United States
Department of the Interior
Geological Survey

Relation of Channel Slope to Reaeration of Michigan Streams

by

T. Ray Cummings

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ABSTRACT

Reaeration coefficients (k_2), which are rate constants for the process of oxygen absorption from the atmosphere, have been computed for Michigan's streams using an equation developed by Bennett and Rathbun (1972). Mean velocity and mean depth data, which are necessary for the computation, have been extracted from discharge measurements made at gaging stations throughout the State. The computed k_2 values have been related to channel slopes obtained from topographic maps. Regression equations have been derived that express the relation of k_2 to slope for streams at mean flow, median flow, 7-day 2-year low flow, and 7-day 10-year low flow. The equations indicate that an increase in channel slope or a decrease in streamflow increases k_2.

INTRODUCTION

Streeter and Phelps (1925) described the assimilation of organic wastes by streams in terms of two major processes--the consumption of oxygen in biochemical degradation of organic matter, and the absorption of oxygen from the atmosphere. They expressed these processes by the differential equation

$$\frac{dD}{dt} = K_1L - K_2D \quad ,$$

where D represents the dissolved-oxygen deficit, L is the biochemical oxygen demand of carbonaceous material, K_1 is the deoxygenation coefficient or rate constant for biochemical oxidation, and K_2 is the reaeration coefficient or rate constant for oxygen absorption from the atmosphere. D and L are usually expressed in milligrams per liter, and the coefficients K_1 and K_2, which are to a natural logarithm base, are expressed in reciprocal days at 20°C. Because common logarithms generally are more convenient to use in most calculations, the deoxygenation and reaeration coefficients are usually represented by k_1 and k_2, where $k_1 = 0.434\ K_1$ and $k_2 = 0.434\ K_2$.

Reaeration in open-channel flow was studied by Bennett and Rathbun (1972). They reviewed an extensive body of literature on reaeration and considered the basic methods for measuring reaeration coefficients. Experiemental field and flume data obtained by many investigators were assembled and subjected to regression analysis and statistical interpretation. Although three equations for predicting k_2 were derived by Bennett and Rathbun, they concluded that the equation

$$k_2 = 8.76 \frac{U^{0.607}}{H^{1.689}} ,$$

which was based on the widest range of field data available, was the best available for prediction of reaeration coefficients for natural streams. In the equation, U is the mean flow velocity, in feet per second, H is the mean depth of flow, in feet, and k_2 is in reciprocal days at 20°C.

The above equation, of course, expresses the reaeration coefficient under ideal conditions. In water-pollution studies, such factors as wind and waves, surfactants, the dissolved-solids content and temperature of water, and the type and quantity of sewage present, must be taken into account.

MacKichan and others (1970), using an equation[1/] for k_2 suggested by Langbein and Durum (1967), computed k_2 values for different flow conditions at several sites on the Elkhorn River in Nebraska. Using the k_2 values obtained, they derived an equation that related k_2 at any point on the Elkhorn River to channel slope and discharge.

1/ $k_2 = 3.3 \frac{v}{H^{1.33}}$, where v is mean flow velocity, in feet per second, and H is mean depth, in feet.

This report presents the results of the computation of reaeration coefficients, using the Bennett and Rathbun equation, for specific sites on Michigan's streams, and relates these values to channel slope. If possible, a k_2 value was computed for four flow conditions at each site: mean flow (average annual discharge), median flow (median annual discharge), 7-day low flow having a recurrence interval of 2 years, and 7-day low flow having a recurrence interval of 10 years. All k_2 values for a given flow condition were plotted against channel slope, in feet per mile; a regression equation relating k_2 to channel slope was computed for each flow condition.

COMPUTATION OF REAERATION COEFFICIENTS (k_2)

At approximately 200 sites on streams in Michigan, the U.S. Geological Survey, in cooperation with State and Federal agencies, operates gaging stations at which continuous records of stage are obtained. Discharge measurements are made routinely at each gaging station to define a stage-discharge relation. The exact site chosen for a discharge measurement may be either upstream or downstream from the gaging station, providing there is no change in flow. Usually the site is one that permits the most accurate results from the measuring techniques used at the time of the visit to the station. Channel geometry at the measuring site may or may not be representative of the reach of the stream in the vicinity of the gaging station.

For most gaging stations, the period of record is sufficiently long that mean flow, median flow, 7-day 2-year low flow, and 7-day 10-year low flow have been computed in other studies. These discharge values, in cubic feet per second, have been used in this study; table 1 gives these data for 142 gaging stations.

In order to obtain velocity and depth information for use in the reaeration equation, the files of the Geological Survey were searched for individual discharge measurements made at times when the flow of a stream at a gaging station was as close as possible to one of the four flow conditions cited above. For example, the mean flow of the Black River near Bessemer is 226 cfs (cubic feet per second). From the files, the six most recent discharge measurements that were within 10 percent of 226 cfs were selected, and width, area, and mean velocity were tabulated on work sheets; mean depth was computed. The exact location of each measurement also was noted. The files were again searched for the six most recent discharge measurements of the Black River near Bessemer that did not differ by more than 10 percent from the median flow (83.6 cfs). The process was repeated for the 7-day 2-year and 7-day 10-year low flows. Data for each gaging station were selected in the same manner, although as many as six measurements were not always available for each flow condition. At some stations it was possible to select six measurements that did not differ by more than 5 percent from the discharge value sought.

Once the above information was assembled, the work sheets were reviewed to eliminate from consideration those measurements that were not typical of present stream conditions. Measurements made prior to a known channel modification were deleted. Because individual discharge measurements may have been made upstream or downstream from a gaging station, measuring sites were spotted on topographic maps. If a measurement was found to have been made at a point where channel configuration was significantly different from that where the other measurements at the station were made, the measurement was eliminated from the work sheet. If a measurement was found to have been made at a point where channel slope differed from that where the other measurements were made, it too was eliminated.

Mean depth and mean velocity for each flow condition at a site were determined by averaging the individual mean depths and mean velocities of each measurement that remained after the above review. Reaeration coefficients for each site and each flow condition were calculated from these mean values. (See table 1.)

The range, average, and median k_2 values for each flow condition are shown below. Only those sites for which it was possible to compute a k_2 for all four flow conditions were used in determining average and median k_2 values.

	Range of k_2	Average k_2	Median k_2
Mean flow	0.23 - 61.7	5.43	4.6
Median flow	.23 - 38.6	6.74	5.8
7-day 2-year low flow	.25 - 97.8	10.63	7.3
7-day 10-year low flow	.16 - 98.7	12.05	7.8

RELATION OF REAERATION COEFFICIENTS (k_2) TO CHANNEL SLOPE

U. S. Geological Survey topographic maps were used to determine channel slope. Maps published at a 7½-minute scale have either 5- or 10-foot contour intervals and, thus, are more desirable for computing channel slope than maps prepared at a 15-minute scale, which usually have 20-foot contour intervals. Unfortunately, it was necessary to compute channel slope from 15-minute topographic maps in slightly more than half the cases because maps at 7½-minute scale were not available.

Channel slope was computed for the site at which discharge measurements were made rather than at the exact gaging-station location, if the two locations differed. At three gaging stations, 04-0455., 04-0615., and 04-1655. (table 1), the locations of discharge measurements varied to the extent that it was desirable to compute k_2 and channel slope values for two different locations.

A plot of channel slope (S) versus k_2 for streams at mean flow is shown in figure 1. A line of best fit, based on a regression analysis, also is shown. Plots of channel slope versus k_2 for median flow, for 7-day 2-year low flow, and for 7-day 10-year low flow are shown in figures 2, 3, and 4. Figure 5 compares the reaeration coefficient-channel slope relations of the four flow conditions. Regression equations are as follows:

	Equation
Mean flow	$k_2 = 1.68\ S^{0.70}$
Median flow	$k_2 = 2.37\ S^{0.63}$
7-day 2-year low flow	$k_2 = 3.25\ S^{0.60}$
7-day 10-year low flow	$k_2 = 3.46\ S^{0.64}$

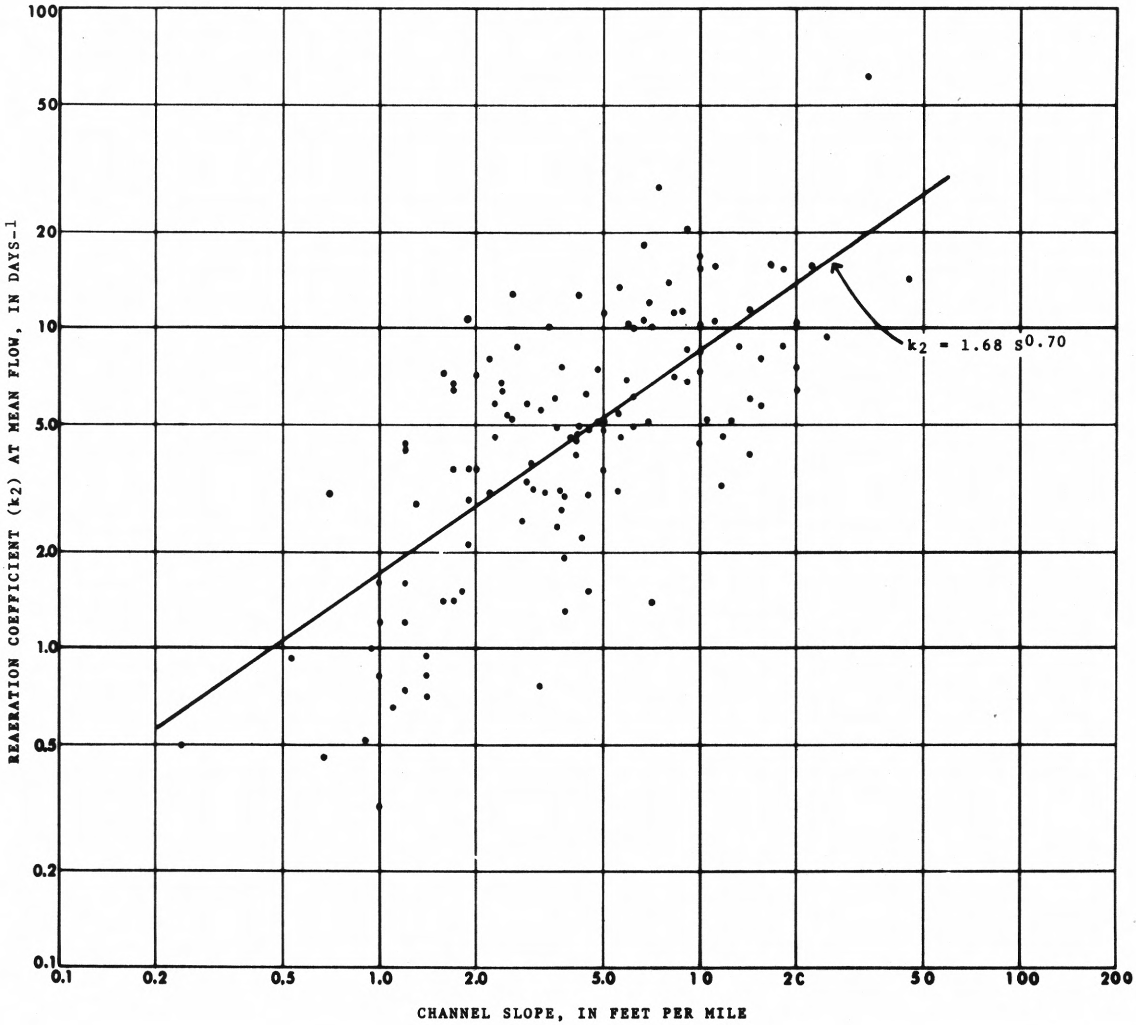

Figure 1.--Relation of reaeration coefficient (k_2) at mean flow to channel slope of streams in Michigan.

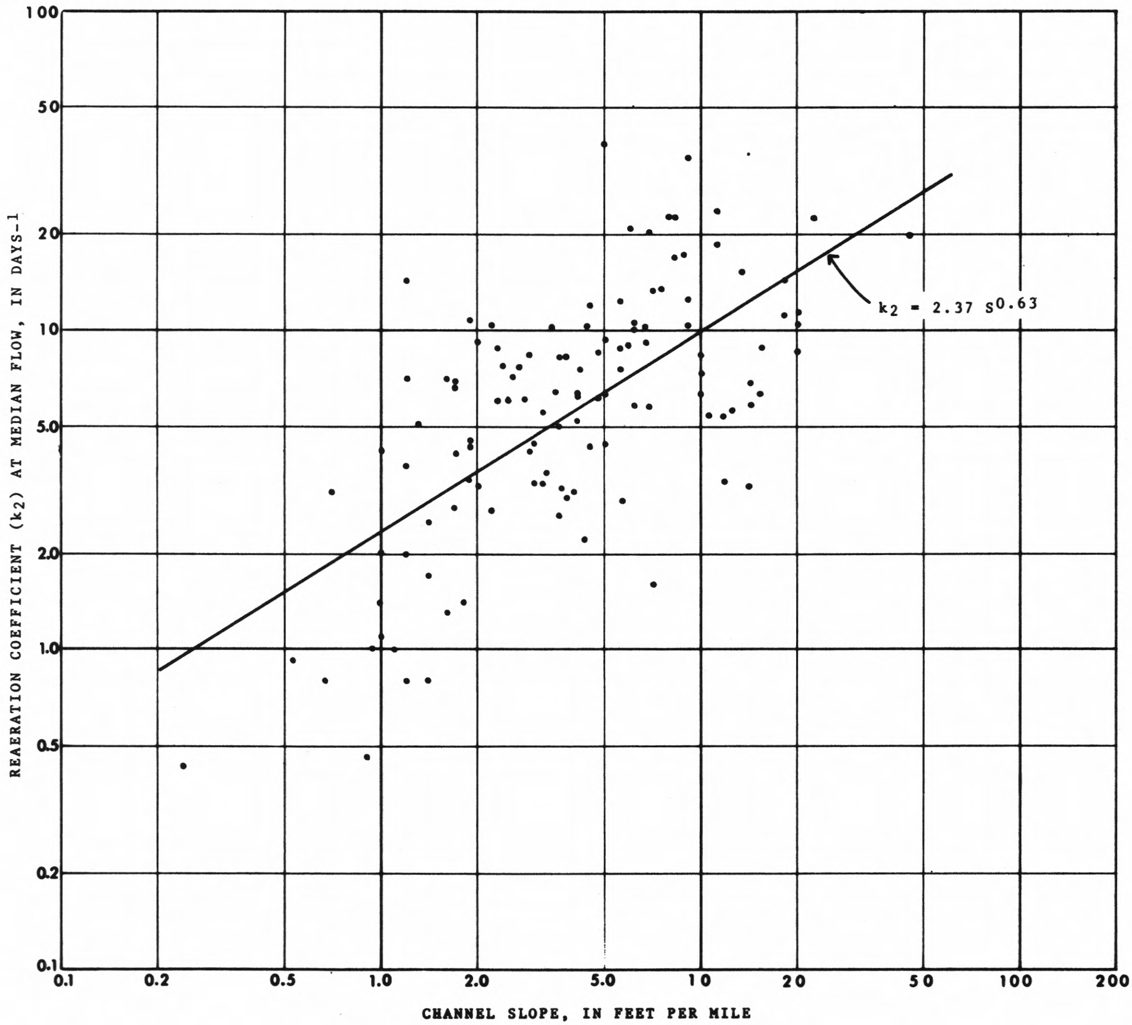

Figure 2.--Relation of reaeration coefficient (k_2) at median flow to channel slope of streams in Michigan.

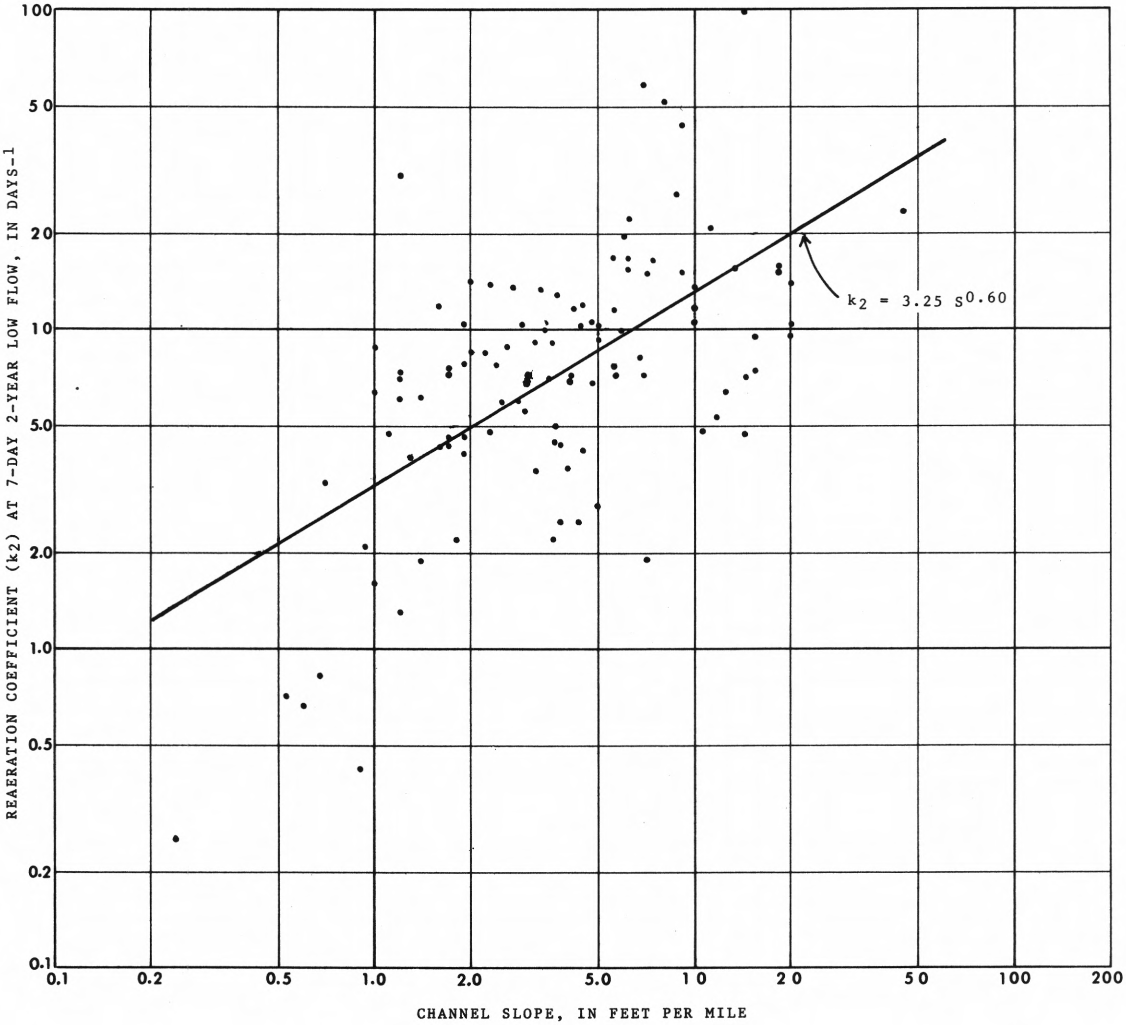

Figure 3.--Relation of reaeration coefficient (k_2) at 7-day 2-year low flow to channel slope of streams in Michigan.

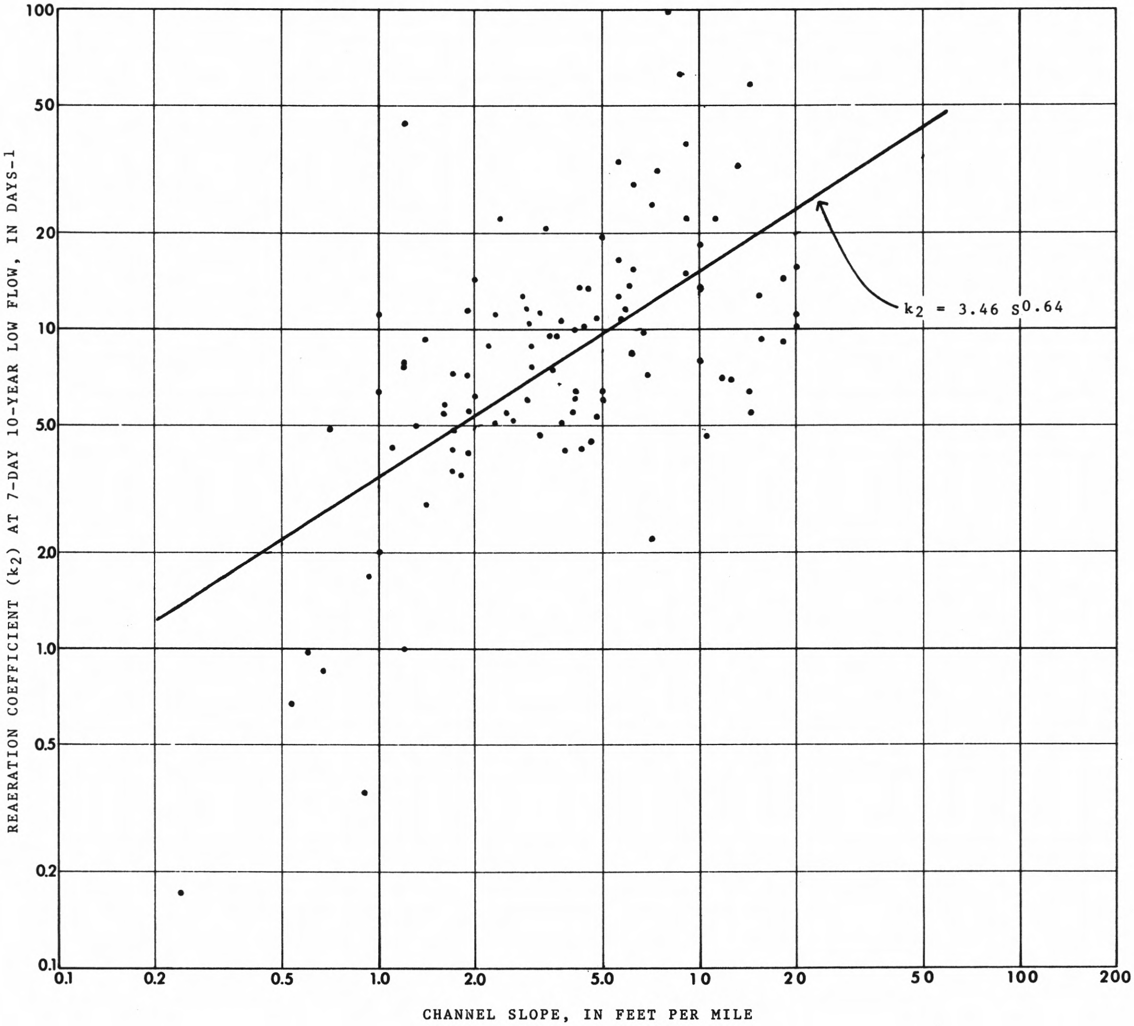

Figure 4.--Relation of reaeration coefficient (k_2) at 7-day 10-year low flow to channel slope of streams in Michigan.

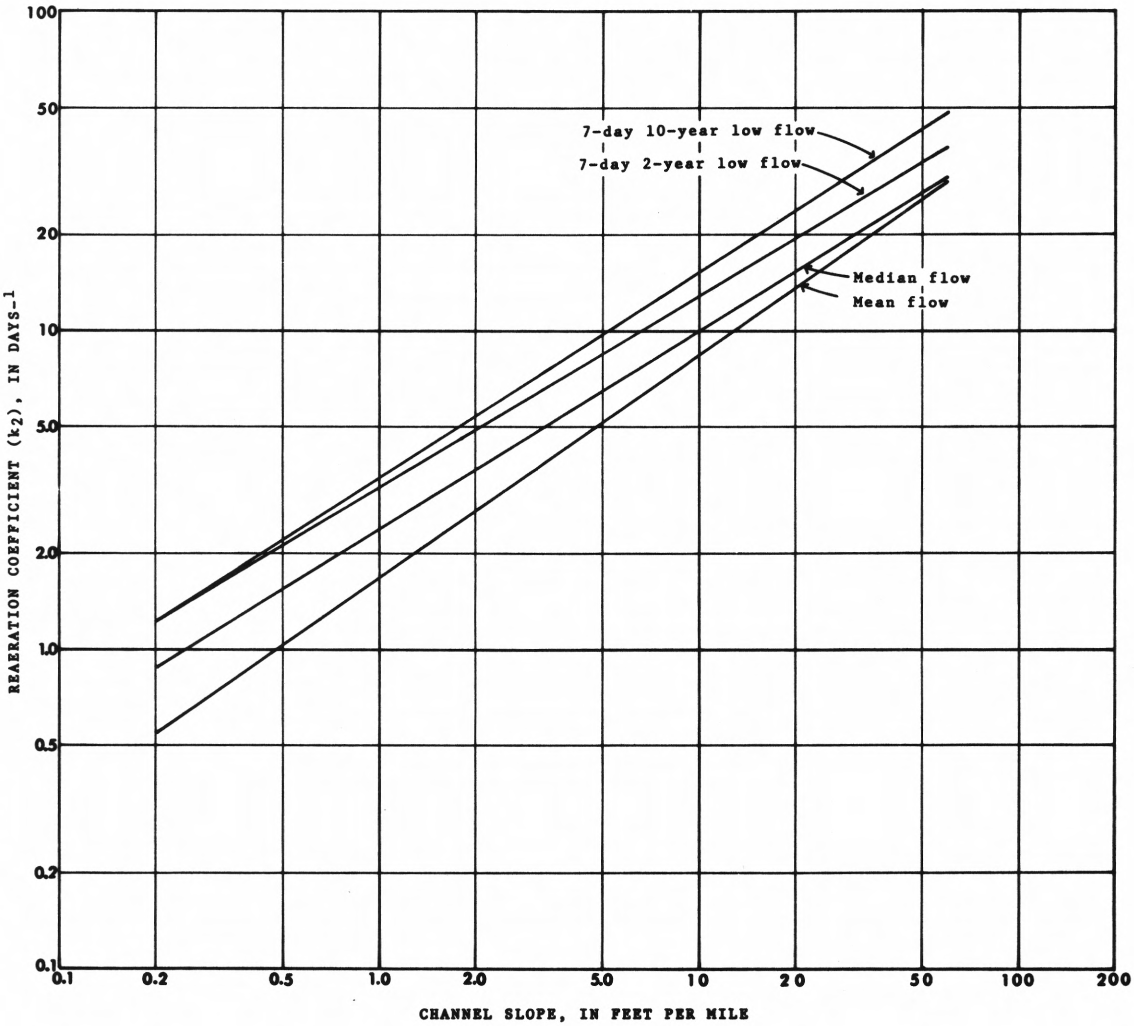

Figure 5.--Comparison of reaeration coefficient (k_2) - channel slope relations at mean flow, median flow, 7-day 2-year low flow, and 7-day 10-year low flow for streams in Michigan.

The above equations suggest that there is a significant relation between k_2 and channel slope that can be predicted if the flow condition of a stream is known. Use of the equations, however, should probably be restricted to estimating the reaeration coefficient at a specific site, or to comparing, in a general way, the reaeration capabilities of one stream with those of another. Estimates of the reaeration coefficient of a stream reach should await field studies that either verify or modify the above equations.

RELATION OF REAERATION COEFFICIENTS (k_2) TO DISCHARGE

An attempt to relate k_2 to discharge by regression analysis was not made in this study. A preliminary analysis of the data indicated that such relationships would be less satisfactory for predicting k_2 than relations developed with channel slope. A plot of all k_2 values against corresponding discharge values, however, indicates that a general increase in k_2 occurs as discharge decreases and that at discharges of less than 100 cfs the increase is rapid. A line of best fit drawn by eye through plotted points suggests that the relation of k_2 to discharge (Q) varies as follows: at 10 cfs, $k_2 \approx \frac{45}{\sqrt{Q}}$; at 100 cfs, $k_2 \approx \frac{70}{\sqrt{Q}}$; at 400 cfs, $k_2 \approx \frac{95}{\sqrt{Q}}$; at 1,500 cfs, $k_2 \approx \frac{120}{\sqrt{Q}}$; and at 3,000 cfs, $k_2 \approx \frac{140}{\sqrt{Q}}$.

SELECTED REFERENCES

Bennett, J. P., and Rathbun, R. E., 1972, Reaeration in open-channel flow: U. S. Geol. Survey Prof. Paper 737, 75 p., 19 figs.

Langbein, W. B., and Durum, W. H., 1967, The aeration capacity of streams: U. S. Geol. Survey Circ. 542, 6 p., 4 figs.

MacKichan, K. A., Stuthmann, N. G., and Bentall, Ray, 1970, Use of channel slope and discharge to determined reaeration coefficients for Elkhorn River in Nebraska: U. S. Geol. Survey Prof. Paper 700-C, p. 193-197.

Streeter, H. W., and Phelps, E. G., 1925, A study of the pollution and natural purification of the Ohio River: U. S. Public Health Service, Public Health Bull. 146, 75 p.

TABLE OF DATA

Table 1.--Flow, reaeration coefficients, and channel slope of streams in Michigan.

[Q_a = mean flow (average annual discharge); Q_m = median flow (median annual discharge); $M_{7,2}$ = 7-day 2-year low flow; $M_{7,10}$ = 7-day 10-year low flow; Q_ak_2, Q_mk_2, $M_{7,2}k_2$, and $M_{7,10}k_2$ = reaeration coefficients at indicated flow condition; slope = channel slope at gaging station or measuring site, in feet per mile.]

Station Number	Station Name	Q_a	Q_m	$M_{7,2}$	$M_{7,10}$	Q_ak_2	Q_mk_2	$M_{7,2}k_2$	$M_{7,10}k_2$	Slope
04-0310.	Black River near Bessemer	226	83.6	24.1	15.7	5.1	9.3	10.3	19.5	5.0
0315.	Presque Isle River at Marenisco	172	97.3	41.7	23.7	3.3	4.2	5.5	6.0	2.9
0330.	M. Br. Ontonagon R. nr. Paulding	170	125	84.3	69.6	5.1	5.7	7.2	7.2	6.9
0350.	E. Br. Ontonagon R. nr. Mass	254	165	107	84.3	1.4	1.6	1.9	2.2	7.1
0405.	Sturgeon River near Sidnaw	203	89.7	17.6	8.30	4.6	6.4	6.9	10.0	4.1
0415.	Sturgeon River near Alston	410	259	--	--	3.2	3.3	--	--	11.8
0425.	Otter River near Elo	212	119	79.8	73.8	3.6	6.3	9.3	6.4	5.0
0430.	Sturgeon River near Arnheim	797	464	273	206	.45	.79	.81	.85	.67
0455.	Tahquamenon R nr Tahquamenon Paradise	865	512	212	187	.23	.23	--	.16	--
-Do-	-do-	-do-	-do-	-do-	-do-	--	6.8	6.1	5.9	--
0460.	Black River near Garnet	26.3	15.7	8.10	6.24	3.2	5.6	8.4	7.3	--
0495.	Manistique River at Germfask	440	385	200	159	2.7	3.2	4.2	4.3	--
0545.	Duck Creek near Blaney	93	44.2	9.74	5.94	3.0	3.5	3.7	6.0	--
0550.	Manistique River near Blaney	820	611	287	216	.82	.92	2.8	3.1	--
0560.	W. Br. Manistique R. nr. Manistique	411	269	124	93.3	2.1	4.1	7.6	9.8	--
0565.	Manistique River near Manistique	1,355	943	457	343	1.2	1.9	3.3	3.2	--
0580.	M. Br. Escanaba River near Ishpeming	133	69.3	21.8	16.2	6.2	10.3	10.3	10.3	4.4
0585.	E. Br. Escanaba River at Gwinn	98.8	53.9	27.3	22.3	10.0	10.3	22.0	28.3	6.2
0590.	Escanaba River at Cornell	829	466	210	163	5.1	5.6	6.4	6.9	12.5
0595.	Ford River near Hyde	341	148	38.1	29.1	8.6	12.5	15.0	15.0	9.1
0610.	Brule River near Florence, Wis.	348	280	194	159	7.3	6.3	10.7	7.9	10.0
0615.	Paint River at Crystal Falls	568	356	213	167	7.5	10.4	10.3	10.1	20.0
-Do-	-do-	-do-	-do-	-do-	-do-	2.4	2.6	2.2	--	3.6
0653.	W. Br. Sturgeon R. nr. Randville	39.6	--	--	--	12.8	--	--	--	2.6
0655.	Sturgeon River near Foster City	171	--	--	--	3.0	--	--	--	2.2
0975.	St. Joseph River at Three Rivers	919	693	285	166	2.8	5.1	4.0	5.0	1.3
0985.	Fawn River near White Pigeon	138	122	--	--	6.4	6.9	--	--	1.7
0990.	St. Joseph River at Mottville	1,472	1,190	534	345	3.1	3.3	7.1	8.8	3.0
1015.	St. Joseph River at Niles	3,044	2,420	1,292	888	.51	.46	.42	.35	.92
1025.	Paw Paw River at Riverside	384	316	176	145	.70	.79	1.9	2.8	1.4
1035.	Kalamazoo River at Marshall	280	232	130	80.0	4.0	3.2	4.7	6.4	14.3
1050.	Battle Creek at Battle Creek	189	118	46.9	30.7	4.9	5.0	9.1	9.4	3.6
1055.	Kalamazoo River near Battle Creek	613	474	254	163	7.4	8.6	10.7	10.8	4.8
1060.	Kalamazoo River at Comstock	794	650	345	246	2.9	4.5	7.8	7.2	1.9
1065.	Portage Creek at Kalamazoo	56.5	54.3	39.2	29.3	5.7	6.3	7.5	9.2	15.4
1085.	Kalamazoo River near Fennville	1,301	1,126	550	334	.74	.79	1.3	.99	1.2

Table 1.--Flow, reaeration coefficients, and channel slope of streams in Michigan.--Continued

[$\bar{Q}_a$ = mean flow (average annual discharge); Q_m = median flow (median annual discharge); $M_{7,2}$ = 7-day 2-year low flow; $M_{7,10}$ = 7-day 10-year low flow; Q_ak_2, Q_mk_2, $M_{7,2}k_2$, and $M_{7,10}k_2$ = reaeration coefficients at indicated flow condition; slope = channel slope at gaging station or measuring site, in feet per mile.]

Station Number	Station Name	Q_a	Q_m	$M_{7,2}$	$M_{7,10}$	Q_ak_2	Q_mk_2	$M_{7,2}k_2$	$M_{7,10}k_2$	Slope
04-1090.	Grand River at Jackson	110	72.8	31.6	20.8	2.5	6.1	6.0	12.8	2.8
1100.	Orchard Creek at Munith	37.2	17.0	4.06	2.34	7.2	7.0	11.9	5.5	1.6
1110.	Grand River near Eaton Rapids	394	249	85.2	61.3	5.2	7.1	8.8	5.2	2.6
1115.	Deer Creek near Dansville	8.67	3.05	0.48	0.17	12.0	20.7	58.4	--	6.9
1120.	Sloan Creek near Williamston	4.52	0.89	--	--	10.5	23.7	--	--	11.1
1125.	Red Cedar River at East Lansing	185	81.8	18.8	8.30	4.2	7.0	7.3	7.8	1.2
1130.	Grand River at Lansing	787	441	138	71.7	3.6	4.4	4.6	4.1	1.9
1140.	Grand River at Portland	744	428	159	105	3.8	4.4	7.0	7.6	3.0
1145.	Lookingglass River near Eagle	158	71.7	24.8	14.5	4.0	5.2	6.9	6.2	4.1
1150.	Maple River at Maple Rapids	232	88.0	16.4	8.10	.81	2.5	6.2	9.4	1.4
1160.	Grand River at Ionia	1,597	875	273	181	.65	.99	4.7	4.3	1.1
1165.	Flat River at Smyrna	399	319	157	121	3.7	2.7	2.9	2.7	--
1170.	Quaker Brook near Nashville	5.17	3.54	1.60	0.97	10.3	7.3	13.7	13.6	10.0
1175.	Thornapple River near Hastings	279	154	66.9	45.6	8.0	10.3	8.4	8.9	2.2
1180.	Thornapple River near Caledonia	508	328	169	116	4.5	6.3	7.2	6.4	4.1
1185.	Rogue River near Rockford	211	162	83.1	67.0	4.6	5.4	5.3	7.0	11.8
1190.	Grand River at Grand Rapids	3,372	2,155	981	681	11.5	6.8	7.1	5.5	14.3
1210.	Muskegon River near Merritt	221	169	64.6	35.6	1.4	1.3	4.3	5.8	1.6
1215.	Muskegon River at Evart	964	708	380	300	3.6	4.1	4.6	4.9	1.7
1220.	Muskegon River at Newaygo	1,908	1,630	829	649	3.1	3.2	4.5	5.1	3.7
1222.	White River near Whitehall	390	337	--	--	.94	1.7	--	--	1.4
1225.	Pere Marquette R. at Scottville	621	553	376	344	.99	1.0	2.1	1.7	.94
1230.	Big Sable River near Freesoil	139	128	91.8	85.2	5.5	5.5	9.2	11.2	3.2
1235.	Manistee River near Grayling	182	178	156	146	6.7	6.7	7.3	7.3	1.7
1240.	Manistee River near Sherman	1,034	981	804	699	1.5	1.4	2.2	3.5	1.8
1245.	E. Br. Pine River nr. Tustin	25.9	14.7	6.31	5.51	8.8	11.1	15.2	9.2	18.2
1250.	Pine River near LeRoy	88.0	66.0	46.9	43.7	4.6	2.9	7.2	10.8	5.7
1255.	Pine River near Hoxeyville	276	241	196	183	5.2	5.4	4.8	4.6	10.5
1260.	Manistee River near Manistee	1,958	1,810	1,329	1,193	1.2	1.1	1.6	2.0	1.0
1262.	Little Manistee R. nr. Freesoil	197	157	--	--	10.7	9.1	--	--	6.7
1270.	Boardman River near Mayfield	190	174	130	96.1	8.0	8.8	9.5	12.9	15.4
1280.	Sturgeon River near Wolverine	200	184	141	126	15.2	14.3	15.6	14.5	18.2
1285.	Indian River at Indian River	544	527	351	274	.92	.92	.71	.67	.53
1290.	Pigeon River near Vanderbilt	74.8	67.4	45.9	40.2	15.6	18.7	20.6	22.0	11.1
1295.	Pigeon River at Afton	133	113	72.1	60.9	10.4	11.4	13.9	15.7	20.0
1300.	Cheboygan River near Cheboygan	775	749	330	212	.49	.43	.25	.17	.24

Table 1.--Flow, reaeration coefficients, and channel slope of streams in Michigan.--Continued

/$\overline{Q}a$ = mean flow (average annual discharge); Qm = median flow (median annual discharge); $M_{7,2}$ = 7-day 2-year low flow; $M_{7,10}$ = 7-day 10-year low flow; Qak_2, Qmk_2, $M_{7,2}k_2$, and $M_{7,10}k_2$ = reaeration coefficients at indicated flow condition; slope = channel slope at gaging station or measuring site, in feet per mile./

Station Number	Station Name	Q_a	Q_m	$M_{7,2}$	$M_{7,10}$	Q_ak_2	Q_mk_2	$M_{7,2}k_2$	$M_{7,10}k_2$	Slope
04-1305.	Black River near Tower	251	207	119	84.2	6.4	8.6	9.5	11.1	20.0
1310.	Rainy River near Onaway	24.9	6.70	--	--	15.7	22.7	--	--	22.4
1315.	Rainy River near Ocqueoc	36.3	14.2	1.19	0.56	8.8	15.2	15.5	32.7	13.3
1325.	Thunder Bay River near Hillman	208	180	127	114	2.5	2.6	4.4	4.4	--
1340.	N. Br. Thunder Bay R. nr. Bolton	105	42.2	7.14	2.06	7.7	7.6	11.9	7.8	--
1355.	Au Sable River at Grayling	73.2	68.6	50.4	42.5	10.1	10.1	10.0	9.6	3.4
1356.	E. Br. Au Sable R. at Grayling	40.7	--	--	--	6.8	--	--	--	2.4
1365.	Au Sable River at Mio	926	846	642	567	3.1	3.1	3.0	3.7	--
1380.	E. Br. Au Gres River at McIvor	62.8	46.4	30.9	26.1	10.0	13.4	15.0	24.4	7.1
1385.	Au Gres River near National City	93.6	48.5	12.9	9.28	6.1	10.3	16.7	8.4	6.2
1390.	Houghton Creek near Lupton	50.8	43.9	35.5	33.1	6.0	6.4	7.0	7.5	3.5
1395.	Rifle R. at "The Ranch" nr. Lupton	90.5	78.0	60.3	55.2	13.3	12.5	17.0	16.3	5.6
1400.	Prior Creek near Selkirk	16.3	11.0	5.57	4.97	20.4	34.7	43.6	38.6	9.1
1405.	Rifle River at Selkirk	140	112	74.4	68.1	5.1	6.1	6.8	5.3	4.8
1410.	S. Br. Shepards Creek nr. Selkirk	0.52	0.12	--	--	61.7	--	--	--	33.3
1415.	W. Br. Rifle River near Selkirk	60.2	44.5	28.0	25.0	18.3	10.3	8.2	9.8	6.7
1420.	Rifle River near Sterling	302	221	132	117	3.0	3.0	4.4	4.2	3.8
1435.	N. Br. Kawkawlin R. nr. Kawkawlin	53.7	5.15	--	--	2.9	2.7	--	--	2.2
1440.	Shiawassee River at Byron	238	131	45.2	26.6	4.6	3.1	3.7	5.5	4.0
1445.	Shiawassee River at Owosso	302	154	49.8	18.6	4.8	4.4	2.8	6.0	5.0
1450.	Shiawassee River near Fergus	401	193	63.6	39.0	.32	1.4	8.8	11.1	1.0
1455.	Bad River near Brant	62.9	8.28	--	--	1.3	8.2	--	--	3.8
1460.	Farmers Creek near Lapeer	27.8	13.0	2.32	1.12	8.8	7.7	13.6	--	2.7
1475.	Flint River near Otisville	248	123	44.7	28.3	3.6	3.2	14.2	14.2	2.0
1480.	Flint River at Genesee	358	164	48.1	24.3	1.2	3.8	7.0	--	1.2
1482.	Swartz Creek near Holly	5.80	3.24	0.41	0.12	14.0	22.7	51.4	98.7	8.0
1485.	Flint River near Flint	531	231	73.0	40.3	1.9	3.0	2.5	--	3.8
1500.	S. Br. Cass R. nr. Cass City	117	18.0	2.03	0.80	4.6	6.0	4.8	5.1	2.3
1505.	Cass River at Cass City	190	34.9	3.60	1.40	4.9	5.8	15.2	15.4	6.2
1510.	Cass River at Vassar	371	107	28.0	16.3	7.1	9.2	8.4	6.2	2.0
1515.	Cass River at Frankenmuth	454	139	35.8	18.5	.81	4.2	6.4	6.4	1.0
1525.	Tobacco River at Beaverton	358	248	124	76.2	2.7	3.2	5.0	10.5	3.7
1535.	Salt River near North Bradley	76.5	20.1	5.45	3.00	6.3	7.7	7.7	22.6	2.4
1540.	Chippewa River near Mount Pleasant	292	213	98.1	67.8	3.6	4.1	4.3	3.6	1.7
1545.	Chippewa River near Midland	419	260	116	90.0	5.3	6.0	6.0	5.5	2.5
1550.	Pine River at Alma	198	128	49.0	27.4	2.1	3.4	4.1	5.5	1.9

Table 1.--Flow, reaeration coefficients, and channel slope of streams in Michigan.--Continued

/Qa = mean flow (average annual discharge); Qm = median flow (median annual discharge); $M_{7,2}$ = 7-day 2-year low flow; $M_{7,10}$ = 7-day 10-year low flow; Q_ak_2, Q_mk_2, $M_{7,2}k_2$, and $M_{7,10}k_2$ = reaeration coefficients at indicated flow condition; slope = channel slope at gaging station or measuring site, in feet per mile./

Station Number	Station Name	Q_a	Q_m	$M_{7,2}$	$M_{7,10}$	Q_ak_2	Q_mk_2	$M_{7,2}k_2$	$M_{7,10}k_2$	Slope
04-1555.	Pine River near Midland	271	166	60.3	32.9	4.9	7.5	11.7	13.7	4.2
1560.	Tittabawassee River at Midland	1,548	769	254	169	.76	3.3	3.6	4.7	3.2
1575.	Sebewaing River near Sebewaing	34.7	3.55	--	--	11.2	22.7	--	--	8.3
1580.	E. Fk. Sebewaing R. nr. Sebewaing	18.2	1.66	--	--	7.0	16.2	--	--	8.3
1585.	Pigeon River near Owendale	27.2	7.34	1.47	0.63	17.0	24.7	44.0	87.3	--
1595.	Black River near Fargo	271	43.7	10.4	5.07	4.8	12.0	11.9	13.6	4.5
1600.	Mill Creek near Abbottsford	97.0	21.7	6.11	4.11	4.4	8.4	11.9	18.6	10.0
1605.	Black River near Port Huron	289	53.4	12.0	6.18	1.5	4.3	4.2	--	4.5
1610.	Clinton River at Auburn Heights	74.8	62.4	22.5	10.4	6.8	10.3	15.0	22.0	9.1
1615.	Paint Creek near Lake Orion	19.9	14.4	2.54	1.52	14.2	19.5	23.6	--	45.4
1618.	Stony Creek near Washington	29.1	--	--	--	8.4	--	--	--	10.0
1629.	Big Beaver Creek near Warren	11.2	--	--	--	12.8	--	--	--	4.2
1635.	Plum Brook near Utica	11.4	3.13	--	--	11.1	38.6	--	--	5.0
1640.	Clinton River near Fraser	318	197	81.1	64.5	1.4	2.8	7.5	4.2	1.7
1641.	East Pond Creek at Romeo	10.6	--	--	--	16.9	--	--	--	10.0
1643.	E. Br. Coon Creek at Armada	4.72	--	--	--	16.0	--	--	--	16.7
1645.	N. Br. Clinton R. nr. Mount Clemens	108	28.7	2.30	0.73	4.3	14.2	30.1	44.0	1.2
1655.	Clinton River at Mount Clemens	470	234	89.4	54.7	1.6	2.0	--	--	1.0
-Do-	-do-	-do-	-do-	-do-	-do-	--	--	.66	.96	0.6
1660.	River Rouge at Birmingham	13.7	6.15	1.30	0.48	6.0	5.8	97.8	58.4	14.3
1661.	River Rouge at Southfield	39.5	--	--	--	3.0	--	--	--	4.5
1662.	Evans Ditch at Southfield	5.78	--	--	--	15.2	--	--	--	10.0
1663.	Upper River Rouge at Farmington	8.11	--	--	--	9.4	--	--	--	25.0
1665.	River Rouge at Detroit	104	42.4	9.43	4.52	3.1	8.8	7.7	33.1	5.6
1670.	Middle River Rouge near Garden City	62.5	29.6	7.95	4.09	5.4	7.5	11.7	12.8	5.6
1680.	Lower River Rouge at Inkster	46.5	11.0	1.52	0.77	10.3	20.8	19.8	13.6	6.0
1695.	Huron River at Commerce	35.2	25.6	9.10	5.60	11.2	17.0	26.5	62.7	8.8
1700.	Huron River at Milford	89.2	68.6	30.1	19.1	5.8	8.4	10.3	11.7	2.9
1705.	Huron River near New Hudson	102	83.1	27.2	16.6	10.8	10.8	10.3	11.7	1.9
1715.	Ore Creek near Brighton	21.3	16.0	3.48	1.82	27.6	13.5	16.2	32.2	7.4
1720.	Huron River near Hamburg	184	146	59.6	42.6	3.0	3.1	3.3	4.9	0.7
1730.	Huron River near Dexter	341	247	87.7	51.9	5.8	8.8	13.9	11.1	2.3
1735.	Mill Creek near Dexter	62.6	33.2	14.1	11.3	7.6	8.2	12.9	10.5	3.7
1745.	Huron River at Ann Arbor	407	276	93.2	40.5	6.9	8.9	9.8	11.7	5.9
1757.	River Raisin near Tecumseh	140	94.4	34.2	14.8	3.1	3.6	13.5	20.8	3.3
1760.	River Raisin near Adrian	261	155	54.5	34.3	1.6	2.0	6.0	7.9	1.2
1765.	River Raisin near Monroe	648	273	80.4	26.7	2.2	2.2	2.5	4.2	4.3