Additional stations were added during the study in the vicinity of waste discharges and in other areas where variability was thought to be significant. A center transect, running from the Superior Bay to a point north of the Apostle Islands, was also established with sampling stations at 1.0, 1.5, 2.5, 5.0, 8.0, 16.0, 24.0, 40.0, 64.1, 89.0, and 113.0 km northeast of Superior Bay and equidistant between the Minnesota and Wisconsin shorelines (Fig. 1).

Dissolved Oxygen

Dissolved oxygen was sampled during daylight hours near waste sources and outside Superior Bay. Samples were collected with a brass Kemmerer water bottle and analyzed by the azide modification of the Winkler method (Amer. Public Health Assoc. et al., 1965). Extensive sampling was not conducted in open waters because Beeton (1965) reported saturated dissolved oxygen concentrations at all depths in Lake Superior.

Nutrients

Nitrogen and phosphorus samples were analyzed according to standard methods (Amer. Public Health Assoc. et al., 1965). Analyses were made for several major Wisconsin tributaries, Superior Bay, Chequamegon Bay, and along the center transect of Lake Superior.

Transparency

Secchi disc readings and turbidity samples were taken at nearly all sampling stations. A Hack turbidimeter was used with results expressed in standard units.

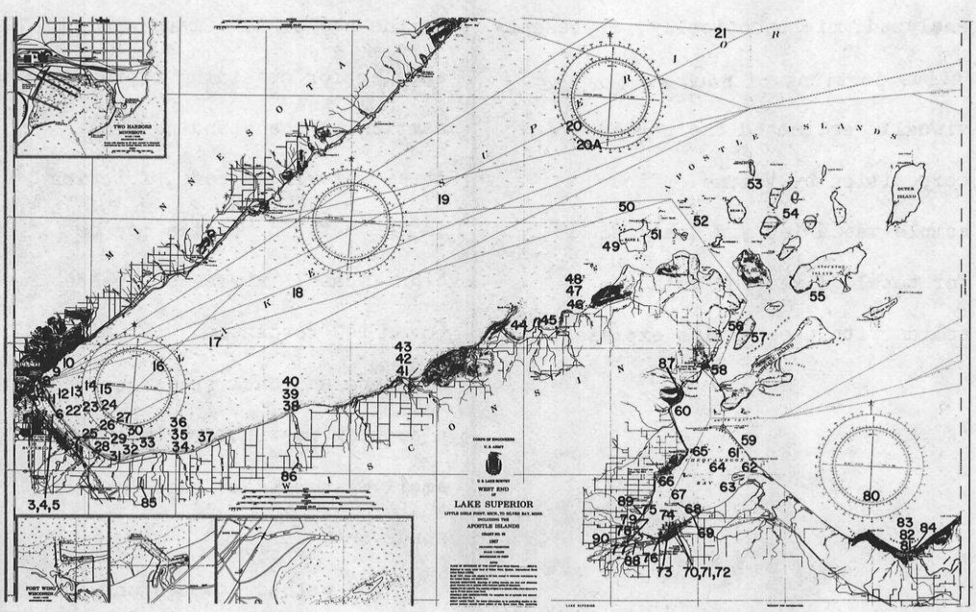

FIGURE 1. Sampling Locations During July, 1968, Survey

Bottom Sediments

At each station where Petersen dredge samples were collected, visual observations of the physical characteristics of the sediments were recorded. These were considered important because bottom sediments may be related to the distribution and abundance of benthic organisms and may indicate unnatural conditions due to waste discharges.

Benthos

Benthic organisms were collected with a Petersen dredge. Macro-invertebrates were concentrated with a standard 30 sieve, preserved with 10 percent formalin in the field then tentatively identified and enumerated in the laboratory. Most organisms were identified to genus and were categorized as to their sensitivity to organic pollution or lowered dissolved oxygen concentrations. Those considered less sensitive are able to withstand lower dissolved oxygen concentrations for extended periods of time while the more sensitive organisms require higher concentrations. In lotic environments, rock or gravel riffles often produce the greatest species diversity. In lentic environments, there is generally little species diversity. In both lotic and lentic environments, organically enriched or slightly polluted habitats support the highest number of organisms.

Seston

Seston was collected with a Clarke-Bumpus sampler using a 20-mesh net with a 12.5 cm diameter. The samples were concentrated in the 20-mesh Clarke-Bumpus cup and preserved in 10 percent formalin. Three different observers analyzed, microscopically, representative portions of each sample and visually estimated the percentage composition by volume. Each sample was dried and analyzed for total, fixed and volatile solids with the results expressed as micrograms of solids per liter of water filtered (Amer. Public Health Assoc. et al., 1965). The measurements of volatile solids are of particular importance since they are an indication of standing crop which is related to nitrogen and phosphorus concentrations in the water.

Net collections as described above fail to capture many of the smaller algal species such as Chlorella sp. and for this reason are not representative of the total species composition nor do they represent the total solids concentration. McNaught (1965) describes other limitations in the use of the Clarke-Bumpus sampler for obtaining representative samples of the standing crop. At slow-towing speeds, friction in the metering device may be significant. At faster speeds (over 140 revolutions per minute) clogging and back pressure become a problem particularly with small mesh nets as used in this study.

The method, though only an approximation of the standing

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crop, is valuable in comparing standing crops of various lakes as well as different areas of large lakes.

Cladophora

Visual observations were made of the distribution and abundance of Cladophora sp., a green, filamentous algae that grows on wave-washed rocks, pilings or other suitable substrate. These growths have been personally observed in nuisance proportions in some shoreline areas of Lake Michigan and other lakes.

Fish Net Slimes

Numerous complaints had been received, principally from commercial fishermen in the Bayfield area, regarding the accumulation of slime growths on fish nets, a problem apparently of recent years. Growths are sometimes so heavy that the nets are difficult to lift. Several requests were made of commercial fishermen to collect samples of the slime growths for microscopic examination.

Dissolved Oxygen

No dissolved oxygen was found 3.0 m off the lagoon overflow of Superior Fiber Products, Inc. (Station 4A) (Table 2). None of the other concentrations were low enough to be critical for aquatic life. The concentration 90 meters off the Superior sewage treatment plant was 8.5 mg/liter. Other values in the St. Louis River and Superior Bay ranged from 4.3 to 6.5 mg/liter. Values of 10.9 and 11.3 were found 2.5 kilometers off the Superior entrance and were near saturation.

In Chequamegon Bay at Ashland, samples 90 meters and 1.0 kilometers off the American Can Company had concentrations of 8.4 and 9.2 mg/liter respectively. A sample 30 meters off the plant could not be titrated due to some unknown chemical interference.

Nutrients

Organic nitrogen is that which is bound in plankton and organic detritus and is thus an indication of standing crop or trophic conditions.

Organic nitrogen was at a minimum in the Apostle Island region where the concentration

Table 2

Daytime Dissolved Oxygen Concentrations in the Vicinity of Waste Sources and Superior Bay

Station No.	Sample Location	Sample Depth (m)	mg/liter
1	St. Louis River - mouth	0.5 6.0	6.2 5.8
3	Superior Bay - south of Superior Fiber Products lagoon	0.5 1.0	6.1 4.3
4A	Superior Bay - 3 m off Superior Fiber Products lagoon outfall	0.5	0.0
4B	Superior Bay - 30 m off Superior Fiber Products lagoon	0.5	5.5
5	Superior Bay - 150 m east of Superior Fiber Products lagoon	0.5 2.0	5.0 6.5
26	Lake Superior - 2.5 km off Superior entrance	0.5 15.0	10.0 11.3
71	Chequamegon Bay - 100 m off American Can Company outfall	0.5	8.4
72	Chequamegon Bay - 1.0 km off American Can Company	0.5 4.0	9.2 9.5

was 0.10 mg/liter (Table 3; Figs. 2 and 3). Multiple samples along the center transect produced the lowest mean concentration followed by those in Chequamegon Bay and Superior Bay.

Inorganic nitrogen, that which is ultimately available for organic production, followed a similar pattern (Fig. 4). Only the sample in the Apostle Island region and the mean concentration for the center transect samples, 0.242 and 0.291 mg/liter respectively, were below 0.30 mg/liter, the concentration often considered critical for nuisance algal populations (Sawyer, 1947). The mean concentrations for Chequamegon Bay and Superior Bay were 0.395 and 0.680 mg/liter.

Total phosphorus concentrations were also lowest in the Apostle Island region with the mean concentrations increasing in the center transect samples, Chequamegon Bay, and Superior Bay (Figs. 5 and 6). These values may also be related to standing crop during the active growing season.

Soluble phosphorus is that

TABLE 3

Nitrogen and Phosphorus Concentrations (mg/liter)

Station No.	Sample Area	Organic	NH_3-N	NO_2-N	NO_3-N	Total Inorganic	Soluble Phosphorus	Total Phosphorus
1	St. Louis River	0.98	0.34	0.012	0.41	0.762	0.057	0.112
2	Superior Bay	0.90	0.17	0.010	0.37	0.550	0.028	0.108
6	Superior Bay	0.83	0.21	0.040	0.49	0.740	0.058	0.110
7	Superior Bay	0.89	0.24	0.014	0.49	0.740	0.042	0.106
12	1.5 km off Superior Bay	0.27	0.08	0.002	0.26	0.340	0.011	0.035
14	5 km off Superior Bay	0.18	0.05	0.002	0.26	0.312	0.007	0.022
15	8 km off Superior Bay	0.14	0.04	0.002	0.26	0.302	0.008	0.020
16	16 km off Superior Bay	0.13	0.04	0.002	0.24	0.282	0.007	0.020
17	24 km off Superior Bay	0.13	0.04	0.002	0.24	0.282	0.006	0.020
18	40 km off Superior Bay	0.14	0.05	0.002	0.24	0.292	0.008	0.020
19	64 km off Superior Bay	0.17	0.02	0.002	0.24	0.282	0.009	0.028
20	89 km off Superior Bay	0.14	0.02	0.002	0.22	0.242	0.006	0.020
21	113 km off Superior Bay	0.14	0.06	0.002	0.22	0.282	0.008	0.014
54	Apostle Islands (South Twin)	0.10	0.02	0.002	0.22	0.242	0.007	0.018
61	Chequamegon Bay	0.19	0.05	0.003	0.24	0.293	0.004	0.016
67	Chequamegon Bay	0.25	0.05	0.012	0.36	0.422	0.050	0.076
74	Chequamegon Bay	0.26	0.05	0.010	0.36	0.420	0.012	0.170
78	Chequamegon Bay	0.23	0.12	0.006	0.32	0.446	0.008	0.040
85	Amnicon River	0.88	0.12	0.005	0.29	0.415	0.005	0.060
86	Brule River	0.72	0.10	0.002	0.17	0.272	0.042	Turbid
87	Pikes Creek	0.35	0.10	0.007	0.24	0.347	0.031	0.050
88	South Branch Fish Creek	1.07	0.14	0.006	0.34	0.486	0.097	0.110

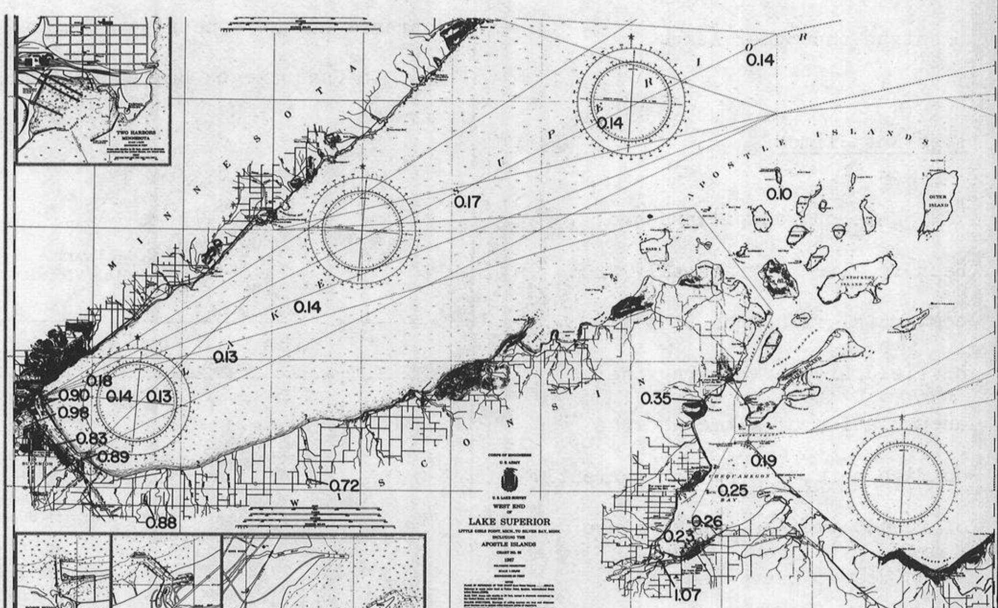

FIGURE 3. Location of Organi
Nitrogen Concentration

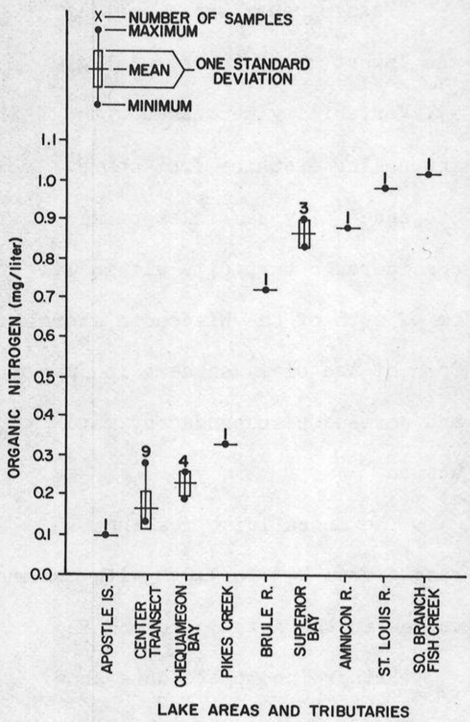

FIGURE 2. Organic Nitrogen by Lake Areas and Tributaries

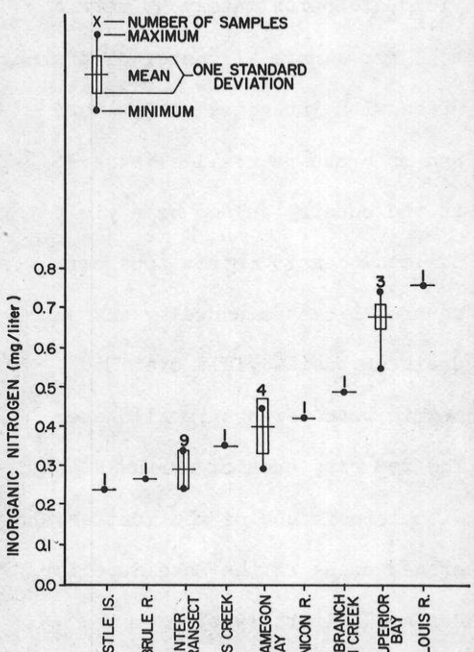

FIGURE 4. Inorganic Nitrogen by Lake Areas and Tributaries

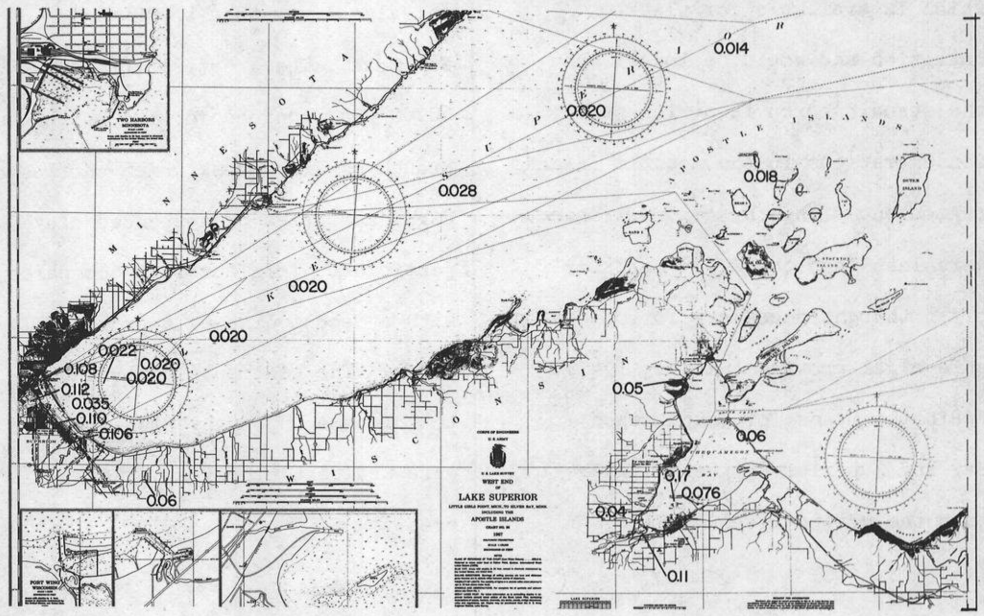

FIGURE 6. Total Phosphorus Concentrations

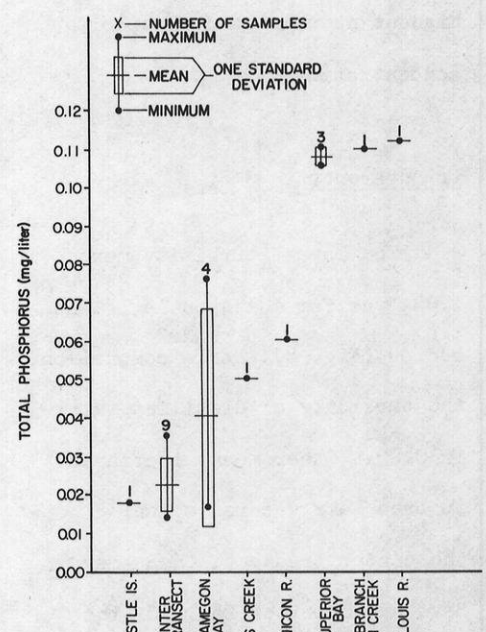

FIGURE 5. Total Phosphorus by Lake Areas and Tributaries

which is available for plankton nutrition and would be lowest when the standing crop is at its peak. Concentrations in the Apostle Island region and along the center transect were less than the 0.015 mg/liter often thought necessary for objectionable algal growths (Sawyer, 1947). Again the means for Chequamegon Bay and Superior Bay were higher than the critical value (Fig. 7).

Nitrogen and phosphorus concentrations for grab samples from tributary streams were highly variable. The South Branch of Fish Creek and the St. Louis River had the highest nitrogen and phosphorus concentrations.

Transparency

The lowest turbidity mean, 1.06, was for the Apostle Island region (Fig. 8). As a comparison, the turbidity of distilled water is 0.02. Other means increased in open lake waters including the center transect, Chequamegon Bay, and Superior Bay. Of the five rivers tested, the St. Louis had the lowest measurement which was also lower than the Superior Bay mean. The greatest turbidity, 60.00 was recorded for the South Branch of Fish Creek which carries high quantities of suspended clay particles. This turbidity compares with a Secchi disc of approximately 0.3 m. The sediments contributed to Chequamegon Bay by Fish Creek were noticeable over an extensive area.

Turbidity From Fish Creek Sediments in Chequamegon Bay

Transparency was generally the lowest close to shore (Fig. 9). Variability decreased with increasing distance from shore. Suspended clay particles caused considerable turbidity within 1.1 km of much of the Wisconsin shoreline Some of the clay was held in suspensi and perhaps resuspended by wave action.

The Secchi disc readings ranged from 0.3 to 7.0 m with maximum values in the Apostle Island Region.

Rather incomplete data show the Bad River near Odanah, Wisconsin, to have an average annual sediment yield of approximately 95 metric tons per square kilometer of drainage. Areas with intensive agriculture and moderate rainfall elsewhere in the country seldom have yields of less than 35 metric tons per square kilometer annually and some drainage basins yield over 350 metric tons per square kilometer. The red clay area of northwestern Wisconsin is one of the most severely eroded areas in the Lake Superior Basin (Collier, 1968).

Hack turbidity measurements and Secchi disc values do not show a linear relationship as might be expected (Fig. 15). In relatively clear water the Secchi disc values vary from 0.6 to 6.1 meters. The Hack turbidity measurements, in this range where the Secchi values vary widely, are between 0 and 7. These values between 0 and 7 represent considerably less variability. Reasons for this discrepancy in transparency measurements are the numerous factors affecting the Secchi disc readings. The depth of disappearance from sight is related to the apparent decrease in disc diameter or vanishing point as the disc moves away from the observer. This effect is obviously greater in clear waters as the distance from observer to disc is greater. Other effects on the depth of disappearance may be the shadow of the vessel, the reflection of the disc, and glare and image distortion of the disc

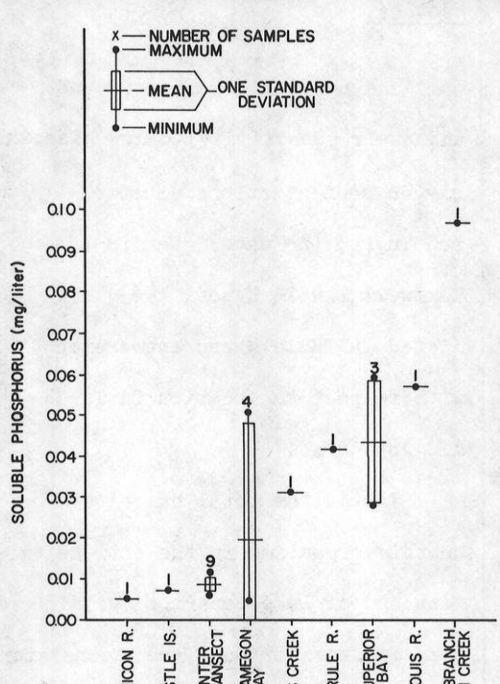

FIGURE 7. Soluble Phosphorus by Lake Areas and Tributaries

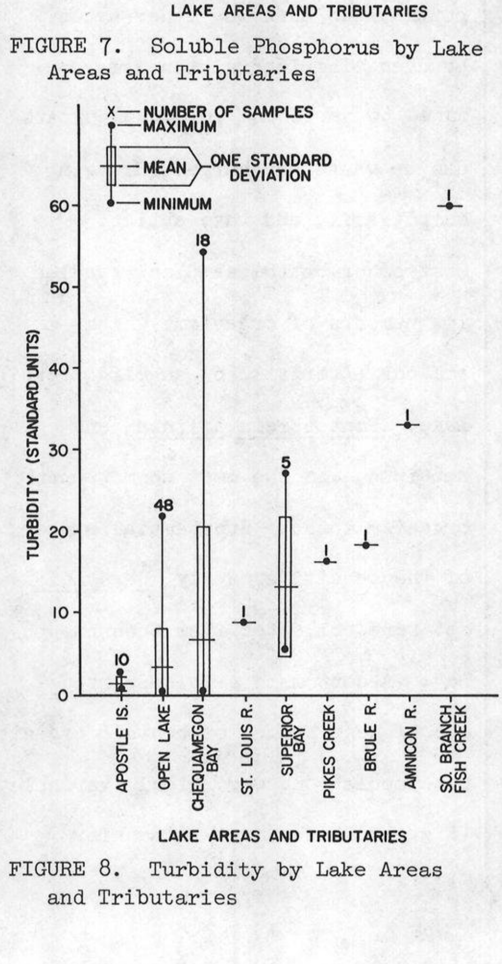

FIGURE 8. Turbidity by Lake Areas and Tributaries

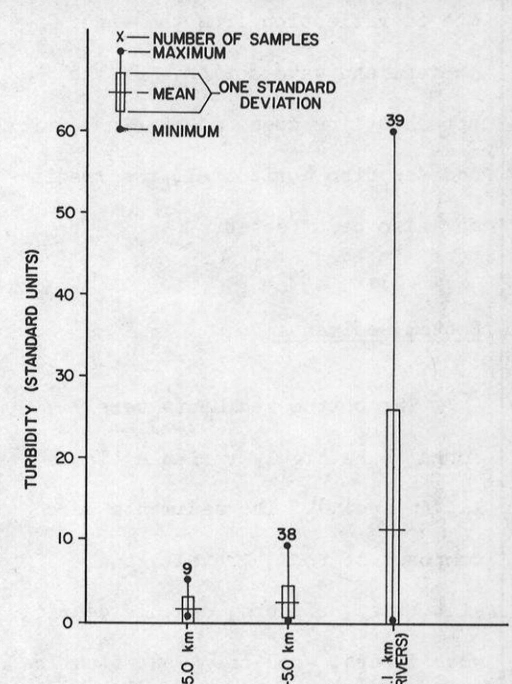

FIGURE 9. Turbidity Relative to Distance from Shore

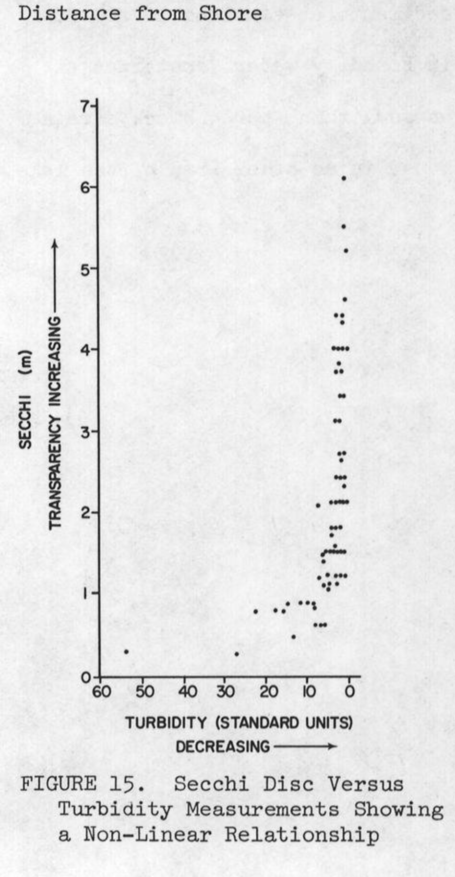

FIGURE 15. Secchi Disc Versus Turbidity Measurements Showing a Non-Linear Relationship

BIOTIC CONDITIONS

due to reflection from the water surface and wave action. If the attached line does not remain vertical and the disc horizontal, the reading may also be affected.

Bottom Sediments

The bottom sediments were found to be highly variable (Table 11, Appendix). The sediments were composed of rock, gravel, sand, silt, clay, cinders, organic debris, wood fibers, wood chips and plastic film, with almost all combinations noted. The predominately clay sediments at stations 10 and 20 in boundary waters contained an unusual thin, hard, black strata found in no other area of the lake.

Benthos

The benthic organisms found and their sensitivity to low dissolved oxygen concentrations (Bartsch, and Ingram (no date); Gaufin and Tarzwell, 1952; Hynes, 1963) are listed in Table 4 and enumerated with respect to location in Table 11, Appendix.

Though the total number of benthic organisms in the extreme west end of Lake Superior (within 6 km of Superior Bay) are inconsistent, the area supports somewhat higher populations than the other areas studied. The inconsistency may be attributed to variation in microhabitats due to waste discharges, dredging, ship traffic and wave action. Most other bottom samples revealed low numbers of organisms which are characteristic of an oligotrophic lake. Pontoporeia affinis, an amphipod, was the most common sensitive organism found. Substantial numbers of the sensitive mayfly, Hexagenia sp. were collected from Chequamegon Bay. A bottom of silt supported the highest number of benthic organisms but populations were highly variable (Fig. 10). The mean values for clay, sand, hard bottom, and wood fibers were 1,771; 810; 76; and 22 respectively.

There appears to be no definite correlation between the number of organisms and water depth. However the seven highest concentrations of organisms were found in less than 17 m of water (Fig. 11).

Seston

The more common organisms in the Clarke-Bumpus net collections appear in Table 5, and Table 10, Appendix. Copepods, cladocerans and ostracods were most predominant among the zooplankton. Melosira sp. was the most common diatom except in Chequamegon Bay where Tabellaria sp. was the most common. Very few blue-green algae were noted in the samples. Aphanizomenon sp. was the most common genus. In some cases substantial quantities of inorganic and organic debris were present in the samples. The inorganic debris was primarily sand or clay, and organic debris included plant fragments, insect fragments, exuvia, and the like.

TABLE 4

Benthic Organisms Found and Their Relative Tolerances to Low Dissolved Oxygen (Bartsch and Ingram (no date); Gaufin and Tarzwell, 1952; Hynes, 1963)

Very Tolerant	Tolerant	Sensitive
Pisidium sp.	*Musculium* sp.	*Hexagenia* sp.
Helobdella stagnalis	*Macrobdella* sp.	*Pontoporeia* sp.
Tubifex sp.	*Haemopsis* sp.	*Molanna* sp.
Nais sp.	*Procladius* sp.	*Ephemera simulans*
Valvata sp.	*Asellus militaris*	*Oecetis* sp.
Chironomus sp.	*Cryptochironomus* sp.	*Phylocentropus* sp.
Gordius sp.	*Orthocladius* sp.	*Psychomyia* sp.
Chironomus attenuatus	*Mysis* sp.	*Stenonema* sp.
Valvata tricarinata	*Metriocnemus* sp.	
Glossiphonia sp.	*Stictochironomus* sp.	
Chironomus staegeri	*Phaenopsectra* sp.	
Amnicolidae	*Nanocladius* sp.	
	Tanypus sp.	
	Gammarus sp.	
	Lampsilis sp.	
	Bezzia sp.	
	Atherix variegata	
	Tanytarsus sp.	
	Viviparis sp.	
	Polypedilum sp.	
	Caenis sp.	

TABLE 5

More Common Planktonic Organisms in Clarke-Bumpus Net Collections From Lake Superior

Copepods	*Asterionella* sp.
Cladocerans (*Daphnia* sp.)	*Tabellaria* sp.
Ostracods	*Fragellaris* sp.
Rotifers	*Aphanizomenon* sp.
Ceratium sp.	*Mysis* sp.
Protozoans	Flagellates
Melosira sp.	*Dinobryon* sp.

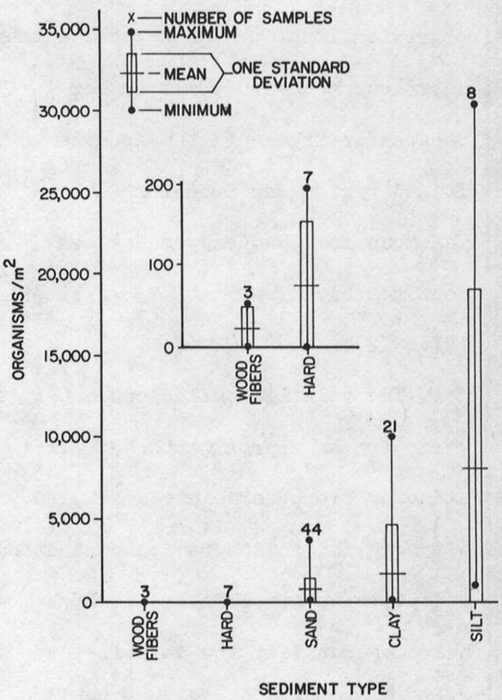

FIGURE 10. Number of Benthic Organisms Relative to Predominant Sediment Type

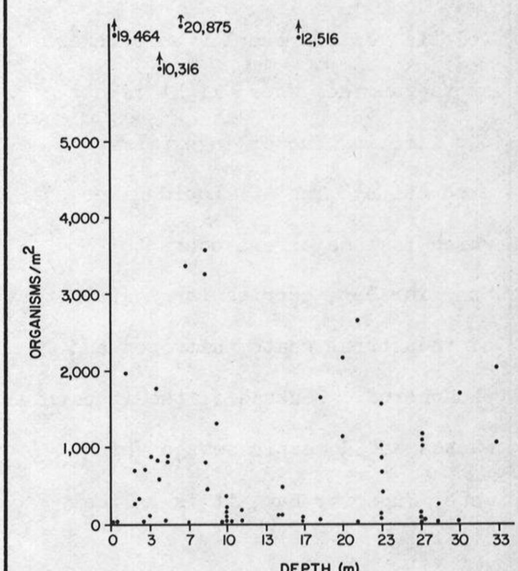

FIGURE 11. Number of Benthic Organisms Relative to Depths up to 33 Meters

The mean volatile solids concentrations for the net collections were less than 100 μg/liter for the center transect, the Apostle Island region and Superior Bay. The mean for Chequamegon Bay was considerably higher at 473 μg/liter (Fig. 12).

The volatile solids concentrations, which are an approximation of standing crop, correlate well with nitrogen and phosphorus concentrations except in Superior Bay. The bay has comparatively low volatile solids with excessive nutrient concentrations. The mean turbidity value for Superior Bay is higher than for other lake areas, and reduces the photic zone. However, volatile solids samples were taken at the surface where light is not the limiting factor in primary production. The St. Louis River, which is a major tributary to Superior Bay, carries large quantities of industrial waste, nitrogen and phosphorus. Because of the industrial wastes and domestic sewage which enter Superior Bay, it is unlikely that the absence of a trace element is limiting plankton growths. More likely is the presence of an element or compound which limits growth. Another possibility is the presence of very small plankton which passed through the tow net.

In many lakes it is the volatile solids in the water which are most objectionable from a recreational and aesthetic point of view. Characteristically those lakes with substantial algae blooms are of a eutrophic nature and will produce a high concentration of volatile solids in the surface waters. Concentrations of 2,500 μg/liter are not uncommon in very productive Wisconsin lakes. Total solids of 5,000 μg/liter have been recorded. The most oligotrophic or least productive lakes in Wisconsin with no ice cover generally support less than 100 μg/liter of volative solids in the surface waters and some are occasionally less than 5 μg/liter. With large concentrations of diatoms, the percentage of fixed solids may increase as silicates are incorporated into the cell structure.

Cladophora

Cladophora sp. growths were variable but never approached nuisance proportions (Table 6).

Fish Net Slimes

One sample, collected on July 13, 1968 from float nets set in Big Bay on the east side of Madeline Island, was received. Microscopic examination revealed virtually all diatoms, with *Tabellaria* sp. predominating along with a few cells of *Fragilaria* sp. Similar slime growths on fish nets have been documented along the Minnesota shore of Lake Superior (Putnam and Olson, 1961).

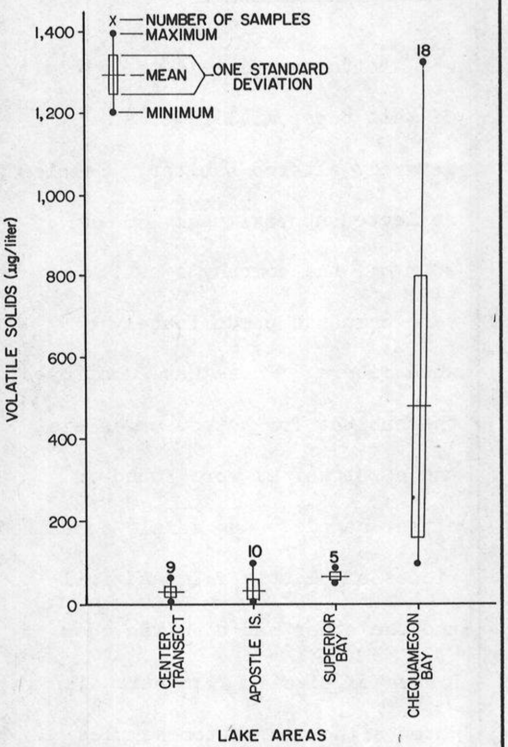

FIGURE 12. Volatile Solids for Center Transect, Apostle Islands, Superior Bay, and Chequamegon Bay

Maximum Cladophora Growths Observed, Madeline Island Near La Pointe

TABLE 6

Comparative Cladophora Growths Along the Bayfield Peninsula and Apostle Islands, Lake Superior, July, 1968

Nearest Permanent Station Numbers	Location	Extent	Remarks
44	Bark Bay	Light	1 - 3 cm strip
44,45	Point between Bark Bay and Siskiwit Bay	Moderate	3 - 15 cm strip
46	Squaw Point	Moderate	
51	Sand Island, east of light	Moderate	
51	York Island, northwest point	Moderate	
52	Raspberry Island, at light	Light	
52	Raspberry Island, east of light	None	
52	Raspberry Island, southeast side	Light	
52	Raspberry Island, east side	Trace	$<$ 1 cm strip
52	Bear Island, southwest side	Light	
55	Oak Island, south and southeast sides	Trace	
55	Stockton Island, south and southwest sides	None	
55	Hermit Island, east side	Light	
56	Roys Point, on mainland	Light	
56	Basswood Island, west side	None	
57	Basswood Island, east side	None - Trace	
58	Bayfield Harbor area	Moderate	
58	Madeline Island, La Pointe	Moderate - Heavy	15 cm strip
58	Madeline Island, 1.5 km north of La Pointe	Light	
58	Madeline Island, 3.0 km northeast of La Pointe	None	
59,60	Madeline Island at S. Channel	None	
68	Ashland breakwater	Moderate	
80	Marble Point	None	
81	Montreal River mouth	Moderate	
84	1.5 km northeast of Montreal R.	Moderate	

POTENTIAL POLLUTION SOURCES

The Lake Superior Drainage Basin in Wisconsin is sparsely populated and has relatively little industry. Though surface waters in the basin are generally of good quality, localized problems do exist in the vicinity of some communities and industries. Table 7 is a summary of the potential sources of pollution within Wisconsin.

Those sources which were shown to be adversely affecting local water quality were Superior Fiber Products, Inc., Superior; E. I. Du Pont de Nemours and Company, Barksdale; and American Can Company, Ashland. A concentrated effort was also made to determine if taconite tailings discharged by the Reserve Mining Company at Silver Bay, Minnesota were present within Wisconsin boundaries of Lake Superior.

Superior Fiber Products, Inc.

The dissolved oxygen concentration 3.0 m off the Superior Fiber Products, Inc. wastewater lagoon overflow was zero. This was the only pollution effect shown and was limited to the immediate vicinity of the overflow.

E. I. Du Pont de Nemours and Company

E. I. Du Pont de Nemours and Company discharges wastewater to Boyd Creek which turns the stream a blood red color. The stream, which would likely be intermittent if the wastewater did not enter the watercourse, has numerous riffle areas. These riffles which are an excellent physical habitat for immature insects are completely devoid of all macro-invertebrates. The red color is noticeable in Chequamegon Bay a considerable distance from the creek's mouth.

The wastewater discharged also has a high nitrite nitrogen concentration and may be a significant nutrient source to the Bay (Schraufnagel et al., 1966).

American Can Company

Bottom samples in the vicinity of this paper mill revealed a severely altered habitat. Samples collected approximately 30 and 90 m off the company's outfall were composed predominately of wood fibers. These have destroyed the habitat for bottom organisms, and no organisms were found in either sample. One sample contained pieces of plastic film and foil and the other had a septic odor. Pieces of plastic film were also noted either in bottom samples or in the water at several other stations in Chequamegon Bay, and at the public boat landing at the northeast end of Ashland. Pieces of plastic film are reportedly found periodically in the Apostle Island region; however, none were observed during this survey.

Wood fibers constituted nearly 100 percent of the plankton sample near the discharge.

Reserve Mining Company

No evidence was found to indicate the presence of taconite tailings in Wisconsin waters. The net currents which could carry colloidal size particles into Wisconsin waters are shown in Figure 13. Portions of the bottom sediments from stations 19, 20, 23, 34, and 54 were submitted to the National Water Quality Laboratory, Duluth, Minnesota, for mineralogical analysis by x-ray defraction in an effort to isolate the mineral cummingtonite. This mineral is a possible tracer for taconite tailings discharged

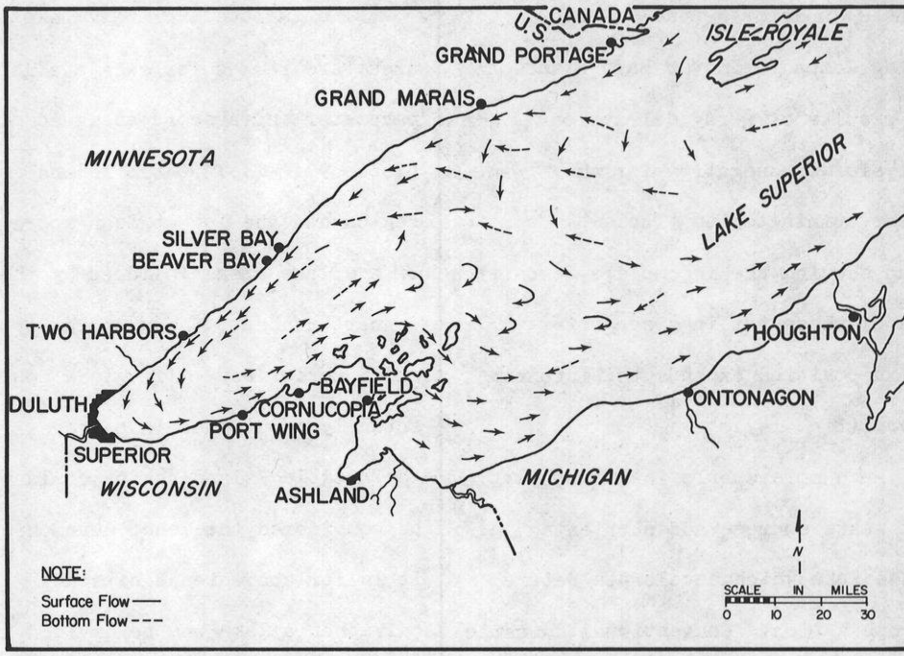

FIGURE 13. Direction of Net Flow

TABLE 7

Potential Sources of Surface Water Pollution in the Wisconsin Drainage Basin to Lake Superior

Source	Type of Waste
American Can Co. - Ashland Div.	Paper
Andersonville Co-op Dairy Assn.	Milk
Ashland, City of	Sewage
Bayfield, City	Sewage
Bodin Fisheries	Fish Processing
Douglas Co. Hospital and Sanitary	Sewage
E. I. Du Pont de Nemours and Co.	Chemical
Evertt Fisheries, Inc.	Fish Processing
Farmers Cheese Factory	Milk
Fuhrmann's South Shore Dairy	Milk
Great Northern Railroad Co.	Oil
Hurley, City of	Sewage
Iron Belt, Unincorporated	Sewage
Iron River, Unincorporated	Sewage
Koppers Company	Chemical
Marengo Co-op Dairy Assn.	Milk
Martens Dairy	Milk
Mason Milk Products	Milk
Mellen, City of	Sewage
Middle River Sanitorium and Douglas Co. General Hospital	Sewage
Montreal, Village of	Sewage
Moquah Cheese Factory	Milk
Mountain Valley Cheese Factory	Milk
Murphy Oil Corporation	Oil
Ondassagon School	Sewage
Pence, Town of	Sewage
Penokee Veneer Company	Wood
Pureair Sanitorium	Sewage
Ruppe Cement Company	Silt
Sand Bay Fisheries	Fish Processing
Saxon, Town of	Sewage
Soo Ling Railroad Company	Oil
Stott Briquet Company	Coal
Superior, City of	Sewage
Superior Fiber Products, Inc.	Wood Processing
Superior, Village of	Sewage
Twin Ports Dairy	Milk
Union Tank Car Company	Oil
Washburn, City of	Sewage

American Can Company's Submerged Outfall and Offshore Area to Lake Superior by the Reserve Mining Company, Silver Bay, Minnesota. The results of x-ray defraction analysis were negative for the tracer cummingtonite (Table 8). A map showing the incomplete deposition area of these tailings suggests that deposition extends to Wisconsin waters (Fig. 14).

Much more subtle is eutrophication. Most waste sources add nutrients to the lake which accelerate natural eutrophication. Conventional domestic sewage treatment removes very few nutrients. E. I. Du Pont de Nemours and Company discharges wastes high in nitrites which may oxidize to nitrates and thus become an available nutrient.

The fish net diatom slimes, Cladophora growths, and comparatively high standing crop in Chequamegon Bay cannot be related to any particular sources of waste but may result from increased eutrophication. The fish net slimes are claimed to be a problem only of recent years.

The various arbitrary lake areas are ranked for each available parameter and a score assigned (Table 9). The Apostle Island region had the lowest mean score of the lake areas followed by the center transect, Chequamegon Bay and Superior Bay. If a lake could actually be divided into areas, the Apostle Island region could be considered the least eutrophic. It is for convenience of study only that a lake can be divided into areas. By comparing these areas where water quality may differ, the lake as a unit may be understood and its trophic status established.

The tributary streams are also ranked in the same manner (Table 9). Pikes Creek had the lowest mean followed by the Brule, Amnicon, and St. Louis Rivers and Fish Creek. The parameters considered may be affected by agriculture, timber cutting, wastewaters, recreation and other activities within the watershed.

TABLE 8

Results of Mineralogical Analysis of Bottom Sediments From Areas With Possible Taconite Tailings

Sample No.	Sample Location (see map)	Mineralogical Composition* Chlorite-Vermiculite	Quartz	Mica	Kaolinite	Montmorillonite	Other
20	Midway between Silver Bay and the Apostle Islands	Tr	++	+	++		Tr Feldspar
19	Approx. 10 mi. S.W. of above	+	++	+	++		-
23	Just East of Outer Bar at Duluth-Superior Harbor	++	-	++	++	++	-
34	East of Superior Harbor Entrance on Wisconsin Shore	++	-	++	++	++	-
54	Apostle Islands Area	-	-	[illegible]	++		-

* Designations - ++ Major Component, + Minor Component, Tr - Trace only, - not detected.

TABLE 9

Trophic Ranking of Lake Areas and Rivers
(1 Being Least Enriched)

	Apostles	Center Transect	Chequamegon Bay	Superior Bay
Total Inorganic Nitrogen	1	2	3	4
Organic Nitrogen	1	2	3	4
Total Phosphorus	1	2	3	4
Soluble Phosphorus	1	2	3	4
Volatile Solids	2	1	4	3
Trubidity	1	2	3	4
Total	7	11	19	23
Mean	1.2	1.8	3.2	3.8

	Pikes	Brule	Amnicon	St. Louis	Fish
Total Inorganic Nitrogen	2	1	3	5	4
Organic Nitrogen	1	2	3	4	5
Total Phosphorus	1	-	2	4	3
Soluble Phosphorus	2	3	1	4	5
Trubidity	2	3	4	1	5
Total	8	9	13	18	22
Mean	1.6	2.3	2.6	3.6	4.4

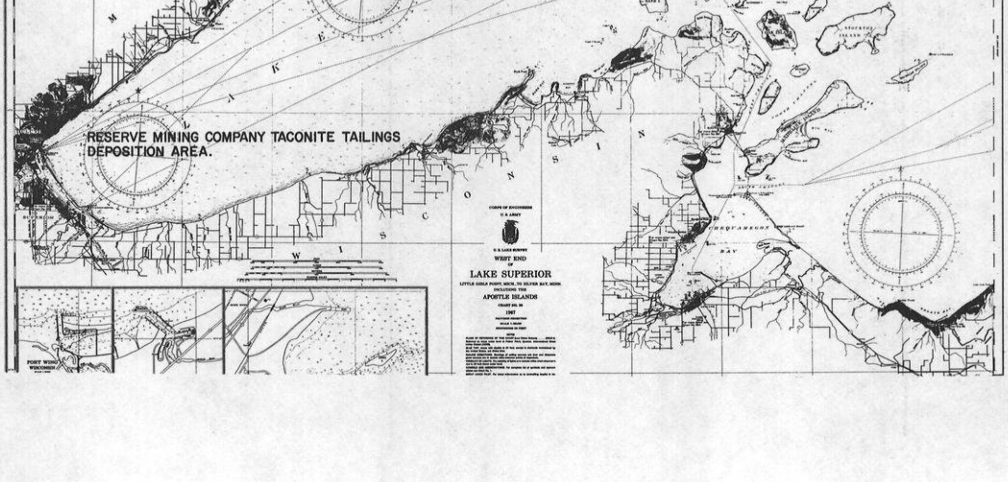

FIGURE 14. Taconite Tailings Deposition Area, Reserve Mining Company

CONCLUSIONS

1. Minimum dissolved oxygen concentrations were not critical for aquatic life except in the immediate vicinity of the Superior Fiber Products, Inc. lagoon outfall.

2. Nitrogen and phosphorus concentrations were lowest in open waters and in the Apostle Island region.

3. Transparency was highest in open waters and in the Apostle Island region. Transparency was generally the lowest close to shore. Secchi disc readings are not linearly related to turbidity measurements.

4. Numbers of benthic organisms are related to type of bottom sediment.

5. Volatile solids concentrations were highest in Chequamegon Bay.

6. Cladophora growths were not observed in nuisance proportions.

7. Fish net slimes were caused by diatoms, growths which cannot be attributed to any source of waste.

8. Pollution is extremely difficult to demonstrate to any extent in the open water of Lake Superior, and was shown to occur only in the immediate vicinity of waste discharges. Deleterious effects can only be demonstrated in localized areas near Superior Fiber Products, Inc., E. I. Du Pont de Nemours and Company, and American Can Company.

9. Most waste sources are accelerating natural eutrophication by the addition of nutrients.

10. Corrective measures are necessary where waste sources are causing pollution.

11. Cultural eutrophication should be reduced to an absolute minimum.

TABLE 10 Transparency, Solids, and Seston By Lake Areas And Tributaries

Station No.	Secchi Disc (m)	Hack Turbidity (s.u.)	Fixed Solids (g/l)	Volatile Solids (g/l)	Zoo-plankton	Proto-zoans	Mean Percentage Observed (T=trace) Diatoms	Blue-greens	Greens	Organic Debris	Inorganic Debris
St. Louis River											
1	0.6	8.50	44	71	48	3	17	T	T	T	32
Superior Bay											
2	0.8	9.00	30	70	65	3	24	5	T	T	3
3	0.6	7.80	36	51	72		20	T	T	3	5
5	0.6	5.50	39	57	60		28	2	T	5	5
6	0.6	16.00	87	79	59	3	30			3	5
7	0.3	27.00	63	57	65		20		T	3	12
West End of Lake											
8	1.2	4.70	71	62	52		28			T	20
9	1.4	0.60	77	67	57		32	T		T	11
10	2.1	2.30	92	51	46	2	42	T	T	2	8
11	1.5	2.30	69	124	77		18			2	3
12	2.1	1.50									
13	1.5	0.45	73	47	57		28			10	5
14	3.1	1.6	69	26	22	T	63			8	7
Center Transect											
15	4.0	0.73	22	19	49	T	40	T		3	8
16	3.7	0.70	25	13	14	5	55			13	13
17	4.0	0.92	70	24	35	T	20			21	24
18		0.65	20	16	57	5	22			10	6
19		5.00	7	59	98		T			2	T
20		1.30	20	14	45	T	40			12	3
20		0.45									
21		0.55	8	7	45	2	25			3	25
West End of Lake											
22	1.2	2.80	57	77	77		18	T	T	2	3
23	0.9	9.30	70	75	74		23	T		T	3
24	1.5	3.70	67	41	50	T	39			3	8
25	0.5	14.00	106	60	50		32	T	T	3	15
26	1.8	2.30	36	27	60		32		T	5	3
27	2.4	2.40	56	34	48		47			2	3
28	1.2	6.50	101	73	52		23			5	20
29	1.4	5.80	69	48	60		35	T		T	5
30	1.5	3.60	65	43	55		30		T	2	13
31	0.9	10.00	56	44	68	2	25			3	2
32	1.5	4.50	15	71	67	5	26			T	2
33	1.7	3.80	65	54	67	8	25		T		
Off Poplar River											
34	0.9	14.00	84	60	45		38			2	15
35	2.1	1.90	78	49	48		45			2	5
36	2.4	1.70	12	9	70		25	T		2	3
Off Bardon Creek											
37	0.6	22.00									
Off Brule River											
38	0.9	12.00	105	158	78		20			2	T
39	1.8	3.20	46	76	75		20	T		T	5
40	2.7	1.10	29	78	80		15			T	5
Port Wing											
41		4.60	40	33	75		15			T	10
42		3.70	24	39	80		12			T	8
43		1.50	26	21	73		20			T	7
Bark Bay											
44		1.60	5	2	37		60	T		T	3
Cornucopia											
45		0.72	8	4	52		45			T	3
46		1.40	22	10	45		50			T	5
47		1.10	8	4	30		65			T	5
48		1.60	6	4	58		37			T	5

Table 10 (Cont'd)

Station No.	Secchi Disc (m)	Hack Turbidity (s.u.)	Fixed Solids (g/l)	Volatile Solids (g/l)	Mean Percentage Observed (T=trace) Zoo-plankton	Proto-zoans	Diatoms	Blue-greens	Greens	Organic Debris	Inorganic Debris
Sand Island											
49	3.8	0.76	26	20	60		30	T	T	2	8
50	4.3	0.79	11	11	75	T	22		T	T	3
51	2.4	2.50	18	10	58	T	35		T		7
Raspberry Island											
52	3.1	2.00	25	16	62		23		T		15
Devils Island											
53		0.37	46	26	42		52			2	4
South Twin Island											
54		0.08	46	21	17		47		T	3	33
Stockton Island											
55	7.0										
Red Cliff											
56	3.7	1.00	37	26	43		55		T	T	2
Basswood Island											
57	6.1	0.25	8	7	63		32	T	T	T	5
Bayfield											
58	4.0	1.60	187	101	30	T	68			T	2
Long Island											
59	3.4	0.75	256	149	3		95		T	2	T
La Pointe											
60	4.4	2.10	128	64	16	2	80		T	T	2
Chequamegon Bay											
61	2.1	2.00	904	734	28	2	66		T	2	2
62	1.5	1.80	407	332	35	T	55		T	T	10
63	0.6	18.00	288	216	55	2	40		T	T	3
64	2.1	3.10	1056	1124	48	T	52		T	T	
65	4.0	0.61	318	211	42		56		T	T	2
66	2.7	1.50	294	169	32	T	68		T	T	T
67	1.8	2.90	441	268	40	T	60		T	T	T
68	1.5	2.80	371	226	27	T	73		T	T	T
69											
70	0.3	54.00	252	704	12		5			73	10
71	2.3	1.60	97	72	22		70			8	T
72	1.2	2.50	558	390	45		53			2	T
73	1.5	3.20	264	264	63	2	35			T	T
74	2.1	6.8	365	233	26	2	72		T	T	T
75	2.6	1.50	189	192	63		37		T		T
76	1.1	5.00	559	323	28	2	63			T	7
77	1.1	5.50	596	322	32	T	66		T	T	2
78	1.5	5.60	242	149	50		48		T		2
79	1.1	2.70	1319	878	50	T	45		T	T	5
Oronto Bay											
80	4.4	0.58	54	45	12		86	T	2	T	T
81	4.6	0.65	62	33	8		88	T	T	T	2
82	5.2	0.26	128	62	2	2	93	T	T	T	3
83	5.5	0.32	181	90	10		90	T	T	T	T
84	3.4	0.85	301	128	22	10	58		T	3	7
Amnicon River											
85		30.00									
Brule River											
86		18.00									
Pikes Creek											
87		16.00									

Table 10 (Cont'd)

Station No.	Secchi Disc (m)	Hack Turbidity (s.u.)	Fixed Solids (g/l)	Volatile Solids (g/l)	Zoo-plankton	Proto-zoans	Mean Percentage Observed (T=trace) Diatoms	Blue-greens	Greens	Organic Debris	Inorganic Debris
So. Branch Fish Creek											
88		60.00									
Boyd Creek											
89											
Chequamegon Bay											
90		44.00									

TABLE 11 Locations, Benthos and Sediments For All Stations Sampled

Permanent Station No.	July, 1968 Date	Location	Approx. Depth (m)	Sediment	Classification (No./m^2) Sensitive Spp.	Sensitive No.	Tolerant Spp.	Tolerant No.	Very Tolerant Spp.	Very Tolerant No.	Observations
1	10,11	Upstream from the High Bridge	6.0	Silt, sand	0	0	4	409	3	20,466	
2	10	Inside Duluth Entrance	8.5	Silt, sand organ. debris	0	0	1	11	4	1,388	Wood chips.
3	8	South of Superior, Fiber Products Lagoon Outfall	1.0	Silt, organic debris	0	0	0	0	1	19,464	
4A	11	3 m off Superior, Fiber Products Outfall	1.0								
4B	11	30 m off Superior, Fiber Products Outfall	1.0								Effluent cloudy tan color.
5	8	150 m east of Superior Fiber Products Outfall	2.0	Sand	0	0	1	11	2	2,130	
6	10	1.0 km west of Sky Harbor Airport	4.0	Silt	0	0	3	312	1	1,625	
7	10	Inside Superior Entrance	8.0	Silt, sand	1	22	2	32	3	3,440	
8	11	1.0 km off Duluth Entrance	13.5	Sand	1	22	1	11	2	108	
9	11	2.5 km off Duluth Entrance	18.0	Sand, clay, organ. debris cinders	0	0	3	108	2	1,130	
10	11	5.0 km off Duluth Entrance	24.5	Sand, cinders	0	0	1	11	1	11	
11	11	1.0 km offshore, between Superior & Duluth Entrances	9.0	Hard sand	0	0	1	54	1	11	
12	17	1.5 km offshore, between Superior & Duluth Entrances	20.0	Sand, clay, organ. debris	0	0	0	0	0	0	
13	11	2.5 km offshore, between Superior & Duluth Entrances	21.5	Sand, clay, organ. debris	1	151	4	118	2	810	
14	11	5.0 km offshore, between Superior & Duluth Entrances	24.5	Sand, clay organ. debris	1	226	3	86	1	936	
14	17	5.0 km offshore, between Superior & Duluth Entrances	24.5	Sand, clay	0	0	0	0	1	11	
15	17	8.0 km offshore, center transect	30.5	Silt, soft clay, cinders	1	625	2	646	1	441	
16	17	16.0 km offshore, center transect	43.0	Soft clay org. debris, cinders	1	236	1	11	1	194	
17	17	24.0 km offshore, center transect	64.0	Clay, cinders	1	86	0	0	1	43	Some grayish sediment.
18	17	40.0 km off Superior Bay, center transect	107.0	Clay, cinders	1	43	1	11	1	32	Some grayish-black sediments, 0.3 cm strata.

Table 11 (Cont'd)

Permanent Station No.	July, 1968 Date	Location	Approx. Depth (m)	Sediment	Classification (No./m^2) Sensitive Spp.	No.	Tolerant Spp.	No.	Very Tolerant Spp.	No.	Observations
19	17	64.0 km off Superior Bay center transect	162.0	Clay	1	32	0	0	0	0	Thin, hard black strata, water appears greenish-brown.
20	18	89.0 km off Superior Bay, center transect	162.0	Clay, cinders	1	32	0	0	1	22	Hard black strata 0.1-0.2 cm.
20A	18	89.0 km off Superior Bay 3.0 km southeast of 20	137.0	Clay, cinders	1	32	0	0	0	0	
21	18	113.0 km off Superior Bay, center transect	137.0	Sand, clay	1	194	1	32	1	334	Some black sediment.
22	11	1.0 km northwest of Superior Entrance, 1.1 km offshore	9.0	Sand, clay organ. debris	1	11	2	32	1	140	
23	11	1.0 km northwest of Superior Entrance, 2.5 km offshore	10.5	Sand	0	0	3	32	0	0	Some black sediment.
24	11	1.0 km northwest of Superior Entrance, 5.0 km offshore	26.0	Sand, clay	1	140	3	32	1	97	
25	9	1.0 km off Superior Entrance	13.5	Sand	0	0	2	43	2	97	
26	9	2.5 km off Superior Entrance	15.0	Clay, organ. debris	0	0	5	216	1	12,300	
27	9	5.0 km off Superior Entrance	26.0	Clay	0	0	1	11	0	0	Surface temperature 12°C, Bottom 8°C.
28	10	1.0 km southeast of Superior Entrance, 1.0 km offshore	9.0	Sand, clay organ. debris	1	22	4	324	1	43	
29	10	1.0 km southeast of Superior Entrance, 2.5 km offshore	20.0	Silt, clay organ. debris	1	43	4	43	1	2,781	
30	10	1.0 km southeast of Superior Entrance, 5.0 km offshore	26.0	Silt, sand, clay, organic debris	1	32	2	43	1	3,720	
31	10	4.0 km southeast of Superior Entrance, 1.0 km offshore	9.0	Sand, clay	0	0	1	11	1	11	Water turbid, reddish-brown
32	10	4.0 km southeast of Superior Entrance, 2.5 km offshore	14.0	Hard clay	0	0	0	0	1	11	Very little sample.
33	10	4.0 km southeast of Superior Entrance, 5.0 km offshore	21.0	Clay	1	119	1	54	1	1,520	
34	9	Between Middle R. & Poplar R., 1.0 km offshore	9.0	Sand, clay	1	11	1	11	1	11	Some black sediment.
35	9	Between Middle R. & Poplar R., 2.5 km offshore	17.0	Sand, clay	0	0	2	65	1	11	
36	9	Between Middle R. & Poplar R., 5.0 km offshore	21.0	Sand, clay	1	32	1	11	1	22	
37	9	0.5 km off Bardon Creek	10.5								Very turbid.
38	9	1.0 km off Brule River	9.0	Sand, gravel	0	0	1	11	1	11	Water turbid.
39	9	2.5 km off Brule River	27.0	Hard	1	22	0	0	0	0	Very little sample.
40	9	5.0 km off Brule River	46.0	Sand	1	43	1	11	1	54	
41	19	1.0 km off Port Wing	10.5	Sand, organic debris	1	11	4	65	2	130	
42	19	2.5 km off Port Wing	21.0	Sand, organic debris	1	205	2	130	1	388	Water turbid, brown.
43	19	5.0 km off Port Wing	53.5	Sand, organic debris	1	625	3	108	2	895	Water slightly turbid.
44	19	Middle of Bark Bay	21.0	Sand, organic debris	1	280	2	32	1	130	Water appears green.
45	19	Middle of Siskiwit Bay	13.5	Sand, organic debris	1	173	4	119	1	238	Water appears green.

Table 11 (Cont'd)

Permanent Station No.	July, 1968 Date	Location	Approx. Depth (m)	Sediment	Classification (No./m^2) Sensitive Spp.	Sensitive No.	Tolerant Spp.	Tolerant No.	Very Tolerant Spp.	Very Tolerant No.	Observations
46	19	1.0 km off Squaw Point	24.5	Sand, organic debris	1	464	2	43	2	605	Some black sediment.
47	19	2.5 km off Squaw Point	34.0	Clay, organic debris	1	194	1	22	1	97	Gray streaking in clay.
48	19	5.0 km off Squaw Point	61.0	Sand, clay	1	1110	2	162	1	615	Some black sediment.
49	25	3.0 km west of Sand Is.	46.0	Sand, clay	1	928	1	130	1	970	Water appears slightly green.
50	25	9.5 km west of Sand Is. Light	91.5	Clay, cinders	1	11	2	43	0	0	Water appears slightly green.
51	25	Between Sand & York Is.	18.5	Sand, clay	1	830	2	928	2	583	Water appears greenish-brown.
52	25	Equidisdant between York, Raspberry & Bear Island	27.0	Sand, clay	1	852	3	895	1	75	Water appears green.
53	18	2.5 km south of Devils Is.	30.5	Sand, clay	1	646	3	345	1	1,200	Some black sediment.
54	18	2.0 km south of South Twin Island	45.0	Sand, clay, organ. debris	1	950	0	0	2	970	Water very clear. Some black sediment.
55	24	1.5 km south of Stockton Island	75.0								Secchi only
56	24	Between Red Cliff and Basswood Island	24.5	Sand, clay cinders	1	950	2	75	1	162	
57	24	1.0 km east of Basswood Island	46.0	Clay, organic debris	1	324	3	130	1	755	
58	23	2.0 km southeast of Bayfield	46.0	Clay, cinders organ. debris	1	1760	3	108	1	11	
59	23	3.0 km east of Long Is. Light	24.5	Sand	1	65	3	54	1	32	
60	23	7.0 km southwest of La Pointe	21.0	Clay, organic debris	1	583	4	54	1	270	
61	23	18.0 km off Fish Creek, center transect	4.0	Sand, clay, organic debris	3	119	6	260	4	281	
62	23	Between Chequamegon Point and Oak Point	2.0	Sand	3	54	5	530	3	216	Some weeds.
63	23	2.5 km south of Oak Point, 1.0 km offshore	2.0	Sand	2	22	6	226	2	173	Water turbid, brown.
64	23	13.0 km off Fish Creek, center transect	4.0	Sand, gravel	1	32	5	583	4	334	Water slightly turbid. Many mayfly casts on water.
65	23	1.0 km south of Houghton Point Bouy	17.0	Clay, cinders	1	107	3	54	3	680	
66	23	1.0 km south of Washburn	6.0	Sand, clay organ. debris	2	410	6	267	1	53	Weeds off Washburn boat landing.
67	23	8.0 km off Fish Creek, center transect	8.0	Clay, organic debris	2	288	5	108	1	475	Water appears slightly green. Pieces of plastic noted.
68	23	0.5 km northeast of Ashland Breakwater, 1.0 km offshore	3.0	Clay, organic debris	2	227	6	162	2	560	Some weeds inside breakwater. Pieces plastic and foil noted. Mayfly casts on water
69	23	1.0 km off American Can Co. towards Ashland Breakwater	4.0	Clay, organic debris	1	75	6	366	4	9,950	Pieces of plastic noted.

Table 11 (Cont'd)

Permanent Station No.	July, 1968 Date	Location	Approx. Depth (m)	Sediment	Classification (No./m^2) Sensitive Spp.	No.	Tolerant Spp.	No.	Very Tolerant Spp.	No.	Observations
70	22	10 m off American Can Company Outfall	1.0	Fibers, cinders	0	0	0	0	0	0	Water brown and cloudy. Mayfly casts on water. Pieces of foil and plastic. Bottom almost all fibers. Plastic pieces at boat landing.
71	22	30 m off American Can Company Outfall	2.5	Fibers	0	0	0	0	0	0	Water appears green. Bottom all fibers and odorous. Mayfly casts on water.
72	22	1.0 km off American Can Company	4.0	Bark, pieces of wood	1	22	1	22	1	11	Water appears green. Mayfly casts on water. Poor sample.
73	23	Between ore docks, 1.0 km offshore	8.0	Clay, organic debris	0	0	1	11	2	3,810	Pieces of plastic noted.
74	23	5.0 km off Fish Creek, center transect	8.0	Clay, cinders organ. debris	0	0	4	186	2	302	Pieces of plastic noted. Water appears green.
75	23	1.0 km southeast of Bono Creek	4.0	Sand, clay, organ. debris	0	0	7	679	2	130	Pieces of plastic on water.
76	22	5 m off Ashland STP Outfall	3.0	Hard, organic debris	1	11	0	0	2	162	Bottom materials black and odorous. Water appears greenish-brown.
77	22	Southwest side of Ashland 1.0 km offshore	4.0	Cinders, clay, gravel	2	97	5	670	2	151	Water appears greenish-brown.
78	22	1.5 km off Fish Creek, center transect	2.5	Sand, organic debris	3	32	6	561	2	203	Water appears greenish-brown.
79	22	0.5 km off Boyd Creek	2.0	Sand	0	0	6	162	3	130	Some weeds. Water appears deep red.
80	24	5.0 km north of Marble Pt.	24.5	Sand	1	32	1	11	0	0	Water appears slightly greenish. Some black sediment.
81	24	1.0 km off Saxon Harbor	9.0	Hard, sand, clay	1	108	1	22	2	65	
82	24	2.5 km off Saxon Harbor	17.0	Hard, sand clay	1	11	2	32	1	32	
83	24	5.0 km off Saxon Harbor	21.0	Sand	1	22	0	0	1	86	
84	24	0.5 km off Montreal River	6.0	Hard	0	0	0	0	0	0	Water appears brown but clear. Iron 0. mg/liter. tannins 0.9 mg/liter.
85		Hwy. 13									Nutrient sample.
86		Hwy. 13									Nutrient sample.
87		Below RR Trestle									Nutrient sample.
88		Hwy. 112									Nutrient sample.
89		Hwy. 13			0	0	0	0	0	0	No life present in riffles below DuPont. Water deep red.
90	16	0.5 km off Fish Creek	4								Turbidity only.

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