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THE EFFECTS OF INDUSTRIAL WASTES FROM CHARMIN PAPER PRODUCTS COMPANY ON FISH OF THE CHEBOYGAN RIVER DRAINAGE SYSTEM

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Abstract—This study investigated effects of industrial wastes of a paper mill on fish. Chemical analyses were made of the effluent and of the river water before it entered the mill and at the effluent entry point. Static bioassay techniques were used to determine tolerances to the effluent of ten fish species which were abundant in the paper mill area. Fish were collected from the effluent entry point into the river. An abundant fish fauna was found. Charmin Paper Products Company, Cheboygan, Michigan, treats its waste products thoroughly and is an example of what an industry can do to reduce water pollution. The common shiner, *Notropis cornutus*, was found to be intolerant to even low concentrations of the effluent. Thus, its presence in an area would indicate a very low level of pollution of this type.

INTRODUCTION

AS THE population of this country and the world increases, more and more waste products from cities and towns and from industry will be discarded. Most enter streams, lakes, and the oceans. Much of the waste receives some treatment prior to disposal. Frequently these same waters serve as domestic and industrial sources and support recreation. As needs for waste disposal and water supply increase, care must be taken that the former does not eliminate the latter.

This study investigated effects of pollution on fish. Fish are important to commercial and sport fishermen, to aquarium-keepers, and to biologists. Since so many people encounter fishes, any significant changes in populations are readily evident. Some changes may reflect pollution of the natural habitats. In such cases fish might indicate various types of pollution. A rapid change in population size might result from a change in water chemistry. Intolerance to the particular pollutants might decrease the population density, increase the density of species with high tolerance, or both changes might occur.

Population density of fish could also change for reasons other than pollution. To evaluate this, our study included laboratory tests where different fish species were exposed to various concentrations of industrial wastes as well as field studies and collections ascertaining species present where wastes were being discharged to a river.

It is also important to know the distributions of fish in various habitats, including those receiving industrial or municipal wastes. Fishermen, collectors, and researchers find such information valuable. In dollar values paper manufacturing is among the uppermost half dozen industries that discharge wastes into bodies of water (ROUNSEFELL and EVERHART, 1953). Charmin Paper Products Company, Cheboygan, Michigan, treats its waste products thoroughly (FIG. 1). This outline resulted from touring the paper company, from several interviews with Ralph J. Van Deuren, manager of the paper mill, and from company files (unpublished).

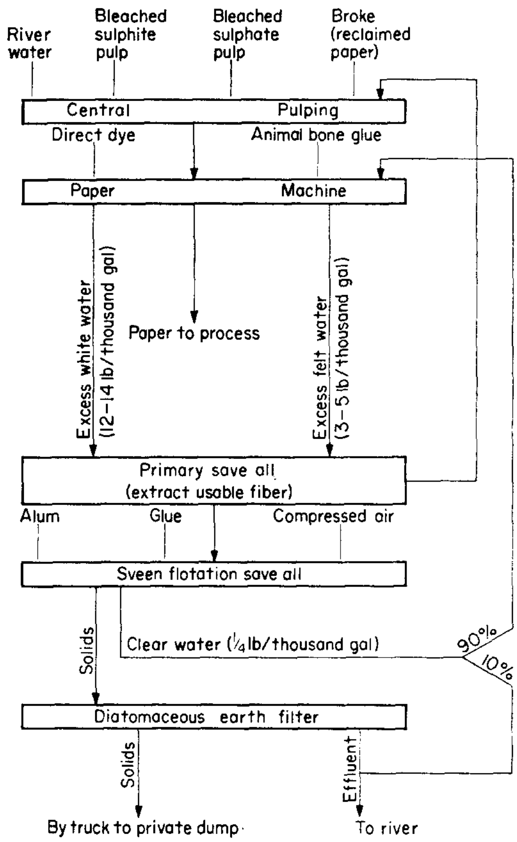

FIG. 1. Process for treatment of wastes. Charmin Paper Products Company, Cheboygan, Michigan.

This study analysed effects of the effluent from Charmin Paper Products Company on ten fish species. It also investigated the Cheboygan River from 100 ft upstream to about 200 ft downstream from the effluent entry point, collecting fish in this area. Finally, the laboratory tolerances were compared with the list of fish found in the river.

MATERIALS, METHODS AND RESULTS

Ten species of fish were exposed to various effluent concentrations: *Catostomus commersoni* (Lacépède), white sucker; *Cottus bairdi* Girard, mottled sculpin; *Ictalurus nebulosus* (LeSueur), brown bullhead; *Lepomis gibbosus* (Linnaeus), pumpkinseed; *Micropterus salmoides* (Lacépède), largemouth bass; *Notropis cornutus* (Mitchill), common shiner; *Perca flavescens* (Mitchill), yellow perch; *Percina caprodes* (Rafinesque), logperch; *Petromyzon marinus* Linnaeus, sea lamprey*, and; *Salmo gairdneri*

* Ammocetes.

Richardson, rainbow trout. These names are according to the AMERICAN FISHERIES SOCIETY (1960). All species were found in the Cheboygan River Drainage System by Legault (unpublished). The effluent used was a representative sample collected over a 24 hr period. The effluent was diluted with Lake Huron water to the following ppm concentrations: 25, 50, 75, 100, 250, 500, 750, 1000, 2500, 5000, 7500 and 10,000. Three or four specimens of each species were immersed in 6 l. of each concentration in a 10 l. glass battery jar. Temperature was 65°F, ±1°, using constant temperature equipment of APPLEGATE *et al.* (1957). Compressed air provided aeration through stone airbreakers. Static bioassay techniques were used and the exposure period was 24 hr. Tests were carried out at Hammond Bay Biological Station (TABLES 1–10).

Mineral analyses with a Baush and Lomb Spectronic colorimeter were made of the effluent, the Lake Huron water, the 10,000 ppm concentration, the Cheboygan River water just above where it enters the paper mill and of the Cheboygan River water just below the effluent entry point (TABLE 11).

TABLE 1. TOLERANCE OF THE WHITE SUCKER TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65°F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death (hr)
4 (89–115)	25	1 (21)
4 (104–113)	50	1 (21)
3 (105–125)	75	0
4 (106–121)	100	0
4 (105–123)	250	0
4 (110–120)	500	0
4 (104–108)	750	0
4 (112–122)	1000	0
4 (47–112)	2500	0
4 (110–115)	5000	0
4 (99–132)	7500	0
4 (97–124)	10,000	0

TABLE 2. TOLERANCE OF THE MOTTLED SCULPIN TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65°F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death
4 (47–65)	25	0
4 (51–76)	50	0
4 (38–57)	75	0
4 (47–92)	100	0
4 (46–67)	250	0
4 (58–87)	500	0
4 (53–62)	750	0
4 (49–62)	1000	0
4 (53–64)	2500	0
4 (49–62)	5000	0
4 (52–55)	7500	0
4 (53–67)	10,000	0

TABLE 3. TOLERANCE OF THE BROWN BULLHEAD TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65°F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death
4 (30–34)	25	0
4 (33–37)	50	0
4 (31–35)	75	0
4 (33–38)	100	0
4 (32–37)	250	0
4 (30–36)	500	0
4 (35–37)	750	0
4 (33–36)	1000	0
4 (30–37)	2500	0
4 (30–36)	5000	0
4 (34–37)	7500	0
4 (35–38)	10,000	0

TABLE 4. TOLERANCE OF THE PUMPKINSEED TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65° F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death
4 (55–63)	25	0
4 (53–58)	50	0
4 (57–69)	75	0
4 (54–62)	100	0
4 (54–68)	250	0
4 (54–62)	500	0
4 (59–65)	750	0
4 (49–58)	1000	0
4 (56–63)	2500	0
4 (51–70)	5000	0
4 (56–61)	7500	0
4 (54–65)	10,000	0

TABLE 5. TOLERANCE OF THE LARGEMOUTH BASS TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65° F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death
4 (43–49)	25	0
4 (42–45)	50	0
4 (45–53)	75	0
4 (47–60)	100	0
4 (46–60)	250	0
4 (51–68)	500	0
4 (41–50)	750	0
4 (47–59)	1000	0
4 (49–53)	2500	0
4 (49–64)	5000	0
4 (50–67)	7500	0
4 (50–57)	10,000	0

TABLE 6. TOLERANCE OF THE COMMON SHINER TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65° F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death (hr)
3 (92–119)	25	2 (21) 1 (24)
3 (102–115)	50	2 (21) 1 (24)
3 (96–114)	75	1 (7¼) 1 (21¼)
3 (80–111)	100	3 (21¼)
3 (83–102)	250	1 (7¼) 2 (21¼)
3 (90–120)	500	1 (7¼) 2 (21¼)
3 (89–106)	750	1 (7) 1 (21) 1 (24 hr)
3 (78–92)	1000	0
3 (88–99)	2500	0
3 (80–101)	5000	0
3 (73–118)	7500	1 (21)
3 (76–122)	10,000	2 (21) 1 (24)

TABLE 7. TOLERANCE OF THE YELLOW PERCH TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65° F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death
4 (51–114)	25	0
4 (47–123)	50	0
4 (47–123)	75	0
4 (48–110)	100	0
4 (46–106)	250	0
4 (45–112)	500	0
4 (51–108)	750	0
4 (53–115)	1000	0
4 (50–106)	2500	0
4 (51–126)	5000	0
4 (51–122)	7500	0
4 (47–112)	10,000	0

TABLE 8. TOLERANCE OF THE LOGPERCH TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65° F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death (hr)
4 (52–100)	25	1 (21)
4 (49–98)	50	0
4 (51–93)	75	0
3 (90–101)	100	0
4 (51–95)	250	0
4 (91–110)	500	0
3 (59–102)	750	1 (21)
4 (55–95)	1000	0
4 (83–104)	2500	0
4 (58–100)	5000	1 (21) 1 (24)
4 (88–107)	7500	0
4 (94–101)	10,000	0

TABLE 9. TOLERANCE OF THE SEA LAMPREY TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65° F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death
4 (102–122)	25	0
4 (100–126)	50	0
4 (66–123)	75	0
4 (69–120)	100	0
4 (101–110)	250	0
4 (80–126)	500	0
4 (94–126)	750	0
4 (86–122)	1000	0
4 (92–112)	2500	0
4 (81–114)	5000	0
4 (85–130)	7500	0
4 (69–142)	10,000	0

TABLE 10. TOLERANCE OF THE RAINBOW TROUT TO VARIOUS CONCENTRATIONS OF EFFLUENT IN LAKE HURON WATER AT 65° F

No. of individuals and length range (mm)	Concentration (ppm)	No. dead and length of exposure at death (hr)
4 (88–95)	25	0
4 (109–112)	50	0
4 (102–115)	75	0
4 (101–117)	100	0
4 (102–121)	250	0
4 (93–111)	500	0
4 (87–102)	750	0
4 (84–111)	1000	0
4 (91–107)	2500	0
4 (98–111)	5000	0
4 (91–115)	7500	1 (24)
4 (87–109)	10,000	4 (21)*

* Air tube came out of this jar, cutting off the air supply.

Fish were collected from the effluent entry point into the Cheboygan River by two teams of five members each, for an hour, using Common Sense Minnow Seines of various lengths and electrofishing equipment. Species, with number collected in parentheses, were: *Ambloplites rupestris* (Rafinesque), rockbass (30); *Catostomus commersoni* (Lacépède), white sucker (1); *Chrosomus eos* Cope, northern redbelly dace (3); *Cottus bairdi* Girard, mottled sculpin (2); *Etheostoma nigrum* Rafinesque, Johnny darter (26); *Lepomis megalotis* (Rafinesque), longear sunfish (7); *Micropterus dolomieui* Lacépède, smallmouth bass (3); *Micropterus salmoides* (Lacépède), largemouth bass (5); *Notropis atherinoides* Rafinesque, emerald shiner (62); *Notropis cornutus* (Mitchill), common shiner (1); *Notropis hudsonius* (Clinton), spottail shiner (20); *Notropis stramineus* (Cope), sand shiner (29); *Notropis volucellus* (Cope), mimic

TABLE 11. ANALYSES OF EFFLUENT AND WATER SAMPLES

	Effluent	Lake Huron	10,000 ppm	Cheboygan River above Mill	Cheboygan River below Mill
Conductivity (μMhos)	349.7	168.7	173.3	263.9	263.5
pH	7.4	7.9	7.9	8.3	8.3
Methyl orange alkalinity	87.0	89.0	87.0	147.0	146.0
Phenolphthalein alkalinity	0.0	0.0	0.0	Trace	Trace
Turbidity (in Jackson units)	172.0	12.0	—	—	—
Calcium hardness as calcium carbonate	120.0	64.0	60.0	88.0	92.0
Total hardness as calcium carbonate	176.0	94.0	104.0	146.0	146.0
Chloride	11.5	6.0	7.5	4.5	4.5
Sodium chloride	19.0	9.9	12.4	7.4	7.4
Chlorine	0.022	0.018	0.022	0.022	0.018
Copper	0.20	0.13	0.20	0.11	0.13
Ferric iron	0.08	0.06	0.01	0.10	0.08
Ferrous iron	0.02	0.02	0.02	0.02	0.02
Total iron	0.10	0.08	0.03	0.21	0.10
Ammonium nitrogen	1.54	0.15	0.15	0.48	0.56
Nitrate nitrogen	0.092	0.189	0.89	0.097	0.097
Nitrite nitrogen	0.008	0.011	0.01	0.003	0.003
Sulphate	141.0	21.0	12.5	15.0	19.0
Silica	4.56	1.0	0.88	0.61	5.28
Tannin and lignin	0.90	0.10	0.1	0.20	0.20
Meta phosphate	0.38	0.63	0.06	0.82	0.65
Ortho phosphate	0.04	0.21	0.11	0.02	0.11
Total phosphate	0.42	0.84	0.17	0.84	0.75

In ppm unless otherwise stated.

shiner (11); *Perca flavescens* (Mitchill), yellow perch (1); *Percopsis omiscomaycus* (Walbaum), trout-perch (1) and Cyprinidae, very small (227). Collection was limited to a strip from 5 to 15 ft wide on the east side of the river and a strip from 5 to about 35 ft wide on the west side. The center of the river was too deep for seining or electric shocking. Heavy boat traffic precluded use of gill nets and fyke nets in the deeper areas. In this portion of the river current was swift, clarity good, water temperature was 22°C and air temperature 20.5°C. (1300–1400 hr, 9 August 1956). The bottom consisted of sand, pebbles and rocks, with very small amounts of submergent vegetation. The banks were steep with low vegetation and some trees were present on the west side at the north end of the area.

Records (Legault, unpublished) were checked for fish collected in this area in previous years. Species caught in previous years that were not obtained in this study included: *Cyprinus carpio* Linnaeus, carp; *Lepomis gibbosus* (Linnaeus), pumpkinseed; and *Pimephales notatus* (Rafinesque), bluntnose minnow.

DISCUSSION

Our experiments exposed 456 fish to various effluent concentrations. Only 35 of these died. Elimination of four rainbow trout, perishing by accidental air shut-off, leaves a total of 461 with 31 dead, or a mortality rate of 6.7 per cent. This is low by comparison with certain other industrial pollution studies on fish (KELLING, 1961). In Kelling's study, minnow populations abandoned the upper region of Grimes Creek, Iowa, a few days after a canning factory discharged wastes into the stream.

Analysis of TABLES 1–10 shows that 24 of the 31 dead fish were one species, the common shiner. Two-thirds of the common shiners exposed were killed. Only one common shiner was obtained from the Cheboygan River where the effluent from the paper mill enters it. Legault's records (unpublished) showed that only one of these shiners was collected when this area was studied in 1963. The area was not studied in 1964.

Of the other nine species, 425 animals were exposed and seven died for a mortality of 1.6 per cent. The distribution of deaths over the species and concentrations involved presented no recognizable pattern.

TABLE 11 shows that the mill effluent did not greatly alter the chemical condition of the river. Much of this was due to the excellent treatment of the waste products by the paper mill. Part of this treatment involved transportation of much of the solid wastes by truck to a private dump. Another consideration is the dilution achieved. The flow of the Cheboygan River just above the paper mill for 18 August 1964 was 306 ft^3/sec (U.S. DEPARTMENT OF INTERIOR, 1965). This is the sum of daily discharge of 250 ft^3/sec of the Cheboygan River above the mouth of the Black River and daily discharge of 56 ft^3/sec of the Black River (Appendices A and B). This is the volume that flows past the paper mill. Volume flow of this river is taken each month. However, complete analysis and adjustment were completed only through February 1965. Data for August 1965 will not be available until May 1966. Since our study was made in August 1965, the data from the previous August were more applicable because of seasonal variations. Only a rough estimation, however, of dilution was desired. The paper mill utilized 948,600 gal of river water during the 24 hr in which the effluent sample was collected. Using the figure of volume flow for August 1964, the effluent from the mill was only 0.48 per cent of the volume of the river.* The effluent was 1 per cent of the 10,000 ppm concentration of this study. Thus, the highest concentrations used in these experiments were more than two times that of the effluent in the river. As can be seen from Appendices A and B, volume flow was at its lowest for the year during the middle of August. A 22 year average discharge is 1182 ft^3/sec just above the paper mill (767 ft^3/sec for the Cheboygan River above the mouth of the Black River and 415 ft^3/sec for the Black River). The greater the volume flow, the lower the effluent concentration in the river would be.

High turbidity of the effluent was mainly due to short fibers. In addition to measuring turbidity in Jackson units, a 5 g sample of the effluent was evaporated to determine the residue, mainly fiber. It was 0.032 per cent by weight. Comparison of the Cheboygan River water above the mill with that below the mill (TABLE 11), indicates that of the chemicals analysed, those added to the river in greatest quantities were silica, sulphates, ammonium nitrogen, copper and the calcium hardness was increased. Reduction in certain chemicals below the mill indicated that some chemical reactivity took place between the effluent and the river water.

* The conversion figure for changing ft^3/sec to gal/day is 1 ft^3/sec = 646,317 gal/day (U.S. DEPARTMENT OF INTERIOR, 1953).

CONCLUSIONS

After a tour of the Charmin Paper Products Company plant, several talks with Mr. Ralph J. Van Deuren and a review of certain information from company files, the writers believed the company was making a substantial effort towards control of its industrial wastes. This belief was sustained by analyses of the effluent and the Cheboygan River water above and below the mill. It was further substantiated by the very low mortality rate in bioassay experiments. One fish species, the common shiner, was quite susceptible to the wastes in the experiment and was rare in river collections from this area. It was noted, however, that this species was also somewhat more vulnerable to ordinary retention in aquaria and tanks in the Hammond Bay Laboratory for the four or more days they were held prior to the tests.

The most abundant fish species in the area of the river where effluent was received were not bioassayed. The presence of a particular species, therefore, cannot be taken as an indicator of pollution, which was low in this case. However, the most abundant species in the study area were the emeral shiner, the rock bass, the sand shiner, the Johnny darter, and the spottail shiner.

Since the common shiner was extremely intolerant to the effluent, its presence in an area would indicate a very low level of pollution of this type.

The degree of pollution is as low as possibly could be expected from such an industry. Other industries, as well as other paper companies, could give attention to the treatment of waste products by Charmin Paper Products Company, Cheboygan, as an example of what an industry can do to reduce water pollution.

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Zusammenfassung—Diese Studie untersuchte die Auswirkungen der industriellen Abfallprodukte einer Papierfabrik auf Fische. Es wurden chemische Analysen des Abwassers gemacht, sowie des Flusswassers und zwar bevor dieses in die Fabrik floss und wiederum an der Einflusstelle des Abwassers. Statische Bioprobentechnik wurde angewandt um die jeweilige Abwasser-Toleranz von zehn Fischarten zu bestimmen, die sich in reichlicher Zahl in der Fabrikgegend vorfanden. An der Einflusstelle des Abwassers wurden Fische aus dem Fluss genommen. Es stellte sich heraus, dass sich dort eine reichliche Fishfauna befand. Die Firma Charmin Paper Products Company in Cheboygan, Michigan unterzieht ihre Abfallprodukte einer gründlichen physiochemischen Behandlung und dient daher als Beispiel dafür, was ein Industriebetrieb zur Reduzierung der Wasserverunreinigung beitragen kann. *Notropis cornutus* erwies sich selbst niedrigen Abwasserkonzentraten gegenüber als intolerant. Somit erscheint ihre Anwesenheit als Indikator eines sehr niedrigen Grades der Verunreinigung obiger Art.

APPENDIX A

*Streams tributary to Lake Huron**

4–1300. Cheboygan River near Cheboygan, Michigan.

Location. Lat. 45°34′40″, long. 84°29′15″, in SW¼ sec. 19, T.37 N., R.1 W., 300 ft downstream from Mullett Lake, 2½ miles upstream from Black River, and 5 miles south of Cheboygan.

Drainage area. 865 miles^2.

Records available. October 1942 to September 1964. Monthly discharge only for October 1942, published in WSP 1307.

Gage. Water-stage recorder. Datum of gage is 591.21 ft above mean sea level, datum of 1929. Auxiliary staff gage at Cheboygan 5.2 miles downstream read hourly. Datum of auxiliary gage is 590.00 ft above mean sea level, datum of 1929.

Average discharges. 22 yr, 767 ft^3/sec.

Extremes. Maximum daily discharge during year, 1120 ft^3/sec Apr. 30, May 1; maximum daily gage height, 2.53 ft Aug. 3; minimum daily discharge, 150 ft^3/sec Aug. 14; minimum daily gage height, 1.39 ft Mar. 22, 23, 25, 31.

1942–64: Maximum daily discharge, 1640 ft^3/sec May 8, 1959; maximum daily gage height, 3.27 ft May 13, 14, 1960; minimum daily discharge, 90 ft^3/sec Mar. 29, 30, 1958; minimum daily gage height, 1.12 ft Dec. 29, 1952.

Remarks. Records fair except those for periods of ice effect, indefinite stage-discharge relation or no gage-height record, which are poor. Flow affected by variable backwater from powerplant at Cheboygan 5.2 miles below station and by Alverno powerplant.

Cooperation. Auxiliary gage readings furnished by Consumers Power Co.

* Courtesy of U.S. DEPARTMENT OF INTERIOR (1965).

DISCHARGE IN ft^3/sec, WATER YEAR OCTOBER 1963 TO SEPTEMBER 1964

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	557	469	764	630	800‡	578	809	1.120	560	443	414	320
2	498	533	847	636	800‡	586	826	1.110	477	445	475	295
3	507	536	878‡	698	800‡	564	818	1.100	490§	458	840	327
4	523	505	700‡	724	800‡	582	787	1.080	477	470	869	519
5	551	512	760‡	702	813	686	781	1.080	534	470	797	448
6	531	505	741	729	810	740	831	1.100	519	477	554	395
7	507	505	729	727	792	783	907	1.090	533	477	600	363
8	474	541	738	733	780†	786	933	1.100	532	596	593	533
9	491	543	816	735	780†	867	896	1.110	542	540	454	587
10	490	516	756	761	760†	906*	842	1.090	591*	471	395	603
11	434	581	740	720‡	740†	888	849	1.090	607	440	350	585
12	366	590*	760*	741	731	902	879	1.080*	595	466	412	462
13	339	607	813	726	725	916	878	1.080	609	542	227	454
14	494	615	740‡	714*	713	896	861	1.070	608	616*	150§	450
15	534*	607	682	700‡	713	903	906	1.040	591	573	180§	350§
16	518	527	670	700‡	706	901	895	1.070	548	616	283	385
17	504	566	650†	713	702	907	892	1.070	542	589	210§	433
18	586	706	600†	692	676	912	921	1.040	554	585	250*§	466
19	489	757	540†	690	682	897	921	1.020	617	570	290§	526
20	393	835	560†	717	625	899	953	901	582	513	354	477
21	560	859	572	715	614	868	973	835	566	486	457	463
22	504	893	587	708	599	859	1.030	792	538	478	502	628
23	517	835	593	706	599	837	1.030*	723	528	478	478	847
24	536	899	577	648	599	829	990	735	476	478	423	914
25	605	975	614	755	575	826	984	770	474	497	463	985
26	607	960	625	776	599	846	984	760	497	439	432	987
27	669	927	640	799	599	862	996	694	481	426	420	999
28	630	869	670‡	815	586	857	1.060	693	481	385	469	948
29	624	860	640‡	806	586	857	1.080	691	456	443	427	926
30	564	754	689	816	—	828	1.120	642	442	442	328	700
31	450	—	625	807	—	854	—	628	—	456	366	—
Total	16,052	20,387	21,316	22,539	20,304	25,422	27,632	29,404	16,047	15,365	13,462	17,375
Mean	518	680	688	727	700	820	921	949	535	496	434	579
Cfsm	0.599	0.786	0.795	0.840	0.809	0.948	1.06	1.10	0.618	0.573	0.502	0.669
In.	0.69	0.88	0.92	0.97	0.87	1.09	1.18	1.27	0.69	0.66	0.58	0.75

Calendar year 1963: Max 1390 Min 339 Mean 739 $ft^3/mile^2$ 0.854 In. 11.60
Water year 1963–64: Max 1120 Min 150 Mean 670 $ft^3/mile^2$ 0.775 In. 10.55

* Discharge measurement made on this day. † No gage-height record. ‡ Stage-discharge relation affected by ice. § Stage-discharge relation indefinite.

APPENDIX B

*Streams tributary to Lake Huron**

4–1320. Black River near Cheboygan, Michigan.

Location. Lat. 45°30′00″, long. 84°19′35″, in NW¼NW¼ sec. 21, T.36 N., R.1 E., on left bank 0.3 mile downstream from Black Lake, 5.3 miles upstream from Alverno Dam, and 12.6 miles southeast of Cheboygan.

Drainage area. 597 $miles^2$.

Records available. October 1942 to September 1964. Monthly discharge only for October 1942, published in WSP 1307.

Gage. Water-stage recorder. Datum of gage is 609.26 ft above sea level, datum of 1929. Auxiliary water-stage recorder 3 miles downstream at same datum.

Average discharge. 22 yr, 415 ft^3/sec.

Extremes. Maximum daily discharge during year, 960 ft^3/sec Sept. 27; maximum daily gage height, 3.16 ft Aug. 3; minimum daily discharge, 15 ft^3/sec June 28; minimum daily gage height, about 1.10 ft Mar. 1.

1942–64: Maximum daily discharge, 2,500 ft^3/sec Apr. 20, 1960; maximum daily gage height, 5.74 ft Apr. 20, 1960; minimum daily discharge, 11 ft^3/sec Aug. 14, 1949; minimum daily gage height, that of Mar. 1, 1964.

Remarks. Records fair except those for periods of ice effect, indefinite stage-discharge relation or no gage-height record, which are poor. Flow regulated by powerplant at Alverno Dam.

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* Courtesy of U.S. DEPARTMENT OF INTERIOR (1965).

DISCHARGE, IN ft³/sec, WATER YEAR OCTOBER 1963 TO SEPTEMBER 1964

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	219	124	400	350	284	180	406	723	267	55†	111	68
2	128	130	500	344	290	180	401	728	200	51	112	60
3	175	69	500	330	288	200	413	730	152	118	398	71
4	130†	41	400	332	285	230	404	707	104	97	400	141
5	132	54	446	308	287	250	383	717	112	57	333	145
6	145	83	434	320	290	300	367	710	126	56	312	59
7	156	63	342	318	300	329	394	700	106	166	343	48
8	122	85	348	291	300	315	452	511	104	230	260	232
9	59	56	477	316	300	345	481	315	119	184	40	330
10	97	101	486	300	300	354*	479	307	140*†	82	71	316
11	120	203	474	270	300*	362	558	390	75†	71	81	267
12	117	350*	498*	260	270	362	607	408*	85	79	139	101
13	125	310	480	260	270	372	629	488	109	249	40	119
14	128	310	450	260*	270	382	681	570	81	336*	69	135
15	129*	310	400	260	250	398	678	631	152	373	25	111*
16	140†	200	400	260	220	369	682	616	131	334	72	111
17	200†	150	450	260	220	400	727	520	99	341	20	169
18	311	150	400	260	220	409	758	236	174	319	56	278
19	253	350	400	267	220	399	743	374	316	308	37*	372
20	292	350	400	277	210	391	736	255	311	217	29	244
21	218	350	380	260	190	406	723	270	296	142	80	227
22	306	400	380	250	190	401	726	262	198	102	95	401
23	420	400	380	240	190	377	760*	227	66	98	82	460
24	320	400	380	225	180	389	734	287	85†	120	72	637
25	198	500	380	242	180	398	730	276	65	143	85†	941
26	173	500	380	230	180	429	727	282	115	81	101	924
27	174	450	380	230	180	412	721	353	53	73	96	960
28	154	500	380	230	180	422	711	313	15†	90†	84	924
29	126	450	380	250	180	430	729	292	58	132	97	936
30	89	500	380	278	—	431	728	260	67	107	116	779
31	93	—	350	290	—	422	—	236	—	90	99	—
Total	5,449	7,939	12,835	8,568	7,024	11,044	18,268	13,694	3,981	4,901	3,955	10,566
Mean	176	265	414	276	242	356	609	442	133	158	128	352
Cfsm	0.295	0.444	0.693	0.462	0.405	0.596	1.02	0.740	0.223	0.265	0.214	0.590
In.	0.34	0.50	0.80	0.53	0.44	0.69	1.14	0.85	0.25	0.31	0.25	0.66

Calendar year 1963: Max 1370 Min 40 Mean 383 ft³/mile² 0.642 In. 8.71
Water year 1963–64: Max 960 Min 15 Mean 296 ft³/mile² 0.496 In. 6.76

* Discharge measurement made on this day. † Stage-discharge relation indefinite.

Note—Stage-discharge relation affected by ice Dec. 14 to Jan. 1, Jan. 10–18, 26–29. No gage-height record Nov. 12 to Dec. 4, Dec. 18 to Jan. 1, Jan. 14, 21–23, Feb. 6 to Mar. 6.