ESTIMATES OF DISSOLVED AND SUSPENDED SUBSTANCE YIELD OF STREAM BASINS IN MICHIGAN

By T. Ray Cummings

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 83-4288

Lansing, Michigan

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
6520 Mercantile Way, Suite 5
Lansing, Michigan 48910

Copies of this report can be
purchased from:

Open-File Services Section
Western Distribtuion Branch
U.S. Geological Survey
Box 25425, Federal Center
Denver, Colorado 80225
(Telephone: (303) 234-5888)

CONTENTS

	Page
Abstract	1
Introduction	2
Method of investigation	2
Regression-equation development	2
Computation of yields	3
Data used for analysis	5
Water-quality data	5
Discharge data	7
Results of investigation	8
Variation of load and concentration with discharge	8
Comparison of yields computed by load-dependent and midline equations	8
Assessments of method	11
Comparison of results to other work	13
Measurements at Grand River at Eastmanville	13
Statewide sediment yields	14
Suspended-sediment yield of River Raisin near Monroe	15
Statewide phosphorus yields	15
Prediction of yields from instantaneous discharge	16
Conclusions	20
References cited	21
Tables of data	23

ILLUSTRATIONS

		Page
Figure 1.	Graph showing generalized relations between load and discharge	4
2.	Map showing location of water-quality stations and gaging stations used in study	6
3.	Graph showing frequency distribution of correlation coefficients of load-dependent equations	9
4.	Graph showing frequency distribution of standard errors of estimate of load-dependent equations	10

TABLES

		Page
Table 1.	Percentage of unsampled high flow at water-quality stations	7
2.	Comparison of equivalents of cations and anions using estimated yields of the Au Sable and Saginaw Rivers	11
3.	Comparison of measured and estimated yields for Grand River at Eastmanville	13
4.	Comparison of estimated sediment yields at water-quality stations	14
5.	Comparison of estimated phosphorus yields at water-quality stations	16
6.	Comparison of measured and estimated yields for the St. Joseph River at Niles during high flow	17
7.	Comparison of measured and estimated yields for the River Raisin near Monroe at high flow	18
8.	Comparison of measured and estimated yields for the Clinton River at Mt. Clemens during low flow	19
9.	Comparison of measured and estimated yields for the Kalamazoo River at Saugatuck during low flow	20
10.	Description of water-quality stations	24
11.	Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$	26

TABLES--continued

		Page
Table 12.	Estimated annual yield of dissolved and suspended substances at water-quality stations	36
13.	Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations	46
14.	Chemical characteristics of water during high flow conditions at water-quality stations	56

ESTIMATES OF DISSOLVED AND SUSPENDED SUBSTANCE YIELD OF STREAM BASINS IN MICHIGAN

By T. Ray Cummings

ABSTRACT

Water-quality data collected at 20 stations in Michigan were used to develop regression equations relating loads of dissolved and suspended substances to discharge. These equations and mean daily discharge were used to estimate long-term loads, which then were converted to estimates of drainage basin yields. These yields were compared to measured yields and to previous estimates.

Equations were developed for each station that express the relation between load and discharge ($L = aQ^b$) for 19 substances and properties. Fifty percent of the equations had standard errors of 22 percent or less; 90 percent of the equations had standard errors of 80 percent or less. Regression exponents indicate that the load increases as discharge increases in all cases, but for about two-thirds of the substances or properties, the increase is less rapid than that of discharge. Seventy-eight percent of the nitrogen, phosphorus, and sediment loads, taken as a group, increase more rapidly than discharge. Concentrations of about 63 percent of the substances or properties decrease as discharge increases, however.

Although comparative data for most drainage basins are scant, yields estimated by use of regression equations did not differ appreciably from measured values at locations where comparison was possible.

INTRODUCTION

The U.S. Geological Survey has collected water-quality data routinely at sites throughout Michigan. The most important of these sampling stations have been operated as part of a nationwide network of hydrologic benchmarks and as part of the National Stream Quality Accounting Network (NASQAN). The benchmark program was designed to monitor streamflow and water-quality characteristics in areas little influenced by man. The NASQAN program was designed to account for the quantity and quality of water moving to and from the United States, to determine areal variability, to detect changes in water quality, and to provide the basis for future water-quality assessments. Because a wide range of chemical, physical, and biological measurements are made at each station, data are available for various types of studies. In Michigan, as in other parts of the country, dissolved and suspended substances transported by streams are of interest. In the Great Lakes States, these characteristics are particularly important because of the need to protect the quality of the lakes.

The purpose of this study was to investigate the use of regression equations for computing long-term loads[1/] and yields of dissolved and suspended substances at water-quality stations in Michigan, and to compare these estimated yields to measured yields and to previous estimates. (See figure 2.) Because comparative data are scant, the results given in this report should be regarded as tentative until further work is undertaken.

METHOD OF INVESTIGATION

Regression-Equation Development

Regression equations, based on load and discharge, were used to relate 19 chemical characteristics or physical properties measured at 20 stations. Using ordinary least squares, the coefficients a and b were estimated for the equation $\log L = a^* + b \log Q$, where L is load in tons/d (tons per day), Q is discharge in ft^3/s (cubic feet per second), and log is the common logarithm. This relationship was then re-expressed as a power function $L = aQ^b$, where $a = 10^{a^*}$.

Three regression equations were developed for each characteristic or property. They were:

(1) An equation in which load was the dependent variable ($L = a_1Q^{b_1}$); it is referred to in this report as the load-dependent equation.

(2) An equation in which load was the independent variable ($Q = a_xL^{b_x}$); this equation was inverted for use ($L = a_2Q^{b_2}$), and is referred to in this report as the load-independent equation.

1/ Long-term loads, which provide the basis for estimates of yield, have not been tabulated in this report.

(3) An equation defining a line that bisects the angle formed by the load-dependent and load-independent equation lines when represented on a logarithmic plot (fig. 1). The coefficient and exponent of the equation ($L = a_3Q^{b_3}$) were computed from the coefficients and exponents of the load-dependent and load-independent equations in the following manner:

$$b_3 = \tan \{0.5 \ (\tan^{-1} b_1 + \tan^{-1} b_2)\}$$

and

$$a_3 = a_2 \left(\frac{a_1}{a_2}\right)^{\left(\frac{b_2-b_3}{b_2-b_1}\right)}$$

The equation ($L = a_3Q^{b_3}$) is referred to as the midline equation in this report. Although no theoretical basis for the midline equation exists, it was computed for this study because previous work by the author indicated that, when considerable scatter exists in data, it may yield a more accurate result when estimating long-term loads of some Michigan streams. For example, measured total sediment loads for a two and a half year period (1974-77) at each of four streams in the St. Joseph River basin were compared to loads estimated by the load-dependent and midline equations. Total sediment loads computed by the load-dependent equation averaged about 23 percent less than the measured load, whereas those computed by the midline equation averaged about 3 percent higher. Work with sediment data collected on the River Raisin, and chemical quality data collected on the Grand River, also indicated that more accurate estimates might be possible using the midline equation. Although the author knows of no previous use of the midline equation for computing loads, the midline method was found to be one of the more accurate methods for estimating low flows (W. O. Thomas, written communication, 1982).

Computation of Yields

Load-dependent and midline equations were used with mean daily discharge (Q) in a computer program to calculate a load (in tons) of each dissolved and suspended substance for each day during the period of station operation. The program summed daily loads, and provided a monthly total for the period of record. Loads of each substance for the period of record were converted to yields in (tons/mi^2)/yr (tons per square mile per year). Yields based on the load-dependent equation are given in table 12 at the back of the report. For comparative purposes, yields based on midline equations are shown in the table in parentheses.

Yields computed by the load-independent equation have not been included in the report because this equation results from a rearrangement of an equation to make load the dependent variable. None of the equations is a minimum variance, unbiased estimator of load. Expressed in terms of log load and log discharge, however, the load-dependent equation is a minimum variance, unbiased estimator, whereas the midline and load-independent equations are not.

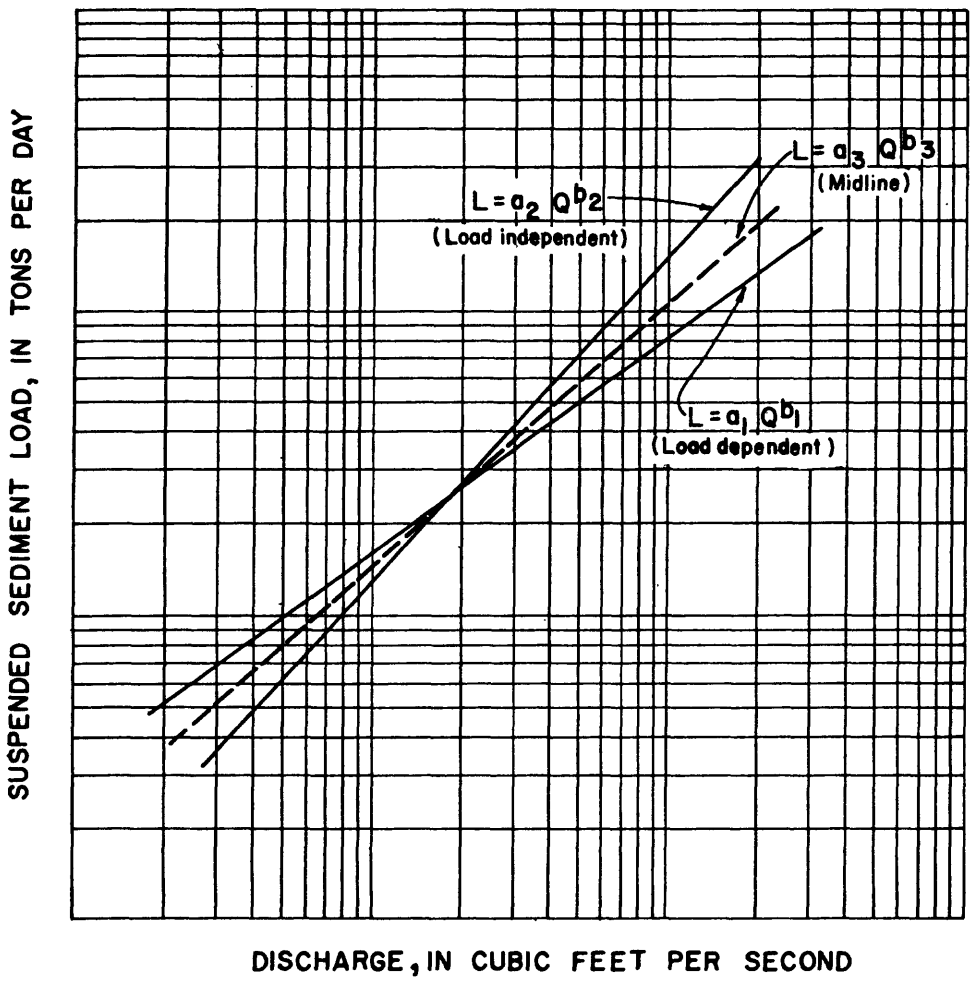

Figure 1.--Generalized relations between load and discharge.

One regression equation for each substance was developed for the range of discharges at each station even though long-term loads and yields might have been made more accurate by using segmented regression relationships. However, this would have prevented some of the comparisons planned for this study.

DATA USED FOR ANALYSIS

Water-Quality Data

Monthly water-quality data collected at 19 NASQAN stations and one benchmark station were analyzed in this study. Table 10 (at back of report) gives the station number, station name, and station location; figure 2 shows the location of each station. Three additional NASQAN stations--on the St. Marys, St. Clair, and Detroit Rivers--lack daily discharge data, which precluded computation of loads by the method described above. About half of the stations began operation in 1974; the most recently established stations began operation in February 1979. One station--Thunder Bay near Alpena--was moved after a year of operation; only data after the re-location were analyzed for this report. At all stations, only data collected through September 1980 have been part of the study.

Monthly samples collected at NASQAN stations were anlyzed for a wide range of characteristics.[1/] Laboratory analyses of the common cations and anions, major nutrients, trace elements, suspended sediment, and biologic characteristics (plankton and periphyton) were made. In addition, field measurements of specific conductance, temperature, pH, and instantaneous discharge were made quarterly. Similar analyses, excluding biologic characteristics, were made 5 to 6 times each year on samples collected at the benchmark station on Washington Creek at Windigo. Table 13 gives maximum, mean, and minimum values of chemical and physical properties based on monthly measurements; table 14 gives chemical analyses of samples collected during the highest flow sampled at each station.

Regression equations were developed only for dissolved and suspended substances measured on a monthly basis at a station.[2/] Those substances are silica, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, nitrogen, phosphorus, hardness, dissolved solids, and suspended sediment.

1/ Chemical, physical, and biologic data are published in the U.S. Geological Survey's annual report "Water Resources Data for Michigan."

2/ Table 12 gives the number of years of record of monthly sampling and thus indicates the approximate number of samples used in developing regression equations at each station. The number of analyses of individual substances, however, may differ slightly as an occasional scheduled analysis was not made, or an additional sample collected.

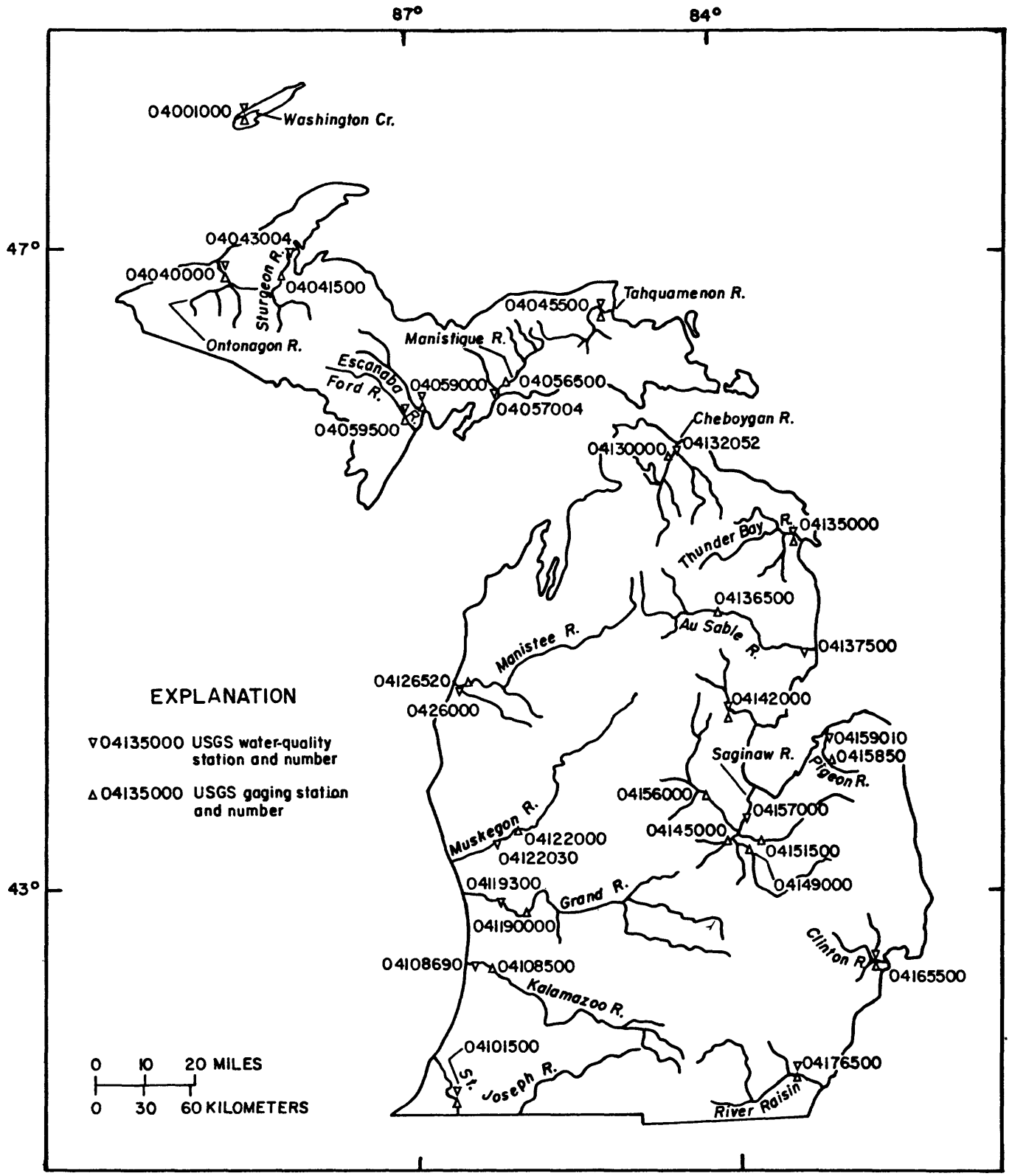

Figure 2.--Location of water-quality stations and gaging stations used in study.

Discharge Data

Gaging stations are located at nine of the water-quality stations; on 10 other streams, the gaging stations are located at varying distances upstream (fig. 2) from the water-quality station. At one station, Saginaw River at Saginaw, no daily record of flow was obtained. Daily discharges for this station for a 6-year period were computed from records collected at four tributary gaging stations upstream from the water-quality station.

At water-quality stations where no daily record of flow was obtained, mean daily discharge at the nearest upstream gaging station was used to calculate a total load for the period of record. These loads were adjusted on the basis of drainage area and used to compute yields at the water-quality station. In most instances this adjustment was slight.

Flow-duration data at gaging stations indicate that samples collected at water-quality stations are representative of the range of daily discharge recorded since the beginning of gaging station operation. The following table shows the percent of time discharge has been greater than the highest discharge at which a sample was collected.

Table 1.--Percentage of unsampled high flow at water-quality stations

Station	Percentage of unsampled high flow
Washington Creek at Windigo	5.3
Ontonagon River near Rockland	.1
Sturgeon River near Chassell	.4
Tahquamenon River near Tahquamenon Paradise	.6
Manistique River above Manistique	1.8
Escanaba River at Cornell	.7
Ford River near Hyde	.4
St. Joseph River at Niles	.1
Kalamazoo River at Saugatuck	.2
Grand River at Eastmanville	3.3
Muskegon River near Bridgeton	1.4
Manistee River at Manistee	.1
Cheboygan River at Cheboygan	4.2
Thunder Bay River near Alpena	5.0
Au Sable River near Au Sable	5.3
Rifle River near Sterling	4.3
Saginaw River at Saginaw	(a)
Pigeon River near Caseville	2.9
Clinton River at Mt. Clemens	.5
River Raisin near Monroe	1.7

[a]Flow duration data not available.

RESULTS OF INVESTIGATION

Regression coefficients and exponents, correlation coefficients, and standard errors of load-dependent equations are given in table 11 (at back of report). Inclusion of the midline equations is not warranted, although yields based on it are commented on in the following sections. Differences between total loads calculated by using the midline equation or by using the load-dependent equation were small for most major dissolved substances or properties. Differences were significantly greater, however, for nutrients, suspended sediment, or poorly correlated data.

Figure 3 is a frequency distribution of the correlation coefficients of the 376 load-dependent equations given in table 11. About 67 percent of the correlation coefficients were equal to or greater than 0.90, and about 92 percent were equal to or greater than 0.70. A frequency distribution of standard errors of the estimate, in percent, for load-dependent equations is shown in figure 4. Fifty percent of the equations had standard errors of 22 percent or less; 90 percent had standard errors of 80 percent or less.

Variation of Load and Concentration with Discharge

Regression exponents (b) given in table 11 indicate that, in all cases, the load increases as discharge increases (b>0). For 37 percent of the dissolved and suspended substances, load increases more rapidly than discharge does (b>1.0); loads of the remainder increase less rapidly than discharge (b<1.0). In contrast, however, seventy-eight percent of the nitrogen, phosphorous, and sediment loads, if considered as a group, increase more rapidly than discharge does.

With respect to concentration, regression exponents[1/] indicate that concentration increases as discharge increases in about 36 percent of the cases (b>1.0). The increase in concentration is generally less rapid than that of discharge, however. Only in one percent of the cases did discharge increase more rapidly than did concentration (b>2.0). Thus, in about 63 percent of the cases, concentration decreases as discharge increases (b<0.99).

Comparison of Yields Computed by Load-dependent and Midline Equations

The average difference between yields of all substances calculated by the load-dependent equation and by the midline equation (table 12) was 8.5 percent. The percentage difference changes, however, if substances are grouped. As a group, the average difference between yields of silica, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, hardness, and dissolved solids calculated by the load-dependent and midline equations was 2.89 percent. As a group,

---

1/ A regression exponent determined in a load-discharge regression can be converted to the regression exponent of a corresponding concentration-discharge regression by subtracting 1.0.

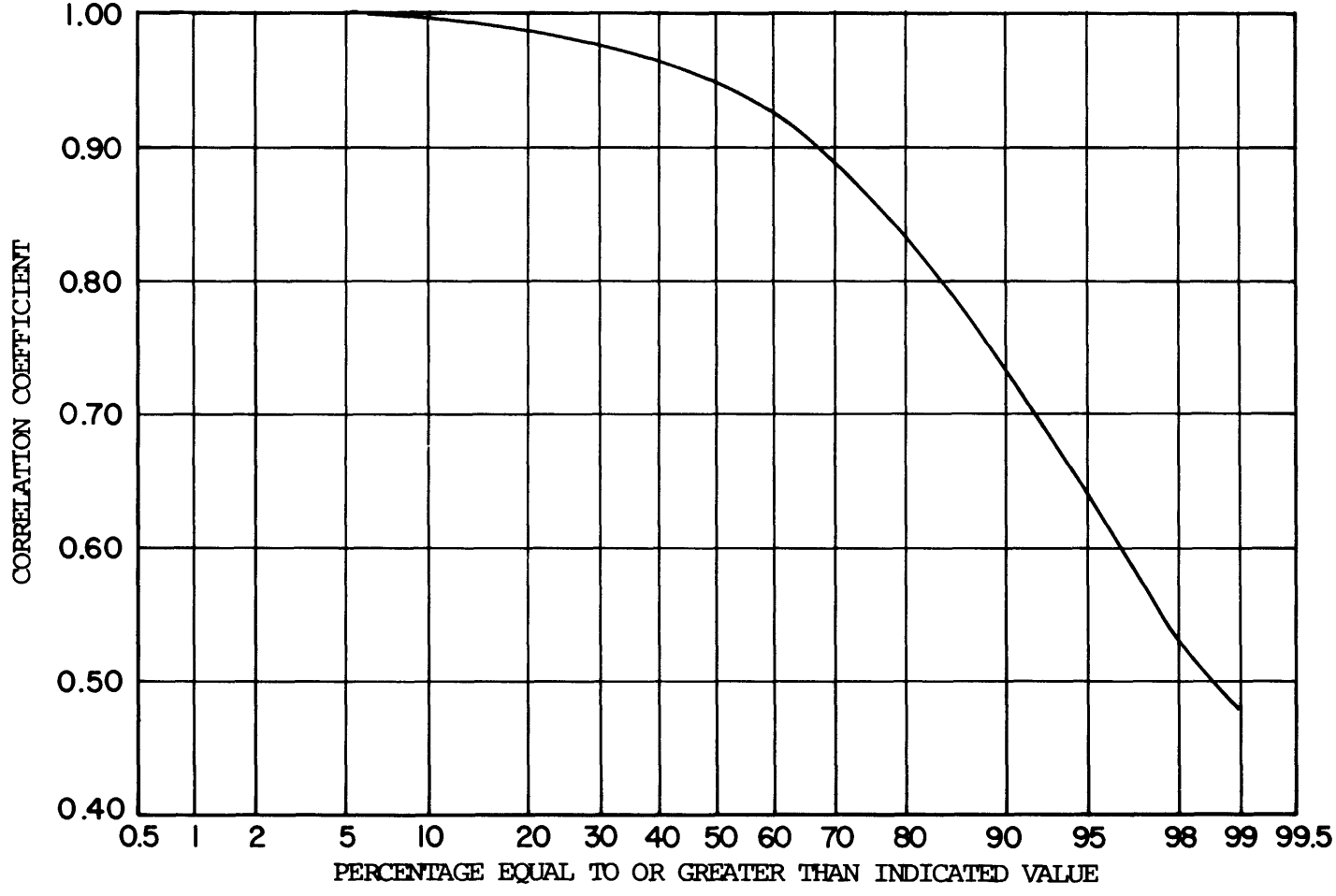

Figure 3.--Frequency distribution of correlation coefficients of load-dependent equations

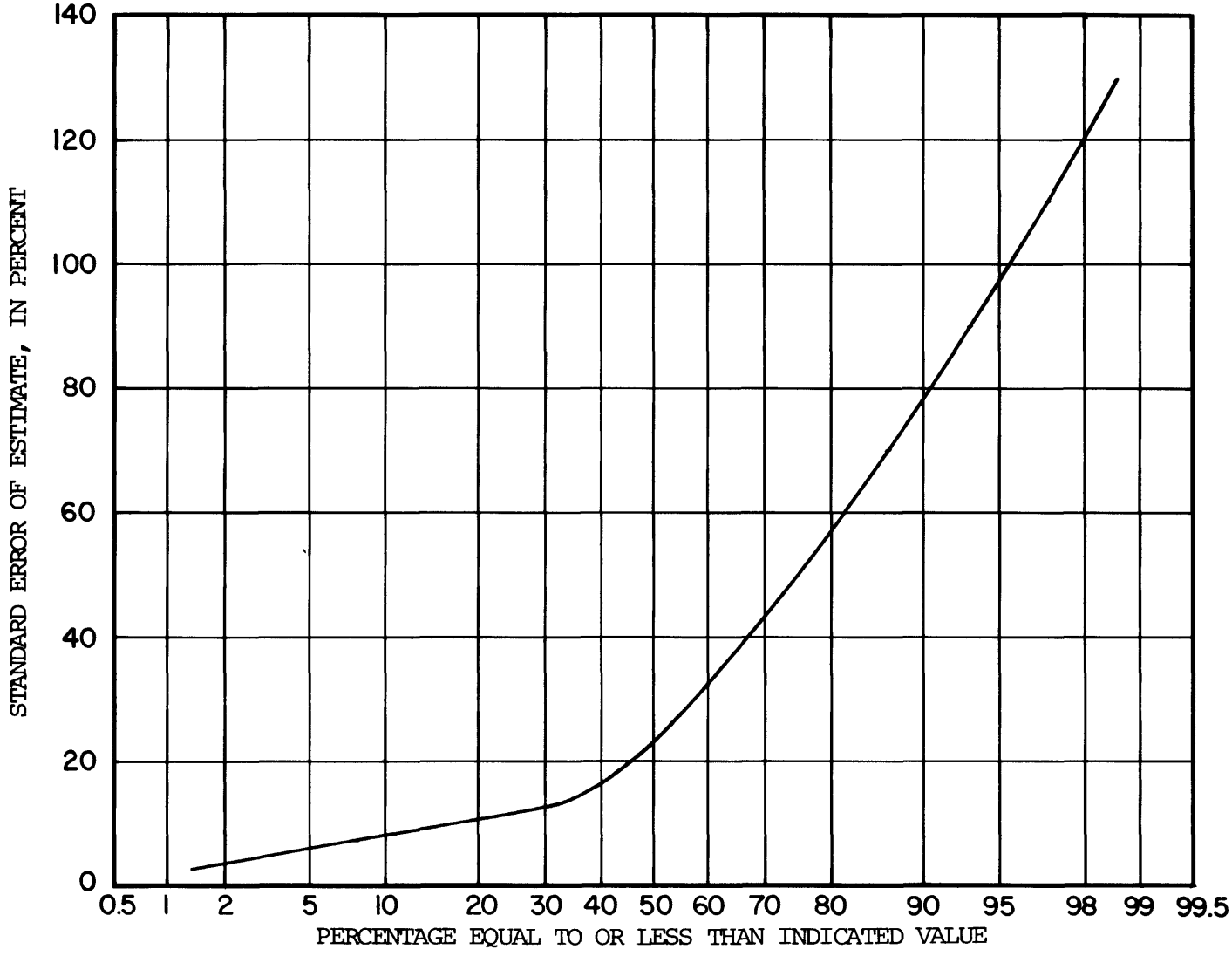

Figure 4.--Frequency distribution of standard errors of estimate of load-dependent equations

yields of ammonia, organic nitrogen, nitrite plus nitrate, total nitrogen, dissolved phosphorus, total phosphorus, and suspended sediment had an average difference of 18.8 percent. The average percentage differences suggest that the equation used is not particularly significant for the major dissolved substances, but for those substances that do not exhibit a strong correlation with discharge, estimated yields depend on whether computation is by the load-dependent or the midline equation.

Assessments of Method

To determine how well individual regression equations provide internally consistent results, independent of accuracy, yields of the major dissolved substances in (tons/mi^2)yr were converted to (eq/mi^2)yr (equivalents per square mile per year), and the sums of the cations and anions were compared. The following table shows the results for two stations.

Table 2.--Comparison of equivalents of cations and anions using estimated yields of the Au Sable and Saginaw Rivers

Substance	Au Sable River near Au Sable		Saginaw River at Saginaw	
	{(tons/mi^2)/yr}	{(eq/mi^2)/yr}	{(tons/mi^2)/yr}	{(eq/mi^2)/yr}
Cation				
Calcium (Ca)	37.6	1,702,100	46.9	2,123,100
Magnesium (Mg)	9.20	686,550	13.5	1,007,440
Sodium (Na)	3.60	142,060	20.7	816,880
Potassium (K)	.52	12,060	2.32	53,820
Total		2,542,770		4,001,420
Anion				
Bicarbonate (HCO_3)	151	2,245,180	145	2,155,970
Sulfate (SO_4)	8.75	165,270	36.8	695,060
Chloride (Cl)	4.20	107,480	44.5	1,138,830
Fluoride (F)	.088	4,200	.15	7,160
Total		2,522,130		3,997,020
Percent difference		0.41		0.05

For 16 of the 20 stations, the difference between the equivalents of cations and anions is less than 1 percent, and for three of the remaining four stations, less than 2 percent.

In addition to comparing yields in terms of equivalents, the sum of individual yields of organic nitrogen, ammonia, and nitrite plus nitrate, which should be about equal to the yield computed for total nitrogen, can be compared. As an example, nitrogen yields of the St. Joseph River at Niles were as follows:

Substance	Yield {(tons/mi²)/yr}
Ammonia (NH_4 as N)	0.26
Nitrite plus nitrate (NO_2 + NO_3 as N)	1.83
Organic nitrogen (as N)	.87
Sum	2.96
Total nitrogen (as N)	3.22

The difference between the sum and total nitrogen is 8.8 percent. For all stations the mean difference was 6.4 percent. Differences ranged from 0.0 percent for the Rifle River near Sterling to 14.3 percent for the Au Sable River near Au Sable. Similar results were obtained for nitrogen yields when the midline equation was used.

The dissolved solids (sum) yield was also compared to the total of individual yields of the major cations and anions. For example, yields of the Rifle River near Sterling were as follows:

Substance	Yield {(tons/mi²)/yr}
Silica (SiO_2)	6.43
Calcium (Ca)	49.6
Magnesium (Mg)	12.6
Sodium (Na)	8.89
Potassium (K)	1.29
Bicarbonate (HCO_3)	[a]89.7
Sulfate (SO_4)	27.4
Chloride (Cl)	14.4
Fluoride (F)	.12
Total	210
Dissolved solids (sum)	212

[a]Value of 182 (tons/mi²)/yr (table 12) converted to dry weight.

Based on all stations, the mean difference between the total of individual yields and dissolved solids (sum) yield was 1.3 percent; the maximum difference was 3.1 percent.

Yields calculated from mean concentrations or mean values of properties (table 13) were compared to those computed by load-dependent regression equations.[1/] About half the yields computed from mean concentrations were higher, and half lower. The average difference for

---

1/ The yield for each substance or property at each station was determined by using total discharge (in ft³/day) for a period of record to calculate a total load.

higher values was 23.3 percent; the average difference for lower values was 19.7 percent. Although a computation of yield from mean concentration may give a value that does not differ greatly from that obtained by a regression equation, the average difference cited suggests that differences, in many cases, can be substantial.

COMPARISON OF RESULTS TO OTHER WORK

Measurements at Grand River at Eastmanville

From March 1976 to May 1977 the U.S. Environmental Protection Agency (EPA) operated a daily water-quality station at Grand River at Eastmanville. Daily concentrations measured by EPA and corresponding discharges were used to calculate yields for 11 substances. The following table compares these calculated yields to estimates based on regression analyses of NASQAN data collected from February 1979 to September 1980.

Table 3.--Comparison of measured and estimated yields for Grand River at Eastmanville

Substance	EPA, measured {(tons/mi^2)/yr}	NASQAN, load-dependent equation {(tons/mi^2)/yr}	NASQAN, midline equation {(tons/mi^2)/yr}
Silica (SiO_2)	4.13	3.38	3.50
Calcium (Ca)	55.3	47.0	47.2
Magnesium (Mg)	16.6	14.3	14.4
Sodium (Na)	16.5	15.3	15.3
Sulfate (SO_4)	42.3	40.9	41.0
Chloride (Cl)	27.4	27.0	27.7
Organic nitrogen (as N)	.69	.66	.70
Ammonia (NH_4 as N)	.18	.17	.19
Nitrite plus nitrate (NO_2 + NO_3 as N)	.69	1.03	1.23
Total phosphorus (as P)	.12	.097	.10
Dissolved phosphorus (as P)	.042	.034	.038

These data indicate that, at this station at least, there is a reasonable agreement between measured yields and estimated yields. Agreement is improved if only the EPA data collected during the period March 1976 to February 1977 is considered. Shortening the period eliminates one of the two spring high-flow periods, which is incorporated in the 14-month period of EPA station operation. For example, the measured EPA yield decreases to 3.68 (tons/mi^2)/yr for silica, to 51.9 (tons/mi^2)/yr for calcium, to 15.5 (tons/mi^2)/yr for magnesium, and to 15.1 (tons/mi^2)/yr for sodium.

Statewide Sediment Yields

Erosion and sedimentation were studied by the Great Lakes Basin Commission (GLBC) (1975), and estimates of sediment production were made for 15 of the 20 water-quality stations included in this report. The GLBC defined sediment production as "the total sediment quantity that reached a given point or area in a stream system during a given time"; estimates were reported in tons per square mile per year, and include both suspended and bedload transport. The following table compares GLBC estimates with suspended-sediment estimates computed by regression equations.

Table 4.--Comparison of estimated sediment yields at water-quality stations

Station	Estimated sediment production (GLBC) {(tons/mi^2)/yr}	Load-dependent equation {(tons/mi^2)/yr}	Midline equation {(tons/mi^2)/yr}
Ontonagon River	6	107	128
Sturgeon River	8	26.1	27.1
Tahquamenon River	5	5.30	6.55
Manistique River	2	7.16	7.92
Escanaba River	8	4.14	5.40
St. Joseph River	53	23.1	26.4
Kalamazoo River	64	13.9	15.4
Grand River	41	21.1	26.7
Muskegon River	22	22.2	25.2
Manistee River	13	7.47	7.11
Thunder Bay River	8	2.56	2.66
Au Sable River	4	2.65	2.45
Saginaw River	22	22.8	32.8
Clinton River	61	224	523
River Raisin	94	47.5	74.0

Close agreement between estimates is evident only for the Tahquamenon, Muskegon, and Saginaw Rivers. Differences, however, may not be too significant. The GLBC compared yields measured by the Geological Survey at 7 daily sediment stations in other states to yields computed by their "estimated method." Differences ranged from +74 percent to -69 percent. Thus, it is not surprising that estimates made by regression equation differ by substantial amounts from those computed by the Commission's "estimated method." The GLBC suggested that an error may have been introduced in their method in one instance because a curve was extrapolated for a large drainage basin. A second source of error cited was the fact that soil erosion was an inadequate indication of yields in large metropolitan areas.

A comparison of mean suspended-sediment concentrations (table 13, at back of report), drainage area data (table 12), mean discharges (U.S. Geological Survey, 1982), and data tabulated above, indicates that regression estimates may reflect sediment transport more accurately than

GLBC estimates. For example, the estimated sediment production {6 (tons/mi^2)/yr} of the Ontonagon River seems low if compared to that of the Tahquamenon River, where estimated sediment production {5 (tons/mi^2)/yr} does not differ greatly from the regression estimate {5.3 (tons/mi^2)/yr - load dependent}. The mean sediment concentration of the Ontonagon River is 90.1 mg/L, and that of the Tahquamenon River, 4.5 mg/L. In view of the fact that the drainage area of the Tahquamenon River is 41 percent less than that of Ontonagon River, and that its mean discharge is 34 percent less, the GLBC's estimate for sediment production of the Ontonagon River seems low.

Suspended-Sediment Yield of River Raisin near Monroe

From April 1966 to September 1972, the Geological Survey operated a daily sediment station at River Raisin near Monroe, the site of the current water-quality station. For the period of daily sediment-station operation, the sediment yield was 62.8 (tons/mi^2)/yr. Regression equations, based on data collected from January 1978 to September 1980, gave yields of 47.5 (tons/mi^2)/yr (load-dependent equation), and 74.0 (tons/mi^2)/yr (midline equation). The Great Lakes Basin Commission (1975) estimate for this station is 94 (tons/mi^2)/yr.

Statewide Phosphorus Yields

The International Joint Commission (IJC) estimates loads of total phosphorus transported to the Great Lakes on a yearly basis. Estimates made of phosphorus transport at the mouth of streams in Michigan (John Clark, IJC, written commun., 1982) for the period 1975-80 were averaged, and converted to yield. The following table compares IJC estimates to those calculated with regression equations.

Table 5.--Comparison of estimated phosphorus yields at water-quality stations

Station	Total phosphorus yield		
	International Joint Commission {(tons/mi²)/yr}	Regression equations	
		Load-dependent {(tons/mi²)/yr}	Midline {(tons/mi²)/yr}
Ontonagon River	0.12	0.072	0.086
Sturgeon River	.027	.036	.036
Tahquamenon River	.030	.024	.026
Manistique River	.041	.024	.025
Escanaba River	.076	.017	.020
Ford River	.025	.014	.015
St. Joseph River	.10	.11	.12
Kalamazoo River	.12	.10	.11
Grand River	.11	.097	.10
Muskegon River	.025	.027	.031
Manistee River	.032	.028	.026
Cheboygan River	.011	.021	.017
Thunder Bay River	.014	.010	.011
Au Sable River	.011	.013	.011
Rifle River	.045	.039	.055
Saginaw River	.14	.13	.14
Pigeon River	.065	.049	.052
Clinton River	.20	.29	.48
River Raisin	.16	.16	.17

The above data suggest that the higher the phosphorus yield the closer the estimates of IJC and those based on regressions agree. For five of the seven streams for which IJC estimated yields of 0.10 (tons/mi²)/yr or greater, differences did not exceed 20 percent. Some differences are to be expected because NASQAN stations are not located at the mouth of streams, and thus discharges of phosphorus by cities downstream from the station are not reflected in NASQAN data.

A comparison of estimates made using the load-dependent equation to those made by the midline equation indicate that the midline equation gave results closer to IJC estimates for 12 of the 19 streams.

Prediction of Yields from Instantaneous Discharge

Computations of yield based on single measurements of flow are not normally expected to provide reliable estimates using regression equations, particularly if the measured flow lies outside the range used in developing equations. A test of results is possible in two instances, however. At St. Joseph River at Niles and River Raisin near Monroe, discharges occurred in 1982 that were higher than any used in developing regression equations.

The St. Joseph River, on March 19, 1982, had an instantaneous discharge of 19,400 ft^3/s[1/] at the time a sample was collected. Yields, based on the chemical analysis and this discharge, were calculated. Using the regression equations for St. Joseph River (table 11), yields at the same discharge were also calculated. The following table shows the results in tons per square mile per day.

Table 6.--Comparison of measured and estimated yields for the St. Joseph River at Niles during high flow

Substance or property	Yield based on sample collected March 19, 1982 {(tons/mi^2)/d}	Yield based on regression equations {(tons/mi^2)/d}
Silica (SiO_2)	0.075	0.072
Calcium (Ca)	.66	.69
Magnesium (Mg)	.16	.17
Sodium (Na)	.080	.088
Potassium (K)	.039	.049
Bicarbonate (HCO_3)	2.09	2.14
Sulfate (SO_4)	.47	.54
Chloride (Cl)	.19	.19
Fluoride (F)	.0014	.0012
Nitrogen (N)		
Ammonia (NH_4 as N)	.0034	.0049
Nitrite plus nitrate (NO_2 + NO_3 as N)	.026	.055
Organic (as N)	.0093	.025
Total (as N)	.038	.097
Phosphorus (P)		
Dissolved (as P)	.00086	.0015
Total (as P)	.0021	.0039
Hardness (as $CaCO_3$)	2.29	2.43
Dissolved solids		
Residue	3.07	3.36
Sum	2.70	2.96
Suspended sediment	1.76	.94

The above regression results are based on load-dependent equations. Using the midline equation, subtantially better agreement was found only in total nitrogen and suspended sediment. The midline equation gave 0.034 (tons/mi^2)/d for total nitrogen, and 1.58 (tons/mi^2)/d for suspended sediment.

On March 22, 1982, the River Raisin near Monroe had a discharge of 6,960 ft^3/s[2/], a flow greater than available when developing regression equations. A sample for analysis was collected, and yields calculated. The following table compares these yields to those computed by regression equations.

1/ Mean daily discharge was 18,500 ft^3/s.

2/ Mean daily discharge was 7,020 ft^3/s.

Table 7.--Comparison of measured and estimated yields for the River Raisin near Monroe at high flow

Substance or property	Yield based on sample collected March 22, 1982 {(tons/mi²)/d}	Yield based on regression equations {(tons/mi²)/d}
Silica (SiO_2)	0.096	0.11
Calcium (Ca)	.85	1.08
Magnesium (Mg)	.20	.24
Sodium (Na)	.11	.13
Potassium (K)	.061	.055
Bicarbonate (HCO_3)	2.63	3.17
Sulfate (SO_4)	.63	.68
Chloride (Cl)	.29	.45
Fluoride (F)	.0036	.0027
Nitrogen (N)		
Ammonia (NH_4 as N)	.0022	.0021
Nitrite plus nitrate (NO_2 + NO_3 as N)	.040	.28
Organic (as N)	.012	.025
Total (as N)	.054	.21
Phosphorus (P)		
Dissolved (as P)	.0018	.0016
Total (as P)	.0032	.0042
Hardness (as $CaCO_3$)	2.89	3.73
Dissolved solids		
Residue	4.18	5.55
Sum	3.53	4.01
Suspended sediment	.90	2.19

Because the above results showed better agreement than anticipated, two water-quality stations were selected at random for similar comparisons during periods of low flow. Samples for analysis in both instances were collected in 1981, which is not included in regression equation development. Yields based on instantaneous discharge and the chemical analysis are compared to yields based on regression equations for the Clinton River at Mt. Clemens on July 15, 1981, in the following table. (Discharge at the time of sampling was 151 ft^3/s.)

Table 8.--Comparison of measured and estimated yields for the Clinton River at Mt. Clemens during low flow

Substance or property	Yield based on sample collected July 15, 1981 {(tons/mi^2)/d}	Yield based on regression equations	
		Load-dependent {(tons/mi^2)/d}	Midline {(tons/mi^2)/d}
Silica (SiO_2)	1.24	1.05	0.98
Calcium (Ca)	13.2	14.0	14.0
Magnesium (Mg)	3.85	4.25	4.17
Sodium (Na)	12.0	13.2	11.9
Potassium (K)	1.13	1.12	1.09
Bicarbonate (HCO_3)	42.6	46.2	45.2
Sulfate (SO_4)	7.97	13.9	13.5
Chloride (Cl)	19.9	20.5	18.7
Fluoride (F)	.12	.11	.099
Nitrogen (N)			
Ammonia (NH_4 as N)	.0020	.031	.032
Nitrite plus nitrate (NO_2 + NO_3 as N)	.69	.82	.71
Organic (as N)	.22	.16	.18
Total (as N)	.91	1.13	1.05
Phosphorus (P)			
Dissolved (as P)	.024	.032	.026
Total (as P)	.038	.060	.044
Hardness (as $CaCO_3$)	48.7	53.3	52.4
Dissolved solids			
Residue	97.7	100	97.8
Sum	83.4	93.6	91.4
Suspended sediment	3.24	2.77	2.09

A similar comparison was made for the Kalamazoo River at Saugatuck. Yields were computed from the analysis of a sample collected July 28, 1981; discharge at the time of sampling was 701 ft^3/s.

Table 9.--Comparison of measured and estimated yields for the Kalamazoo River at Saugatuck during low flow

Substance or property	Yield based on sample collected July 28, 1981 {(tons/mi²)/d}	Yield based on regression equations	
		Load-dependent {(tons/mi²)/d}	Midline {(tons/mi²)/d}
Silica (SiO_2)	2.60	1.58	0.93
Calcium (Ca)	22.9	24.5	24.0
Magnesium (Mg)	7.87	8.04	7.89
Sodium (Na)	8.89	8.72	8.08
Potassium (K)	.68	.71	.69
Bicarbonate (HCO_3)	88.9	95.6	93.5
Sulfate (SO_4)	16.8	17.2	16.3
Chloride (Cl)	13.0	14.1	13.4
Fluoride (F)	.069	.069	.054
Nitrogen (N)			
Ammonia (NH_4 as N)	.020	.061	.034
Nitrite plus nitrate (NO_2 + NO_3 as N)	.25	.17	.10
Organic (as N)	.44	.30	.25
Total (as N)	.72	.55	.52
Phosphorus (P)			
Dissolved (as P)	.014	.016	.0094
Total (as P)	.047	.043	.031
Hardness (as $CaCO_3$)	88.9	95.0	93.4
Dissolved solids			
Residue	133	130	128
Sum	118	123	121
Suspended sediment	6.84	3.20	2.07

If both the Clinton and Kalamazoo Rivers are considered, 57 percent of the yields based on the midline equation were closer to the yields based on instantaneous discharge and a single chemical analysis than were the yields based on the load-dependent equation.

CONCLUSIONS

Regression equations based on periodic measurements of loads of dissolved and suspended substances and corresponding instantaneous discharge may be used with mean daily discharge to provide usable estimates of long-term loads and yields for Michigan streams. Such a procedure, even when accuracy of estimates is unknown, can serve either to support or to suggest the need for reevaluation of estimates made by other techniques. Daily measurements of concentration over an extended period which can provide an accurate measure of long-term load have not been made, and thus a basis for confirming the accuracy of estimates by regression does not exist. Intensive water-quality sampling of selected streams whose quality and flow ranges are broad, accompanied by a closer examination of the regression procedure, is desirable.

REFERENCES CITED

Great Lakes Basin Commission, 1975, Erosion and sedimentation: Great Lakes basin framework study, app. 18, 127 p.

U.S. Geological Survey, 1982, Water resources data for Michigan 1981, U.S. Geological Survey Water-Data Report MI-81-1, 524 p.

page 23 follows

TABLES OF DATA

Table 1.--Description of water-quality stations

(Station numbers are downstream order numbers used by the U.S. Geological Survey)

Station number	Name and location
04001000	Washington Creek at Windigo (Lat 47°55'23", long 89°08'42", in NW¼ sec.28, T.64 N., R.38 W., Keweenaw County).
04040000	Ontonagon River near Rockland (Lat 89°43'15", long 89°12'25", in NE¼ sec.20, T.50 N., R.39 W., Ontonagon County).
04043004	Sturgeon River near Chassell (Lat 46°58'28", long 88°31'21", in NE¼ sec.20 T.53 N., R.33 W., Houghton County).
04045500	Tahquamenon River near Tahquamenon Paradise (Lat 46°34'30", long 85°16'10", in NE¼ sec.11, T.48 N., R.8 W., Luce County).
04057004	Manistique River above Manistique (Lat 45°58'18", long 86°14'35", in SE¼ SE¼ sec.1, T.41 N., R.16 W., Schoolcraft County).
04059000	Escanaba River at Cornell (Lat 45°54'31", long 87°12'49", in NW¼ sec. 32, T.41 N., R.23 W., Delta County).
04059500	Ford River near Hyde (Lat 45°45'20", long 87°12'05", in SW¼ sec.19, T.39 N., R.23 W., Delta County).
04101500	St. Joseph River at Niles (Lat 41°49'45", long 86°15'35", in SW¼ sec. 26, T.7 S., R.17 W., Berrien County).
04108690	Kalamazoo River at Saugatuck (Lat 42°38'50", long 86°11'53", in NE¼ sec.16, T.3 N., R.16 W., Allegan County).
04119300	Grand River at Eastmanville (Lat 43°00'53", long 85°57'21", in NE¼ NW¼ sec.10, T.7 N., R.14 W., Ottawa County).
04122030	Muskegon River near Bridgeton (Lat 43°19'05", long 86°02'11", in SW¼ NW¼ sec.30, T.11 N., R.14 W., Newago County).
04126520	Manistee River at Manistee (Lat 44°15'02", long 86°19'09", in SW¼ SW¼ sec.1, T.21 N., R.17 W., Manistee County).
04132052	Cheboygan River at Cheboygan (Lat 45°38'02", long 84°28'52", in NW¼ NE¼ sec.6, T.37 N., R.1 W., Cheboygan County).
04135000	Thunder Bay River near Alpena (Lat 45°05'39", long 83°29'50", in SW¼ SE¼ sec.7, T.31 N., R.8 E., Alpena County).
04137500	Au Sable River near Au Sable (Lat 44°26'09", long 83°26'28", in NE¼ NW¼ sec.35, T.24 N., R.8 E., Iosco County).
04142000	Rifle River near Sterling (Lat 44°04'21", long 84°01'12", in NE¼ SW¼ sec.5, T.19 N., R.4 E., Arenac Coutny).

Table 1.--Description of water-quality stations--Continued

Station number	Name and location
04157000	Saginaw River at Saginaw (Lat 43°24'46", long 83°57'47", in NW¼ SE¼ sec.26, T.12 N., R.4 E., Saginaw County).
04159010	Pigeon River near Caseville (Lat 43°56'22", long 83°14'30", in SW¼ NW¼ sec.31, T.18 N., R.11 E., Huron County).
04165500	Clinton River at Mt. Clemens (Lat 42°35'45", long 82°54'35", Macomb County).
04176500	River Raisin near Monroe (Lat 41°57'38", long 83°31'52", Monroe County).

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04001000	Washington Creek at Windigo	Silica (SiO_2)	0.03792	0.8837	0.99	19.3
		Calcium (Ca)	.06978	.7600	.99	15.5
		Magnesium (Mg)	.02072	.7564	.99	15.0
		Sodium (Na)	.01448	.6586	.98	15.6
		Potassium (K)	.001738	.8844	.97	27.3
		Bicarbonate (HCO_3)	.3041	.7155	.98	19.2
		Sulfate (SO_4)	.01392	1.0491	.94	55.2
		Chloride (Cl)	.01845	.5232	.88	39.2
		Fluoride (F)	.0003788	1.0400	.92	69.6
		Nitrogen (N)				
		Ammonia (NH_4)	-	-	-	-
		Nitrate plus Nitrite (NO_2+NO_3)	.0001946	.8436	.77	111
		Organic (as N)	-	-	-	-
		Total (as N)	-	-	-	-
		Phosphorus (P)				
		Dissolved (as P)	-	-	-	-
		Total (as P)	.00003988	.9782	.92	60.7
		Hardness (as $CaCO_3$)	.2604	.7582	.99	14.4
		Dissolved Solids				
		Residue	.3805	.8250	.99	15.9
		Sum	.3238	.7726	.99	13.5
		Suspended Sediment	.007367	1.3002	.88	142
04040000	Ontonagon River near Rockland	Silica (SiO_2)	.05269	.8756	.92	34.0
		Calcium (Ca)	.2006	.7878	.97	17.9
		Magnesium (Mg)	.08219	.7194	.95	20.0
		Sodium (Na)	.03166	.7608	.96	19.8
		Potassium (K)	.002201	1.0380	.98	18.3
		Bicarbonate (HCO_3)	1.5488	.6955	.96	19.4
		Sulfate (SO_4)	.01472	.9962	.94	32.8
		Chloride (Cl)	.01060	.9139	.91	36.6
		Fluoride (F)	.0002403	1.0449	.90	44.9
		Nitrogen (N)				
		Ammonia (NH_4)	.00006917	.9944	.77	66.4
		Nitrate plus Nitrite (NO_2+NO_3)	.000005728	1.4714	.79	125
		Organic (as N)	.0001860	1.2578	.86	58.9
		Total (as N)	.0001578	1.3303	.95	41.7
		Phosphorus (P)				
		Dissolved (as P)	.000004525	1.3010	.87	51.1
		Total (as P)	.000003730	1.5016	.91	67.1
		Hardness (as $CaCO_3$)	.8162	.7683	.97	17.6
		Dissolved Solids				
		Residue	.4484	.9141	.98	14.0
		Sum	.9844	.7753	.98	15.3
		Suspended Sediment	.0001243	1.9614	.94	71.8

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04043004	Sturgeon River near Chassell	Silica (SiO_2)	0.1059	0.7679	0.95	19.6
		Calcium (Ca)	.7198	.5780	.96	15.4
		Magnesium (Mg)	.2043	.5669	.95	14.9
		Sodium (Na)	.04762	.6795	.97	13.2
		Potassium (K)	.003980	.9305	.98	13.2
		Bicarbonate (HCO_3)	4.1039	.5273	.93	16.1
		Sulfate (SO_4)	.007560	1.0733	.92	36.0
		Chloride (Cl)	.008557	.9068	.94	25.9
		Fluoride (F)	.0002700	1.0000	1.00	.00
		Nitrogen (N)				
		Ammonia (NH_4)	.001167	.6006	.59	68.1
		Nitrate plus Nitrite (NO_2+NO_3)	.00006343	1.1868	.84	63.3
		Organic (as N)	.0003527	1.1684	.91	42.3
		Total (as N)	.0006387	1.1253	.95	30.0
		Phosphorus (P)				
		Dissolved (as P)	.00001538	1.1055	.88	40.2
		Total (as P)	.000007214	1.3516	.94	40.1
		Hardness (as $CaCO_3$)	2.6291	.5753	.95	13.6
		Dissolved Solids				
		Residue	.9472	.8019	.94	22.3
		Sum	2.0768	.6476	.95	16.2
		Suspended Sediment	.000004739	2.3516	.97	44.0
04045500	Tahquamenon River near Tahquamenon Paradise	Silica (SiO_2)	.08712	.7597	.89	30.9
		Calcium (Ca)	.6199	.6200	.96	14.4
		Magnesium (Mg)	.1795	.6058	.97	12.6
		Sodium (Na)	.02304	.7376	.96	15.6
		Potassium (K)	.001408	1.0564	.97	20.2
		Bicarbonate (HCO_3)	3.5019	.5560	.95	14.8
		Sulfate (SO_4)	.05582	.9066	.93	29.7
		Chloride (Cl)	.008939	.9221	.94	26.4
		Fluoride (F)	.0002676	1.0471	.86	44.5
		Nitrogen (N)				
		Ammonia (NH_4)	.003392	.4377	.48	64.6
		Nitrate plus Nitrite (NO_2+NO_3)	.00005986	1.1719	.70	119
		Organic (as N)	.0003349	1.1951	.87	52.2
		Total (as N)	.0007023	1.1139	.92	37.5
		Phosphorus (P)				
		Dissolved (as P)	.00002794	1.0074	.95	23.7
		Total (as P)	.0004295	.7026	.81	39.4
		Hardness (as $CaCO_3$)	2.2867	.6158	.97	12.8
		Dissolved Solids				
		Residue	1.0504	.7967	.97	15.3
		Sum	1.8514	.6773	.97	12.8
		Suspended Sediment	.003432	1.1636	.82	75.8

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04057004	Manistique River above Manistique	Silica (SiO_2)	0.09865	0.7471	0.86	33.2
		Calcium (Ca)	.6464	.6903	.96	15.0
		Magnesium (Mg)	.1251	.7085	.97	12.5
		Sodium (Na)	.01162	.8291	.98	13.2
		Potassium (K)	.004065	.8867	.97	14.7
		Bicarbonate (HCO_3)	2.2095	.6837	.96	13.8
		Sulfate (SO_4)	.7901	.6374	.89	23.8
		Chloride (Cl)	.008255	.9162	.85	43.0
		Fluoride (F)	.0002315	1.0324	.94	25.4
		Nitrogen (N)				
		Ammonia (NH_4)	.0001049	.9850	.65	88.1
		Nitrate plus Nitrite (NO_2+NO_3)	.0002082	1.0288	.79	61.9
		Organic (as N)	.0004194	1.1298	.82	39.9
		Total (as N)	.0002782	1.2201	.95	29.4
		Phosphorus (P)				
		Dissolved (as P)	.00004386	.9632	.83	44.0
		Total (as P)	.00003340	1.0337	.84	50.8
		Hardness (as $CaCO_3$)	2.0864	.6976	.96	13.9
		Dissolved Solids				
		Residue	1.3734	.7997	.97	13.6
		Sum	2.5183	.6963	.97	13.6
		Suspended Sediment	.001140	1.3111	.88	56.1
04059000	Escanaba River at Cornell	Silica (SiO_2)	.05645	.8369	.95	24.4
		Calcium (Ca)	.1767	.8233	.98	12.5
		Magnesium (Mg)	.07962	.8064	.98	12.7
		Sodium (Na)	.1295	.5923	.73	48.2
		Potassium (K)	.006246	.8657	.96	20.7
		Bicarbonate (HCO_3)	1.4129	.7404	.98	12.6
		Sulfate (SO_4)	.03335	.9784	.93	33.6
		Chloride (Cl)	.02419	.8393	.94	25.8
		Fluoride (F)	.0008293	.8624	.86	44.5
		Nitrogen (N)				
		Ammonia (NH_4)	.0001577	.8456	.70	77.7
		Nitrate plus Nitrite (NO_2+NO_3)	.0001102	1.1878	.78	96.7
		Organic (as N)	.0004112	1.1567	.92	43.5
		Total (as N)	.0004285	1.2019	.93	42.2
		Phosphorus (P)				
		Dissolved (as P)	.00003947	.9884	.81	62.4
		Total (as P)	.00002845	1.0713	.85	61.3
		Hardness (as $CaCO_3$)	.7649	.8173	.98	12.7
		Dissolved Solids				
		Residue	.5976	.9069	.99	12.5
		Sum	1.0686	.7943	.98	12.0
		Suspended Sediment	.002251	1.2232	.82	83.9

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04059500	Ford River near Hyde	Silica (SiO_2)	0.04051	0.8572	0.96	29.9
		Calcium (Ca)	.2157	.8598	.99	13.5
		Magnesium (Mg)	.1308	.7983	.99	10.4
		Sodium (Na)	.006794	.8680	.96	31.1
		Potassium (K)	.002988	.9223	.97	26.2
		Bicarbonate (HCO_3)	1.3561	.8117	.99	12.6
		Sulfate (SO_4)	.05236	.9027	.92	48.1
		Chloride (Cl)	.008354	.9445	.99	19.1
		Fluoride (F)	.0003304	1.0119	.94	44.8
		Nitrogen (N)				
		Ammonia (NH_4)	.00008978	.9131	.76	93.3
		Nitrate plus Nitrite (NO_2+NO_3)	.0001398	1.0043	.68	207
		Organic (as N)	.0004747	1.1486	.94	44.5
		Total (as N)	.0006665	1.1359	.95	46.5
		Phosphorus (P)				
		Dissolved (as P)	.00002700	1.0000	1.00	.00
		Total (as P)	.00003173	1.0388	.93	55.0
		Hardness (as $CaCO_3$)	1.0821	.8311	.99	11.6
		Dissolved Solids				
		Residue	.9105	.8901	.99	10.8
		Sum	1.1120	.8339	.99	11.1
		Suspended Sediment	.0004256	1.6059	.92	95.7
04101500	St. Joseph River at Niles	Silica (SiO_2)	.02062	.9578	.76	47.9
		Calcium (Ca)	.8826	.8065	.97	10.6
		Magnesium (Mg)	.4092	.7427	.97	10.8
		Sodium (Na)	.3588	.6884	.94	13.7
		Potassium (K)	.0004500	1.3059	.99	12.6
		Bicarbonate (HCO_3)	5.6768	.7324	.97	9.59
		Sulfate (SO_4)	.2317	.9180	.94	18.9
		Chloride (Cl)	.5056	.7332	.96	12.5
		Fluoride (F)	.007663	.6454	.70	38.8
		Nitrogen (N)				
		Ammonia (NH_4)	.0001125	1.2127	.71	76.4
		Nitrate plus Nitrite (NO_2+NO_3)	.00003885	1.5671	.89	47.5
		Organic (as N)	.00002881	1.5152	.91	41.0
		Total (as N)	.00006990	1.5645	.95	29.6
		Phosphorus (P)				
		Dissolved (as P)	.0000000220	1.9561	.88	69.6
		Total (as P)	.0000008180	1.6891	.90	49.9
		Hardness (as $CaCO_3$)	3.7000	.7888	.98	9.88
		Dissolved Solids				
		Residue	3.9319	.8153	.97	11.8
		Sum	4.0448	.7997	.97	10.6
		Suspended Sediment	.00007551	1.7863	.85	69.0

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04108690	Kalamazoo River at Saugatuck	Silica (SiO_2)	0.005954	1.1128	0.63	86.0
		Calcium (Ca)	.4135	.8844	.98	10.8
		Magnesium (Mg)	.2066	.8199	.98	9.75
		Sodium (Na)	.7603	.6334	.89	17.8
		Potassium (K)	.004419	1.0358	.97	12.9
		Bicarbonate (HCO_3)	2.0578	.8470	.97	11.1
		Sulfate (SO_4)	.3069	.8757	.94	17.3
		Chloride (Cl)	.9760	.6685	.93	14.3
		Fluoride (F)	.0007440	.9520	.82	36.6
		Nitrogen (N)				
		Ammonia (NH_4)	.0009348	.8996	.55	83.0
		Nitrate plus Nitrite (NO_2+NO_3)	.0001858	1.3012	.70	81.0
		Organic (as N)	.002350	.9996	.84	34.0
		Total (as N)	.003263	1.0451	.93	22.3
		Phosphorus (P)				
		Dissolved (as P)	.0006621	.7480	.51	67.0
		Total (as P)	.002155	.7227	.64	48.6
		Hardness (as $CaCO_3$)	1.8897	.8589	.98	9.45
		Dissolved Solids				
		Residue	2.7772	.8476	.98	8.80
		Sum	2.9134	.8322	.98	9.26
		Suspended Sediment	.003281	1.3116	.72	78.3
04119300	Grand River at Eastmanville	Silica (SiO_2)	.003747	1.1510	.82	64.1
		Calcium (Ca)	.2915	.9456	.98	15.9
		Magnesium (Mg)	.1817	.8598	.99	9.70
		Sodium (Na)	.8383	.6827	.97	13.6
		Potassium (K)	.004335	1.0715	.99	12.6
		Bicarbonate (HCO_3)	1.5111	.8951	.99	11.6
		Sulfate (SO_4)	.4406	.8792	.97	15.5
		Chloride (Cl)	.8735	.7495	.98	12.0
		Fluoride (F)	.001817	.8453	.94	22.6
		Nitrogen (N)				
		Ammonia (NH_4)	.008121	.7015	.59	82.6
		Nitrate plus Nitrite (NO_2+NO_3)	.00001086	1.6951	.84	95.9
		Organic (as N)	.001665	1.0543	.85	52.6
		Total (as N)	.0007614	1.2752	.86	60.1
		Phosphorus (P)				
		Dissolved (as P)	.0001533	.9830	.66	98.7
		Total (as P)	.0004975	.9685	.76	67.6
		Hardness (as $CaCO_3$)	1.3785	.9181	.98	12.7
		Dissolved Solids				
		Residue	2.3790	.8985	.99	10.8
		Sum	2.6014	.8752	.99	10.0
		Suspended Sediment	.0004831	1.6051	.78	126

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04122030	Muskegon River near Bridgeton	Silica (SiO_2)	0.002734	1.2243	0.94	23.8
		Calcium (Ca)	.3211	.8673	.97	10.8
		Magnesium (Mg)	.08870	.8790	.96	12.7
		Sodium (Na)	.1355	.7813	.92	17.5
		Potassium (K)	.001667	1.0926	.96	16.2
		Bicarbonate (HCO_3)	1.2512	.8707	.96	12.8
		Sulfate (SO_4)	.2098	.8165	.90	20.8
		Chloride (Cl)	.2050	.8081	.92	17.6
		Fluoride (F)	.0002085	1.0649	.80	41.1
		Nitrogen (N)				
		Ammonia (NH_4)	.000004413	1.3957	.72	81.8
		Nitrate plus Nitrite (NO_2+NO_3)	.000000619	1.8970	.77	93.3
		Organic (as N)	.02094	.6168	.55	54.7
		Total (as N)	.0007180	1.1266	.85	36.4
		Phosphorus (P)				
		Dissolved (as P)	.000003858	1.3108	.77	65.6
		Total (as P)	.00001790	1.1919	.74	60.8
		Hardness (as $CaCO_3$)	1.1740	.8708	.97	11.0
		Dissolved Solids				
		Residue	1.6248	.8617	.97	10.7
		Sum	1.5038	.8629	.97	11.1
		Suspended Sediment	.00001456	2.0596	.91	49.9
04126520	Manistee River at Manistee	Silica (SiO_2)	.04941	.8843	.90	14.4
		Calcium (Ca)	.6755	.8085	.82	19.5
		Magnesium (Mg)	.09145	.8699	.94	10.7
		Sodium (Na)	.2658	.7513	.66	29.7
		Potassium (K)	.02877	.7458	.67	28.8
		Bicarbonate (HCO_3)	1.0739	.8973	.95	9.67
		Sulfate (SO_4)	.03994	.9839	.87	19.0
		Chloride (Cl)	1.3807	.6868	.47	46.3
		Fluoride (F)	.00005204	1.2260	.82	30.7
		Nitrogen (N)				
		Ammonia (NH_4)	.001806	.6571	.49	47.5
		Nitrate plus Nitrite (NO_2+NO_3)	.001261	.8823	.50	56.1
		Organic (as N)	.0003120	1.0982	.65	47.3
		Total (as N)	.001269	1.0119	.74	31.2
		Phosphorus (P)				
		Dissolved (as P)	.07727	.04668	.024	64.4
		Total (as P)	.00007466	.9839	.51	61.2
		Hardness (as $CaCO_3$)	2.1503	.8179	.87	15.7
		Dissolved Solids				
		Residue	2.0545	.8660	.81	21.7
		Sum	2.5811	.8234	.86	16.7
		Suspended Sediment	.001400	1.3280	.64	60.4

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04132052	Cheboygan River at Cheboygan	Silica (SiO_2)	0.01658	1.0220	0.97	11.9
		Calcium (Ca)	.09993	1.0208	.99	6.01
		Magnesium (Mg)	.05548	.9330	.99	6.73
		Sodium (Na)	.01587	.9254	.97	12.3
		Potassium (K)	.001751	1.0339	.98	11.8
		Bicarbonate (HCO_3)	.5445	.8975	.99	7.89
		Sulfate (SO_4)	.01653	1.0848	.96	16.5
		Chloride (Cl)	.01872	.9318	.93	18.1
		Fluoride (F)	.0001409	1.1547	.74	54.8
		Nitrogen (N)				
		Ammonia (NH_4)	.00001510	1.1787	.58	87.5
		Nitrate plus Nitrite (NO_2+NO_3)	1.5722×10^{-8}	2.2123	.83	80.5
		Organic (as N)	.0003574	1.0729	.60	78.4
		Total (as N)	.0005242	1.0657	.81	40.6
		Phosphorus (P)				
		Dissolved (as P)	.01088	.2676	.18	92.0
		Total (as P)	.0007125	.6153	.40	82.7
		Hardness (as $CaCO_3$)	.4660	.9890	.99	5.69
		Dissolved Solids				
		Residue	.4614	1.0065	1.00	4.94
		Sum	.5064	.9903	.99	5.67
		Suspended Sediment	.001297	1.2440	.72	67.9
04135000	Thunder Bay River at Alpena	Silica (SiO_2)	.04697	.8688	.98	25.3
		Calcium (Ca)	.1127	1.0297	1.00	12.9
		Magnesium (Mg)	.04760	.9579	.99	16.4
		Sodium (Na)	.01723	.9639	.99	19.7
		Potassium (K)	.0007962	1.1806	1.00	13.6
		Bicarbonate (HCO_3)	.5746	.9938	1.00	14.5
		Sulfate (SO_4)	.01254	1.1723	.99	25.2
		Chloride (Cl)	.01044	1.0599	1.00	8.35
		Fluoride (F)	.0005400	1.0000	1.00	.00
		Nitrogen (N)				
		Ammonia (NH_4)	.0001405	.9766	.92	70.8
		Nitrate plus Nitrite (NO_2+NO_3)	.000004593	1.5784	.93	125
		Organic (as N)	.0002656	1.2077	.97	53.0
		Total (as N)	.0003640	1.1991	.97	48.6
		Phosphorus (P)				
		Dissolved (as P)	.0002428	.6706	.86	61.8
		Total (as P)	.0001097	.8760	.92	61.8
		Hardness (as $CaCO_3$)	.4807	1.0022	1.00	14.2
		Dissolved Solids				
		Residue	.5391	1.0143	1.00	7.98
		Sum	.5170	1.0067	1.00	12.7
		Suspended Sediment	.002113	1.2589	.98	42.8

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04137500	Au Sable River near Au Sable	Silica (SiO_2)	0.02495	0.9862	0.99	14.4
		Calcium (Ca)	.1358	.9765	1.00	9.07
		Magnesium (Mg)	.03341	.9758	.99	10.8
		Sodium (Na)	.01095	1.0015	.99	11.1
		Potassium (K)	.001336	1.0234	.97	25.5
		Bicarbonate (HCO_3)	.5098	.9859	1.00	8.94
		Sulfate (SO_4)	.02215	1.0279	.98	20.2
		Chloride (Cl)	.01261	1.0032	1.00	8.52
		Fluoride (F)	.0002700	1.0000	1.00	.00
		Nitrogen (N)				
		Ammonia (NH_4)	.0000084	1.2394	.87	81.4
		Nitrate plus Nitrite (NO_2+NO_3)	2.3281×10^{-8}	2.1292	.84	98.9
		Organic (as N)	.0008113	.9455	.81	72.6
		Total (as N)	.0005295	1.0479	.91	48.1
		Phosphorus (P)				
		Dissolved (as P)	1.0380×10^{-6}	1.4947	.73	76.6
		Total (as P)	.000004470	1.3168	.81	71.9
		Hardness (as $CaCO_3$)	.4936	.9721	.99	9.67
		Dissolved Solids				
		Residue	.4771	.9961	1.00	6.47
		Sum	.4822	.9892	1.00	8.23
		Suspended Sediment	.0008482	1.3262	.89	71.2
04142000	Rifle River near Sterling	Silica (SiO_2)	.02899	.9300	.88	24.5
		Calcium (Ca)	.3416	.8577	.98	8.14
		Magnesium (Mg)	.1196	.8018	.98	7.24
		Sodium (Na)	.07553	.8214	.96	10.3
		Potassium (K)	.0004637	1.3528	.96	18.8
		Bicarbonate (HCO_3)	1.4767	.8292	.99	6.92
		Sulfate (SO_4)	.08620	.9916	.94	17.7
		Chloride (Cl)	.08453	.8851	.96	11.7
		Fluoride (F)	.0003369	1.0167	.75	44.2
		Nitrogen (N)				
		Ammonia (NH_4)	.00007574	1.0431	.55	103
		Nitrate plus Nitrite (NO_2+NO_3)	.000000442	2.1676	.66	101
		Organic (as N)	.000009188	1.8347	.89	58.2
		Total (as N)	.00001256	1.8467	.88	51.8
		Phosphorus (P)				
		Dissolved (as P)	.000009141	1.2531	.84	50.5
		Total (as P)	.000001003	1.7773	.83	63.4
		Hardness (as $CaCO_3$)	1.2948	.8460	.98	7.58
		Dissolved Solids				
		Residue	1.1596	.9084	.99	7.24
		Sum	1.3471	.8715	.98	7.34
		Suspended Sediment	.00007949	2.1489	.77	103

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04157000	Saginaw River at Saginaw	Silica (SiO_2)	0.001668	1.2262	0.86	76.2
		Calcium (Ca)	.3857	.9138	.99	13.7
		Magnesium (Mg)	.1506	.8780	.99	12.9
		Sodium (Na)	2.3318	.6035	.86	32.8
		Potassium (K)	.02279	.8932	.89	42.0
		Bicarbonate (HCO_3)	1.2020	.9126	.99	13.1
		Sulfate (SO_4)	.3764	.8885	.98	15.1
		Chloride (Cl)	3.7239	.6392	.89	30.3
		Fluoride (F)	.001163	.9207	.91	39.5
		Nitrogen (N)				
		Ammonia (NH_4)	.004017	.8021	.69	93.8
		Nitrate plus Nitrite (NO_2+NO_3)	.0001257	1.3669	.91	62.9
		Organic (as N)	.006536	.8791	.92	37.7
		Total (as N)	.003449	1.0757	.96	30.5
		Phosphorus (P)				
		Dissolved (as P)	.00007280	1.1247	.89	62.2
		Total (as P)	.001479	.8731	.84	56.7
		Hardness (as $CaCO_3$)	1.5442	.9043	.99	12.9
		Dissolved Solids				
		Residue	4.1639	.8429	.98	13.6
		Sum	4.0973	.8284	.98	15.4
		Suspended Sediment	.005987	1.3055	.80	118
04159010	Pigeon River near Caseville	Silica (SiO_2)	.005499	1.0846	.89	188
		Calcium (Ca)	.2926	.9961	1.00	20.0
		Magnesium (Mg)	.08970	.9606	1.00	18.0
		Sodium (Na)	.06917	.8781	.99	33.8
		Potassium (K)	.01155	.9463	.99	31.6
		Bicarbonate (HCO_3)	.7766	.9931	.99	24.0
		Sulfate (SO_4)	.3912	.9245	1.00	18.8
		Chloride (Cl)	.1414	.9779	.99	27.8
		Fluoride (F)	.0006132	.9679	.99	28.0
		Nitrogen (N)				
		Ammonia (NH_4)	.0001770	1.0306	.94	98.8
		Nitrate plus Nitrite (NO_2+NO_3)	.0003863	1.8893	.97	124
		Organic (as N)	.001875	1.0446	.99	30.6
		Total (as N)	.003220	1.3685	.98	67.0
		Phosphorus (P)				
		Dissolved (as P)	.0002440	.9175	.97	57.8
		Total (as P)	.0003233	.9272	.97	50.9
		Hardness (as $CaCO_3$)	1.1226	.9814	1.00	17.9
		Dissolved Solids				
		Residue	1.5639	.9757	1.00	21.3
		Sum	1.4044	.9686	1.00	20.6
		Suspended Sediment	.01465	1.3125	.93	118

Table 11.--Regression coefficients (a), regression exponents (b), correlation coefficients, and standard errors of the estimate for equations relating load (L) to discharge (Q), where $L = aQ^b$--Continued

Station number	Station name	Constituent or property	a	b	Correlation coefficient	Standard error of estimate (percent)
04165500	Clinton River at Mt. Clemens	Silica (SiO_2)	0.01372	1.0032	0.94	27.1
		Calcium (Ca)	.2152	.9754	.98	13.1
		Magnesium (Mg)	.07542	.9429	.98	14.2
		Sodium (Na)	.4733	.8025	.89	31.2
		Potassium (K)	.03897	.8096	.97	15.8
		Bicarbonate (HCO_3)	.7181	.9690	.98	14.8
		Sulfate (SO_4)	.3205	.8912	.97	16.8
		Chloride (Cl)	.5038	.8782	.91	30.9
		Fluoride (F)	.009105	.6377	.84	28.3
		Nitrogen (N)				
		Ammonia (NH_4)	.0001779	1.1674	.80	73.9
		Nitrate plus Nitrite (NO_2+NO_3)	.06353	.6481	.83	33.6
		Organic (as N)	.002140	1.0428	.90	40.6
		Total (as N)	.06097	.7211	.91	24.2
		Phosphorus (P)				
		Dissolved (as P)	.003468	.5849	.72	44.5
		Total (as P)	.002374	.7779	.74	56.1
		Hardness (as $CaCO_3$)	.8501	.9640	.98	13.2
		Dissolved Solids				
		Residue	2.0119	.9182	.98	15.5
		Sum	1.9306	.9128	.98	15.3
		Suspended Sediment	.001874	1.5943	.85	84.9
04176500	River Raisin near Monroe	Silica (SiO_2)	.02060	.9708	.91	44.3
		Calcium (Ca)	.6415	.8446	.99	12.7
		Magnesium (Mg)	.1449	.8423	.99	12.0
		Sodium (Na)	.4970	.6371	.95	21.0
		Potassium (K)	.06266	.7704	.78	66.1
		Bicarbonate (HCO_3)	1.4928	.8704	.98	15.5
		Sulfate (SO_4)	1.7923	.6764	.94	24.4
		Chloride (Cl)	.2935	.8337	.98	16.2
		Fluoride (F)	.001649	.8428	.96	25.9
		Nitrogen (N)				
		Ammonia (NH_4)	.0002454	1.0296	.64	182
		Nitrate plus Nitrite (NO_2+NO_3)	.00003607	1.7984	.93	76.4
		Organic (as N)	.001012	1.1481	.96	34.1
		Total (as N)	.0005041	1.4662	.98	33.0
		Phosphorus (P)				
		Dissolved (as P)	.0004539	.9244	.89	50.2
		Total (as P)	.0002887	1.0893	.95	37.9
		Hardness (as $CaCO_3$)	2.1607	.8470	.99	12.0
		Dissolved Solids				
		Residue	3.2456	.8461	.99	13.6
		Sum	4.1020	.7829	.98	14.3
		Suspended Sediment	.002553	1.5486	.86	118

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04001000	Washington Creek at Windigo	October 1973 - September 1980	7.0	13.2	Silica (SiO_2)	9.67	(9.88)
					Calcium (Ca)	11.9	(12.1)
					Magnesium (Mg)	3.50	(3.55)
					Sodium (Na)	1.82	(1.85)
					Potassium (K)	.44	(.46)
					Bicarbonate (HCO_3)	45.3	(46.1)
					Sulfate (SO_4)	6.33	(7.29)
					Chloride (Cl)	1.59	(1.72)
					Fluoride (F)	.17	(.20)
					Nitrogen (N)		
					Ammonia (NH_4)	-	
					Nitrate plus Nitrite (NO_2+NO_3)	.044	(.069)
					Organic (as N)	-	
					Total (as N)	-	
					Phosphorus (P)		
					Dissolved (as P)	-	
					Total (as P)	.014	(.017)
					Hardness (as $CaCO_3$)	44.3	(44.8)
					Dissolved Solids		
					Residue	80.0	(81.1)
					Sum	57.6	(58.2)
					Suspended Sediment	8.75	(13.8)
04040000	Ontonagon River near Rockland	October 1974 - September 1980	6.0	1,340	Silica (SiO_2)	7.67	(8.04)
					Calcium (Ca)	15.1	(15.4)
					Magnesium (Mg)	3.74	(3.80)
					Sodium (Na)	1.96	(1.99)
					Potassium (K)	1.10	(1.11)
					Bicarbonate (HCO_3)	59.1	(59.9)
					Sulfate (SO_4)	5.33	(5.58)
					Chloride (Cl)	2.06	(2.18)
					Fluoride (F)	.13	(.14)
					Nitrogen (N)		
					Ammonia (NH_4)	.025	(.029)
					Nitrate plus Nitrite (NO_2+NO_3)	.086	(.13)
					Organic (as N)	.51	(.60)
					Total (as N)	.67	(.72)
					Phosphorus (P)		
					Dissolved (as P)	.017	(.020)
					Total (as P)	.072	(.086)
					Hardness (as $CaCO_3$)	53.3	(54.0)
					Dissolved Solids		
					Residue	87.2	(88.0)
					Sum	67.7	(68.4)
					Suspended Sediment	107	(128)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yield in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04043004	Sturgeon River near Chassell	January 1978 - September 1980	2.75	723	Silica (SiO_2)	11.7	(11.5)
					Calcium (Ca)	24.2	(23.9)
					Magnesium (Mg)	6.42	(6.31)
					Sodium (Na)	3.01	(2.97)
					Potassium (K)	1.23	(1.23)
					Bicarbonate (HCO_3)	101	(98.7)
					Sulfate (SO_4)	5.89	(5.81)
					Chloride (Cl)	2.28	(2.24)
					Fluoride (F)	.13	(-)
					Nitrogen (N)		
					Ammonia (NH_4)	.046	(.040)
					Nitrate plus Nitrite (NO_2+NO_3)	.10	(.10)
					Organic (as N)	.52	(.50)
					Total (as N)	.69	(.69)
					Phosphorus (P)		
					Dissolved (as P)	.015	(.015)
					Total (as P)	.036	(.036)
					Hardness (as $CaCO_3$)	87.0	(85.8)
					Dissolved Solids		
					Residue	129	(127)
					Sum	108	(106)
					Suspended Sediment	26.1	(27.1)
04045500	Tahquamenon River near Tahquamenon Paradise	October 1974 - September 1980	6.0	790	Silica (SiO_2)	7.20	(7.55)
					Calcium (Ca)	19.2	(19.4)
					Magnesium (Mg)	5.02	(5.06)
					Sodium (Na)	1.63	(1.65)
					Potassium (K)	.99	(1.01)
					Bicarbonate (HCO_3)	69.3	(70.0)
					Sulfate (SO_4)	13.2	(13.8)
					Chloride (Cl)	2.36	(2.45)
					Fluoride (F)	.18	(.20)
					Nitrogen (N)		
					Ammonia (NH_4)	.030	(.033)
					Nitrate plus Nitrite (NO_2+NO_3)	.098	(.15)
					Organic (as N)	.65	(.73)
					Total (as N)	.75	(.81)
					Phosphorus (P)		
					Dissolved (as P)	.014	(.014)
					Total (as P)	.024	(.026)
					Hardness (as $CaCO_3$)	68.6	(69.2)
					Dissolved Solids		
					Residue	113	(114)
					Sum	85.5	(86.2)
					Suspended Sediment	5.30	(6.55)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04057004	Manistique River above Manistique	October 1975 - September 1980	5.0	1,445	Silica (SiO_2)	7.98	(8.24)
					Calcium (Ca)	34.0	(34.3)
					Magnesium (Mg)	7.56	(7.58)
					Sodium (Na)	1.75	(1.76)
					Potassium (K)	.95	(.96)
					Bicarbonate (HCO_3)	111	(111)
					Sulfate (SO_4)	28.0	(28.4)
					Chloride (Cl)	2.42	(2.56)
					Fluoride (F)	.16	(.17)
					Nitrogen (N)		
					Ammonia (NH_4)	.052	(.059)
					Nitrate plus Nitrite (NO_2+NO_3)	.14	(.16)
					Organic (as N)	.63	(.66)
					Total (as N)	.85	(.88)
					Phosphorus (P)		
					Dissolved (as P)	.018	(.018)
					Total (as P)	.024	(.025)
					Hardness (as $CaCO_3$)	116	(117)
					Dissolved Solids		
					Residue	165	(166)
					Sum	139	(139)
					Suspended Sediment	7.16	(7.92)
04059000	Escanaba River at Cornell	December 1974 - September 1980	5.83	870	Silica (SiO_2)	6.42	(6.62)
					Calcium (Ca)	18.2	(18.4)
					Magnesium (Mg)	7.31	(7.37)
					Sodium (Na)	2.70	(3.02)
					Potassium (K)	.87	(.89)
					Bicarbonate (HCO_3)	81.8	(82.5)
					Sulfate (SO_4)	10.4	(11.0)
					Chloride (Cl)	2.80	(2.89)
					Fluoride (F)	.11	(.12)
					Nitrogen (N)		
					Ammonia (NH_4)	.019	(.022)
					Nitrate plus Nitrite (NO_2+NO_3)	.16	(.22)
					Organic (as N)	.46	(.50)
					Total (as N)	.67	(.74)
					Phosphorus (P)		
					Dissolved (as P)	.013	(.015)
					Total (as P)	.017	(.020)
					Hardness (as $CaCO_3$)	75.8	(86.6)
					Dissolved Solids		
					Residue	111	(112)
					Sum	90.1	(90.8)
					Suspended Sediment	4.14	(5.40)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04059500	Ford River near Hyde	December 1974 - September 1980	5.83	450	Silica (SiO_2)	5.33	(5.56)
					Calcium (Ca)	28.9	(29.1)
					Magnesium (Mg)	11.8	(11.8)
					Sodium (Na)	.96	(1.00)
					Potassium (K)	.60	(.62)
					Bicarbonate (HCO_3)	133	(134)
					Sulfate (SO_4)	9.28	(10.2)
					Chloride (Cl)	1.95	(1.98)
					Fluoride (F)	.12	(.13)
					Nitrogen (N)		
					Ammonia (NH_4)	.017	(.023)
					Nitrate plus Nitrite (NO_2+NO_3)	.048	(.094)
					Organic (as N)	.44	(.47)
					Total (as N)	.56	(.62)
					Phosphorus (P)		
					Dissolved (as P)	.0091	(-)
					Total (as P)	.014	(.015)
					Hardness (as $CaCO_3$)	120	(121)
					Dissolved Solids		
					Residue	149	(150)
					Sum	126	(127)
					Suspended Sediment	9.92	(12.9)
04101500	St. Joseph River at Niles	February 1979 - September 1980	1.67	3,666	Silica (SiO_2)	5.66	(6.12)
					Calcium (Ca)	68.4	(68.7)
					Magnesium (Mg)	18.6	(18.7)
					Sodium (Na)	10.4	(10.5)
					Potassium (K)	2.31	(2.33)
					Bicarbonate (HCO_3)	237	(238)
					Sulfate (SO_4)	45.6	(46.2)
					Chloride (Cl)	21.3	(21.4)
					Fluoride (F)	.16	(.16)
					Nitrogen (N)		
					Ammonia (NH_4)	.26	(.31)
					Nitrate plus Nitrite (NO_2+NO_3)	1.83	(1.97)
					Organic (as N)	.87	(.92)
					Total (as N)	3.22	(3.32)
					Phosphorus (P)		
					Dissolved (as P)	.029	(.033)
					Total (as P)	.11	(.12)
					Hardness (as $CaCO_3$)	247	(248)
					Dissolved Solids		
					Residue	328	(330)
					Sum	296	(298)
					Suspended Sediment	23.1	(26.4)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04108690	Kalamazoo River at Saugatuck	January 1974 - September 1980	6.75	2,020	Silica (SiO_2)	5.53	(6.17)
					Calcium (Ca)	68.1	(68.2)
					Magnesium (Mg)	20.9	(21.0)
					Sodium (Na)	19.0	(19.0)
					Potassium (K)	2.28	(2.30)
					Bicarbonate (HCO_3)	256	(256)
					Sulfate (SO_4)	47.4	(47.5)
					Chloride (Cl)	31.7	(31.7)
					Fluoride (F)	.20	(.20)
					Nitrogen (N)		
					Ammonia (NH_4)	.18	(.20)
					Nitrate plus Nitrite (NO_2+NO_3)	.73	(.81)
					Organic (as N)	.92	(.96)
					Total (as N)	1.82	(1.83)
					Phosphorus (P)		
					Dissolved (as P)	.039	(.043)
					Total (as P)	.10	(.11)
					Hardness (as $CaCO_3$)	257	(257)
					Dissolved Solids		
					Residue	347	(347)
					Sum	324	(324)
					Suspended Sediment	13.9	(15.4)
04119300	Grand River at Eastmanville	February 1979 - September 1980	1.67	5,230	Silica (SiO_2)	3.38	(3.50)
					Calcium (Ca)	47.0	(47.2)
					Magnesium (Mg)	14.3	(14.4)
					Sodium (Na)	15.3	(15.3)
					Potassium (K)	2.00	(2.00)
					Bicarbonate (HCO_3)	160	(160)
					Sulfate (SO_4)	40.9	(41.0)
					Chloride (Cl)	27.0	(27.7)
					Fluoride (F)	.13	(.13)
					Nitrogen (N)		
					Ammonia (NH_4)	.17	(.19)
					Nitrate plus Nitrite (NO_2+NO_3)	1.03	(1.23)
					Organic (as N)	.66	(.70)
					Total (as N)	1.97	(2.11)
					Phosphorus (P)		
					Dissolved (as P)	.034	(.038)
					Total (as P)	.097	(.10)
					Hardness (as $CaCO_3$)	177	(177)
					Dissolved Solids		
					Residue	259	(259)
					Sum	233	(234)
					Suspended Sediment	21.1	(26.7)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04122030	Muskegon River near Bridgeton	July 1974 - September 1980	6.25	2,420	Silica (SiO_2)	5.22	(5.38)
					Calcium (Ca)	37.7	(37.9)
					Magnesium (Mg)	11.4	(11.5)
					Sodium (Na)	8.18	(8.29)
					Potassium (K)	1.13	(1.14)
					Bicarbonate (HCO_3)	151	(152)
					Sulfate (SO_4)	16.6	(17.0)
					Chloride (Cl)	15.2	(15.4)
					Fluoride (F)	.11	(.12)
					Nitrogen (N)		
					Ammonia (NH_4)	.033	(.042)
					Nitrate plus Nitrite (NO_2+NO_3)	.25	(.34)
					Organic (as N)	.35	(.40)
					Total (as N)	.64	(.68)
					Phosphorus (P)		
					Dissolved (as P)	.014	(.018)
					Total (as P)	.027	(.031)
					Hardness (as $CaCO_3$)	142	(143)
					Dissolved Solids		
					Residue	183	(184)
					Sum	171	(172)
					Suspended Sediment	22.2	(25.2)
0412650	Manistee River at Manistee	October 1974 - September 1980	6.0	2,000	Silica (SiO_2)	8.67	(8.53)
					Calcium (Ca)	66.2	(64.4)
					Magnesium (Mg)	14.4	(14.2)
					Sodium (Na)	16.8	(15.8)
					Potassium (K)	1.74	(1.64)
					Bicarbonate (HCO_3)	208	(207)
					Sulfate (SO_4)	15.0	(14.7)
					Chloride (Cl)	53.3	(48.3)
					Fluoride (F)	.12	(.12)
					Nitrogen (N)		
					Ammonia (NH_4)	.055	(.049)
					Nitrate plus Nitrite (NO_2+NO_3)	.21	(.20)
					Organic (as N)	.28	(.26)
					Total (as N)	.60	(.56)
					Phosphorus (P)		
					Dissolved (as P)	.022	(-)
					Total (as P)	.028	(.026)
					Hardness (as $CaCO_3$)	227	(222)
					Dissolved Solids		
					Residue	313	(303)
					Sum	284	(278)
					Suspended Sediment	7.47	(7.11)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04132052	Cheboygan River at Cheboygan	October 1974 - September 1980	6.0	1,500	Silica (SiO_2)	7.86	(7.82)
					Calcium (Ca)	47.0	(46.9)
					Magnesium (Mg)	14.1	(14.1)
					Sodium (Na)	3.83	(3.80)
					Potassium (K)	.90	(.90)
					Bicarbonate (HCO_3)	203	(202)
					Sulfate (SO_4)	12.2	(12.1)
					Chloride (Cl)	4.73	(4.65)
					Fluoride (F)	.17	(.16)
					Nitrogen (N)		
					Ammonia (NH_4)	.021	(.021)
					Nitrate plus Nitrite (NO_2+NO_3)	.040	(.047)
					Organic (as N)	.24	(.23)
					Total (as N)	.33	(.33)
					Phosphorus (P)		
					Dissolved (as P)	-	(-)
					Total (as P)	.021	(.017)
					Hardness (as $CaCO_3$)	175	(175)
					Dissolved Solids		
					Residue	196	(196)
					Sum	192	(192)
					Suspended Sediment	2.93	(2.84)
04135000	Thunder Bay River at Alpena	October 1979 - September 1980	1.0	1,238	Silica (SiO_2)	4.12	(4.20)
					Calcium (Ca)	29.1	(29.2)
					Magnesium (Mg)	7.58	(7.64)
					Sodium (Na)	2.86	(2.89)
					Potassium (K)	.57	(.57)
					Bicarbonate (HCO_3)	116	(117)
					Sulfate (SO_4)	8.46	(8.58)
					Chloride (Cl)	3.30	(3.31)
					Fluoride (F)	.11	(-)
					Nitrogen (N)		
					Ammonia (NH_4)	.025	(.028)
					Nitrate plus Nitrite (NO_2+NO_3)	.049	(.057)
					Organic (as N)	.23	(.24)
					Total (as N)	.29	(.31)
					Phosphorus (P)		
					Dissolved (as P)	.0057	(.0061)
					Total (as P)	.010	(.011)
					Hardness (as $CaCO_3$)	103	(104)
					Dissolved Solids		
					Residue	125	(126)
					Sum	114	(115)
					Suspended Sediment	2.56	(2.66)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04137500	Au Sable River near Au Sable	January 1978 - September 1980	2.75	1,540	Silica (SiO_2)	7.38	(7.34)
					Calcium (Ca)	37.6	(37.5)
					Magnesium (Mg)	9.20	(9.17)
					Sodium (Na)	3.60	(3.60)
					Potassium (K)	.52	(.52)
					Bicarbonate (HCO_3)	151	(150)
					Sulfate (SO_4)	8.75	(8.65)
					Chloride (Cl)	4.20	(4.19)
					Fluoride (F)	.088	(-)
					Nitrogen (N)		
					Ammonia (NH_4)	.014	(.014
					Nitrate plus Nitrite (NO_2+NO_3)	.020	(.016)
					Organic (as N)	.18	(.17)
					Total (as N)	.24	(.23)
					Phosphorus (P)		
					Dissolved (as P)	.010	(.0076)
					Total (as P)	.013	(.011)
					Hardness (as $CaCO_3$)	132	(132)
					Dissolved Solids		
					Residue	151	(151)
					Sum	146	(145)
					Suspended Sediment	2.65	(2.45)
04142000	Rifle River near Sterling	October 1975 - September 1980 (Record of QW began Oct. 1974; Q available from Oct. 1975)	5.0	320	Silica (SiO_2)	6.43	(6.76)
					Calcium (Ca)	49.6	(49.9)
					Magnesium (Mg)	12.6	(12.6)
					Sodium (Na)	8.89	(8.97)
					Potassium (K)	1.29	(1.33)
					Bicarbonate (HCO_3)	182	(183)
					Sulfate (SO_4)	27.4	(28.2)
					Chloride (Cl)	14.4	(14.6)
					Fluoride (F)	.12	(.15)
					Nitrogen (N)		
					Ammonia (NH_4)	.033	(.051)
					Nitrate plus Nitrite (NO_2+NO_3)	.22	(-)
					Organic (as N)	.52	(.65)
					Total (as N)	.77	(.97)
					Phosphorus (P)		
					Dissolved (as P)	.014	(.015)
					Total (as P)	.039	(.055)
					Hardness (as $CaCO_3$)	176	(177)
					Dissolved Solids		
					Residue	227	(228)
					Sum	212	(213)
					Suspended Sediment	34.7	(71.5)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04157000	Saginaw River at Saginaw	October 1974 - September 1980	6.0	5,066	Silica (SiO_2)	3.12	(3.86)
					Calcium (Ca)	46.9	(47.2)
					Magnesium (Mg)	13.5	(13.6)
					Sodium (Na)	20.7	(21.4)
					Potassium (K)	2.32	(2.49)
					Bicarbonate (HCO_3)	145	(146)
					Sulfate (SO_4)	36.8	(37.2)
					Chloride (Cl)	44.5	(45.9)
					Fluoride (F)	.15	(.16)
					Nitrogen (N)		
					Ammonia (NH_4)	.19	(.26)
					Nitrate plus Nitrite (NO_2+NO_3)	.84	(.98)
					Organic (as N)	.59	(.63)
					Total (as N)	1.71	(1.77)
					Phosphorus (P)		
					Dissolved (as P)	.055	(.066)
					Total (as P)	.13	(.14)
					Hardness (as $CaCO_3$)	173	(174)
					Dissolved Solids		
					Residue	276	(278)
					Sum	240	(242)
					Suspended Sediment	22.8	(32.8)
04159010	Pigeon River near Caseville	January 1978 - September 1980	2.75	125	Silica (SiO_2)	1.69	(2.38)
					Calcium (Ca)	59.6	(60.2)
					Magnesium (Mg)	15.6	(15.7)
					Sodium (Na)	8.39	(8.62)
					Potassium (K)	1.88	(1.93)
					Bicarbonate (HCO_3)	156	(158)
					Sulfate (SO_4)	58.0	(58.5)
					Chloride (Cl)	26.6	(27.0)
					Fluoride (F)	.11	(.11)
					Nitrogen (N)		
					Ammonia (NH_4)	.042	(.049)
					Nitrate plus Nitrite (NO_2+NO_3)	-	(-)
					Organic (as N)	.47	(.49)
					Total (as N)	4.02	(4.37)
					Phosphorus (P)		
					Dissolved (as P)	.035	(.038)
					Total (as P)	.049	(.052)
					Hardness (as $CaCO_3$)	214	(216)
					Dissolved Solids		
					Residue	291	(294)
					Sum	253	(256)
					Suspended Sediment	13.7	(17.9)

Table 12.--Estimated annual yield of dissolved and suspended substances at water-quality stations--Continued

{Yields in parentheses are based on midline equation}

Station number	Station name	Period of record	Years of record	Drainage area	Constituent or property	Tons per square mile per year	
04165500	Clinton River at Mt. Clemens	October 1974 - September 1980	6.0	734	Silica (SiO_2)	9.99	(11.4)
					Calcium (Ca)	125	(129)
					Magnesium (Mg)	33.8	(35.0)
					Sodium (Na)	69.9	(83.4)
					Potassium (K)	6.08	(6.37)
					Bicarbonate (HCO_3)	396	(413)
					Sulfate (SO_4)	95.0	(100)
					Chloride (Cl)	135	(160)
					Fluoride (F)	.38	(.46)
					Nitrogen (N)		
					Ammonia (NH_4)	.50	(1.08)
					Nitrate plus Nitrite (NO_2+NO_3)	2.89	(3.59)
					Organic (as N)	2.15	(2.84)
					Total (as N)	4.82	(5.38)
					Phosphorus (P)		
					Dissolved (as P)	.099	(.14)
					Total (as P)	.29	(.48)
					Hardness (as $CaCO_3$)	451	(465)
					Dissolved Solids		
					Residue	739	(772)
					Sum	679	(708)
					Suspended Sediment	224	(523)
04176500	River Raisin near Monroe	January 1978 - September 1980	2.75	1,042	Silica (SiO_2)	4.77	(5.28)
					Calcium (Ca)	59.9	(60.4)
					Magnesium (Mg)	13.3	(13.4)
					Sodium (Na)	10.9	(11.1)
					Potassium (K)	3.46	(4.26)
					Bicarbonate (HCO_3)	167	(170)
					Sulfate (SO_4)	51.3	(53.0)
					Chloride (Cl)	25.3	(25.7)
					Fluoride (F)	.15	(.16)
					Nitrogen (N)		
					Ammonia (NH_4)	.087	(.18)
					Nitrate plus Nitrite (NO_2+NO_3)	-	(-)
					Organic (as N)	.87	(.92)
					Total (as N)	4.92	(5.21)
					Phosphorus (P)		
					Dissolved (as P)	.075	(.085)
					Total (as P)	.16	(.17)
					Hardness (as $CaCO_3$)	205	(207)
					Dissolved Solids		
					Residue	306	(309)
					Sum	247	(249)
					Suspended Sediment	47.5	(74.0)

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04001000	Washington Creek at Windigo	Silica (SiO_2)	16	12.0	6.0
		Calcium (Ca)	32	18.6	8.5
		Magnesium (Mg)	10	5.5	2.5
		Sodium (Na)	8.2	3.4	1.1
		Potassium (K)	.9	.55	.2
		Bicarbonate (HCO_3)	129	77.6	28
		Sulfate (SO_4)	18	6.1	.4
		Chloride (Cl)	15	4.0	.3
		Fluoride (F)	.9	.13	.0
		Nitrogen (N)			
		Ammonia (NH_4)	-	-	-
		Nitrate plus Nitrite (NO_2+NO_3)	.21	.08	.00
		Organic (as N)	-	-	-
		Total (as N)	-	-	-
		Phosphorus (P)			
		Dissolved (as P)	-	-	-
		Total (as P)	.06	.02	.00
		Hardness (as $CaCO_3$)	120	69.1	32
		Dissolved Solids			
		Residue	158	109	48
		Sum	147	88.3	41
		Suspended Sediment	50	7.8	0
04040000	Ontonagon River near Rockland	Silica (SiO_2)	12	8.6	.8
		Calcium (Ca)	27	17.5	9.5
		Magnesium (Mg)	7.2	4.5	1.7
		Sodium (Na)	4.6	2.3	.9
		Potassium (K)	3.1	1.1	.8
		Bicarbonate (HCO_3)	110	72.9	28
		Sulfate (SO_4)	11	5.5	1.9
		Chloride (Cl)	5.7	2.3	.5
		Fluoride (F)	.6	.10	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.07	.03	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.39	.08	.00
		Organic (as N)	.92	.47	.05
		Total (as N)	1.40	.55	.16
		Phosphorus (P)			
		Dissolved (as P)	.05	.02	.00
		Total (as P)	.48	.06	.01
		Hardness (as $CaCO_3$)	93	62.4	31
		Dissolved Solids			
		Residue	130	92.6	59
		Sum	113	78.6	38
		Suspended Sediment	1,400	90.1	10

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04043004	Sturgeon River near Chassell	Silica (SiO_2)	12	8.6	5.4
		Calcium (Ca)	24	16.4	5.7
		Magnesium (Mg)	6.7	4.3	1.6
		Sodium (Na)	3.2	2.1	1.0
		Potassium (K)	1.2	.9	.7
		Bicarbonate (HCO_3)	100	67.6	19
		Sulfate (SO_4)	8.7	4.8	1.5
		Chloride (Cl)	2.9	1.8	.7
		Fluoride (F)	.1	.06	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.12	.04	.01
		Nitrate plus Nitrite (NO_2+NO_3)	.21	.10	.03
		Organic (as N)	1.2	.44	.16
		Total (as N)	1.2	.57	.31
		Phosphorus (P)			
		Dissolved (as P)	.05	.01	.00
		Total (as P)	.07	.03	.01
		Hardness (as $CaCO_3$)	88	58.9	21
		Dissolved Solids			
		Residue	245	95.9	50
		Sum	111	75.0	30
		Suspended Sediment	292	32.7	2
04045500	Tahquamenon River near Tahquamenon Paradise	Silica (SiO_2)	12	7.0	2.3
		Calcium (Ca)	28	19.3	6.6
		Magnesium (Mg)	9.1	5.1	1.8
		Sodium (Na)	2.4	1.6	.7
		Potassium (K)	1.1	.8	.4
		Bicarbonate (HCO_3)	119	73.1	21
		Sulfate (SO_4)	26	11.7	5.4
		Chloride (Cl)	4.3	2.0	1.0
		Fluoride (F)	.4	.10	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.10	.04	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.35	.10	.00
		Organic (as N)	.98	.47	.09
		Total (as N)	1.1	.58	.22
		Phosphorus (P)			
		Dissolved (as P)	.06	.01	.00
		Total (as P)	.08	.02	.00
		Hardness (as $CaCO_3$)	100	69.5	24
		Dissolved Solids			
		Residue	149	104	47
		Sum	117	83.2	33
		Suspended Sediment	11	4.5	0

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04057004	Manistique River above Manistique	Silica (SiO_2)	8.5	6.1	0.6
		Calcium (Ca)	38	25.4	9.6
		Magnesium (Mg)	7.8	5.6	2.2
		Sodium (Na)	1.6	1.2	.7
		Potassium (K)	.9	.7	.4
		Bicarbonate (HCO_3)	120	82.8	33
		Sulfate (SO_4)	41	21.5	7.7
		Chloride (Cl)	3.1	1.8	.4
		Fluoride (F)	.3	.08	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.12	.04	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.86	.12	.02
		Organic (as N)	1.1	.42	.19
		Total (as N)	1.3	.55	.28
		Phosphorus (P)			
		Dissolved (as P)	.04	.01	.00
		Total (as P)	.05	.02	.00
		Hardness (as $CaCO_3$)	120	86.2	33
		Dissolved Solids			
		Residue	168	119	49
		Sum	156	103	42
		Suspended Sediment	28	5.2	1
04059000	Escanaba River at Cornell	Silica (SiO_2)	14	7.9	3.9
		Calcium (Ca)	35	21.6	12
		Magnesium (Mg)	14	8.7	4.9
		Sodium (Na)	27	5.2	1.1
		Potassium (K)	1.8	1.0	.4
		Bicarbonate (HCO_3)	160	104	54
		Sulfate (SO_4)	28	12.0	6.3
		Chloride (Cl)	7.9	3.5	1.1
		Fluoride (F)	.6	.13	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.09	.02	.00
		Nitrate plus Nitrite (NO_2+NO_3)	28	.56	.00
		Organic (as N)	.92	.42	.17
		Total (as N)	28	1.01	.20
		Phosphorus (P)			
		Dissolved (as P)	.08	.01	.00
		Total (as P)	.09	.02	.00
		Hardness (as $CaCO_3$)	150	89.8	50
		Dissolved Solids			
		Residue	203	126	82
		Sum	188	111	66
		Suspended Sediment	14	4.1	0

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04059500	Ford River near Hyde	Silica (SiO_2)	12	7.3	2.8
		Calcium (Ca)	54	38.2	20
		Magnesium (Mg)	27	16.8	8.5
		Sodium (Na)	5.4	1.3	.3
		Potassium (K)	1.2	.75	.4
		Bicarbonate (HCO_3)	292	189	94
		Sulfate (SO_4)	29	12.5	5.6
		Chloride (Cl)	3.5	2.3	1.2
		Fluoride (F)	.3	.10	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.14	.03	.00
		Nitrate plus Nitrite (NO_2+NO_3)	1.2	.11	.00
		Organic (as N)	.88	.42	.12
		Total (as N)	2.6	.56	.12
		Phosphorus (P)			
		Dissolved (as P)	.01	.00	.00
		Total (as P)	.06	.01	.00
		Hardness (as $CaCO_3$)	250	165	85
		Dissolved Solids			
		Residue	254	189	119
		Sum	259	172	93
		Suspended Sediment	100	8.2	0
04101500	St. Joseph River at Niles	Silica (SiO_2)	9.6	6.1	2.1
		Calcium (Ca)	78	69.0	39
		Magnesium (Mg)	21	19.2	9.9
		Sodium (Na)	13	10.9	5.9
		Potassium (K)	3.5	2.1	1.6
		Bicarbonate (HCO_3)	292	244	130
		Sulfate (SO_4)	53	44.5	28
		Chloride (Cl)	27	21.8	12
		Fluoride (F)	.4	.17	.1
		Nitrogen (N)			
		Ammonia (NH_4)	.70	.31	.06
		Nitrate plus Nitrite (NO_2+NO_3)	7.2	1.7	.78
		Organic (as N)	2.5	.76	.37
		Total (as N)	8.7	2.8	1.5
		Phosphorus (P)			
		Dissolved (as P)	.13	.02	.00
		Total (as P)	.39	.09	.03
		Hardness (as $CaCO_3$)	280	251	140
		Dissolved Solids			
		Residue	380	330	186
		Sum	338	300	167
		Suspended Sediment	132	23.2	5.0

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04108690	Kalamazoo River at Saugatuck	Silica (SiO_2)	10	6.2	0.10
		Calcium (Ca)	76	64.8	40
		Magnesium (Mg)	24	19.9	12
		Sodium (Na)	28	18.6	8.2
		Potassium (K)	3.0	2.2	1.6
		Bicarbonate (HCO_3)	300	243	.0
		Sulfate (SO_4)	210	47.4	21
		Chloride (Cl)	43	30.8	15
		Fluoride (F)	.5	.20	.1
		Nitrogen (N)			
		Ammonia (NH_4)	1.0	.21	.04
		Nitrate plus Nitrite (NO_2+NO_3)	2.0	.78	.00
		Organic (as N)	1.7	.88	.00
		Total (as N)	2.9	1.76	.83
		Phosphorus (P)			
		Dissolved (as P)	.14	.05	.01
		Total (as P)	.24	.11	.01
		Hardness (as $CaCO_3$)	280	244	150
		Dissolved Solids			
		Residue	396	331	200
		Sum	452	311	183
		Suspended Sediment	66	15.1	1
04119300	Grand River at Eastmanville	Silica (SiO_2)	9.6	5.4	1.4
		Calcium (Ca)	91	71	48
		Magnesium (Mg)	26	21.8	14
		Sodium (Na)	32	24.3	15
		Potassium (K)	3.7	2.9	2.4
		Bicarbonate (HCO_3)	320	247	170
		Sulfate (SO_4)	85	61.7	43
		Chloride (Cl)	54	42.5	28
		Fluoride (F)	.3	.20	.1
		Nitrogen (N)			
		Ammonia (NH_4)	.88	.35	.04
		Nitrate plus Nitrite (NO_2+NO_3)	5.4	1.59	.11
		Organic (as N)	1.8	.99	.20
		Total (as N)	7.0	2.9	.35
		Phosphorus (P)			
		Dissolved (as P)	.18	.06	.01
		Total (as P)	.29	.15	.02
		Hardness (as $CaCO_3$)	330	267	180
		Dissolved Solids			
		Residue	461	390	289
		Sum	457	353	261
		Suspended Sediment	167	37.3	1

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04122030	Muskegon River near Bridgeton	Silica (SiO_2)	9.2	5.6	2.6
		Calcium (Ca)	52	44.1	27
		Magnesium (Mg)	17	13.4	7.5
		Sodium (Na)	13	9.9	4.4
		Potassium (K)	2.4	1.2	.9
		Bicarbonate (HCO_3)	364	179	112
		Sulfate (SO_4)	29	20.0	10
		Chloride (Cl)	27	18.3	9.4
		Fluoride (F)	.4	.13	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.14	.04	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.86	.27	.01
		Organic (as N)	2.3	.47	.06
		Total (as N)	2.4	.72	.26
		Phosphorus (P)			
		Dissolved (as P)	.07	.01	.00
		Total (as P)	.17	.03	.00
		Hardness (as $CaCO_3$)	200	166	98
		Dissolved Solids			
		Residue	256	215	133
		Sum	285	200	121
		Suspended Sediment	69	20.0	1
04126520	Manistee River at Manistee	Silica (SiO_2)	9.6	7.5	5.0
		Calcium (Ca)	98	56.4	32
		Magnesium (Mg)	29	12.5	8.1
		Sodium (Na)	24	14.6	5.8
		Potassium (K)	3.3	1.5	.8
		Bicarbonate (HCO_3)	219	179	130
		Sulfate (SO_4)	18	13.1	5.1
		Chloride (Cl)	130	48.6	9.6
		Fluoride (F)	.4	.11	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.08	.05	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.42	.21	.05
		Organic (as N)	.60	.25	.00
		Total (as N)	1.90	.55	.28
		Phosphorus (P)			
		Dissolved (as P)	.12	.02	.00
		Total (as P)	.14	.03	.01
		Hardness (as $CaCO_3$)	300	193	130
		Dissolved Solids			
		Residue	386	273	176
		Sum	385	243	159
		Suspended Sediment	60	7.9	0

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04132052	Cheboygan River at Cheboygan	Silica (SiO_2)	9.7	7.3	5.6
		Calcium (Ca)	48	43.2	37
		Magnesium (Mg)	15	12.7	11
		Sodium (Na)	42	4.0	2.2
		Potassium (K)	1.0	.83	.6
		Bicarbonate (HCO_3)	224	185	150
		Sulfate (SO_4)	15	11.5	7.3
		Chloride (Cl)	6.9	4.4	2.4
		Fluoride (F)	2.0	.19	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.10	.02	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.17	.05	.00
		Organic (as N)	.50	.25	.01
		Total (as N)	.88	.33	.09
		Phosphorus (P)			
		Dissolved (as P)	.17	.01	.00
		Total (as P)	.18	.02	.00
		Hardness (as $CaCO_3$)	180	160	140
		Dissolved Solids			
		Residue	200	180	161
		Sum	208	173	-
		Suspended Sediment	9	3.2	0
04135000	Thunder Bay River at Alpena	Silica (SiO_2)	12	8.5	4.1
		Calcium (Ca)	59	50.6	45
		Magnesium (Mg)	16	13.4	10
		Sodium (Na)	6.9	5.0	3.6
		Potassium (K)	1.5	.8	.5
		Bicarbonate (HCO_3)	250	208	170
		Sulfate (SO_4)	21	12.7	7.1
		Chloride (Cl)	7.5	5.7	4.7
		Fluoride (F)	.2	.13	.1
		Nitrogen (N)			
		Ammonia (NH_4)	.07	.03	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.49	.10	.01
		Organic (as N)	.70	.47	.20
		Total (as N)	1.1	.60	.30
		Phosphorus (P)			
		Dissolved (as P)	.05	.02	.00
		Total (as P)	.06	.03	.00
		Hardness (as $CaCO_3$)	210	182	150
		Dissolved Solids			
		Residue	251	222	197
		Sum	241	200	171
		Suspended Sediment	8	3.7	1

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04137500	Au Sable River near Au Sable	Silica (SiO_2)	11	8.4	6.2
		Calcium (Ca)	49	42.2	33
		Magnesium (Mg)	13	10.3	7.7
		Sodium (Na)	5.4	4.1	3.2
		Potassium (K)	.9	.6	.4
		Bicarbonate (HCO_3)	190	170	130
		Sulfate (SO_4)	15	10.2	7.0
		Chloride (Cl)	5.7	4.8	3.9
		Fluoride (F)	.1	.09	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.09	.02	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.17	.06	.00
		Organic (as N)	.62	.23	.00
		Total (as N)	.62	.30	.00
		Phosphorus (P)			
		Dissolved (as P)	.06	.01	.00
		Total (as P)	.07	.02	.00
		Hardness (as $CaCO_3$)	170	149	110
		Dissolved Solids			
		Residue	189	171	143
		Sum	186	160	-
		Suspended Sediment	11	4.2	0
04142000	Rifle River near Sterling	Silica (SiO_2)	11	7.5	2.4
		Calcium (Ca)	71	57.8	39
		Magnesium (Mg)	18	14.9	9.7
		Sodium (Na)	14	10.5	6.6
		Potassium (K)	12	1.4	.8
		Bicarbonate (HCO_3)	250	215	150
		Sulfate (SO_4)	56	30.9	21
		Chloride (Cl)	25	16.8	11
		Fluoride (F)	.4	.14	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.22	.05	.00
		Nitrate plus Nitrite (NO_2+NO_3)	.92	.18	.00
		Organic (as N)	1.2	.39	.04
		Total (as N)	2.0	.61	.08
		Phosphorus (P)			
		Dissolved (as P)	.06	.01	.00
		Total (as P)	.16	.03	.00
		Hardness (as $CaCO_3$)	250	206	140
		Dissolved Solids			
		Residue	316	260	194
		Sum	300	247	185
		Suspended Sediment	131	26.0	1

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04157000	Saginaw River at Saginaw	Silica (SiO_2)	9.9	4.9	0.3
		Calcium (Ca)	110	74.0	40
		Magnesium (Mg)	30	21.6	12
		Sodium (Na)	75	39.1	10
		Potassium (K)	59	4.2	2.1
		Bicarbonate (HCO_3)	330	231	140
		Sulfate (SO_4)	82	58.8	31
		Chloride (Cl)	140	83.4	22
		Fluoride (F)	.8	.25	.1
		Nitrogen (N)			
		Ammonia (NH_4)	1.4	.46	.04
		Nitrate plus Nitrite (NO_2+NO_3)	5.0	1.2	.27
		Organic (as N)	2.1	.93	.01
		Total (as N)	5.6	2.6	1.2
		Phosphorus (P)			
		Dissolved (as P)	.28	.08	.01
		Total (as P)	.61	.22	.01
		Hardness (as $CaCO_3$)	400	274	150
		Dissolved Solids			
		Residue	601	452	235
		Sum	573	398	197
		Suspended Sediment	176	36.4	0
04159010	Pigeon River near Caseville	Silica (SiO_2)	10	3.9	.0
		Calcium (Ca)	150	112	78
		Magnesium (Mg)	44	31.2	19
		Sodium (Na)	46	20.5	6.6
		Potassium (K)	8.7	4.0	2.5
		Bicarbonate (HCO_3)	390	290	170
		Sulfate (SO_4)	200	125	64
		Chloride (Cl)	85	52.7	30
		Fluoride (F)	.4	.22	.1
		Nitrogen (N)			
		Ammonia (NH_4)	.24	.09	.01
		Nitrate plus Nitrite (NO_2+NO_3)	18	4.2	.00
		Organic (as N)	1.6	.79	.49
		Total (as N)	19	5.1	.56
		Phosphorus (P)			
		Dissolved (as P)	.18	.08	.02
		Total (as P)	.26	.11	.03
		Hardness (as $CaCO_3$)	560	396	.0
		Dissolved Solids			
		Residue	998	564	380
		Sum	720	500	257
		Suspended Sediment	90	20.8	2

Table 13.--Maximum, mean, and minimum concentrations of dissolved and suspended substances at water-quality stations--Continued

{Concentrations are in milligrams per liter. Analysis by the U.S. Geological Survey}

Station number	Station name	Constituent or property	Maximum	Mean	Minimum
04165500	Clinton River at Mt. Clemens	Silica (SiO_2)	8.1	5.3	2.4
		Calcium (Ca)	90	68.8	45
		Magnesium (Mg)	24	19.9	12
		Sodium (Na)	110	55.1	3.1
		Potassium (K)	9.0	4.6	2.9
		Bicarbonate (HCO_3)	280	225	150
		Sulfate (SO_4)	89	61.4	28
		Chloride (Cl)	190	92.8	9.1
		Fluoride (F)	.9	.39	.0
		Nitrogen (N)			
		Ammonia (NH_4)	.73	.21	.01
		Nitrate plus Nitrite (NO_2+NO_3)	6.8	3.0	.24
		Organic (as N)	4.8	1.0	.41
		Total (as N)	12	4.3	.79
		Phosphorus (P)			
		Dissolved (as P)	.35	.11	.02
		Total (as P)	.76	.25	.03
		Hardness (as $CaCO_3$)	320	254	170
		Dissolved Solids			
		Residue	636	459	264
		Sum	586	424	231
		Suspended Sediment	511	42.0	6
04176500	River Raisin near Monroe	Silica (SiO_2)	11	6.8	1.3
		Calcium (Ca)	120	92.4	58
		Magnesium (Mg)	25	20.7	13
		Sodium (Na)	40	21.0	7.7
		Potassium (K)	22	7.0	2.1
		Bicarbonate (HCO_3)	330	258	150
		Sulfate (SO_4)	180	96.6	44
		Chloride (Cl)	60	39.6	27
		Fluoride (F)	.3	.24	.1
		Nitrogen (N)			
		Ammonia (NH_4)	.81	.19	.00
		Nitrate plus Nitrite (NO_2+NO_3)	8.5	2.5	.05
		Organic (as N)	2.8	.95	.32
		Total (as N)	10	3.7	1.0
		Phosphorus (P)			
		Dissolved (as P)	.39	.12	.04
		Total (as P)	.39	.19	.08
		Hardness (as $CaCO_3$)	400	316	200
		Dissolved Solids			
		Residue	751	475	317
		Sum	555	410	190
		Suspended Sediment	218	41.8	1

Table 14.--Chemical characteristics of water during high flow conditions of water-quality stations

{Unless otherwise indicated, results are in milligrams per liter}

Substance or property	04001000 Washington Creek at Windigo (May 5, 1975)	04040000 Ontonagon River near Rockland (April 23, 1975)	04043004 Sturgeon River near Chassell (April 25, 1979)	04045500 Tahquamenon River near Tahquamenon Paradise (April 24, 1979)	04057004 Manistique River above Manistique (April 2, 1976)
Discharge (in ft^3/s)	77	16,800	8,150	5,190	8,120
Silica (SiO_2)	8.6	5.7	5.5	4.0	5.0
Calcium (Ca)	8.6	15	5.7	6.6	11
Magnesium (Mg)	2.5	3.4	1.6	1.8	3.0
Sodium (Na)	1.1	1.1	1.0	.8	.9
Potassium (K)	.5	1.5	.8	.8	.5
Bicarbonate (HCO_3)	32	50	19	21	42
Sulfate (SO_4)	6.6	6.9	4.7	6.3	9.0
Chloride (Cl)	1.0	2.2	1.2	1.7	2.0
Fluoride (F)	.4	.2	.0	.0	.1
Nitrogen (N)					
Ammonia (NH_4)	--	--	.0	.01	--
Nitrate plus Nitrite (NO_2+NO_3)	.18	.13	.16	.07	.25
Organic (as N)	--	--	.41	.31	--
Total (as N)	--	1.0	.58	.39	.80
Phosphorus (P)					
Dissolved (as P)	--	--	.00	.00	--
Total (as P)	..01	.11	.03	.00	.03
Hardness (as $CaCO_3$)	32	51	21	24	40
Dissolved Solids					
Residue	65	95	50	52	--
Sum	45	62	30	33	52
Suspended Sediment	22	1,400	292	6	12

Substance or property	04059000 Escanaba River at Cornell (September 13, 1978)	04059500 Ford River near Hyde (April 19, 1979)	04101500 St. Joseph River at Niles (March 19, 1982)	04108690 Kalamazoo River at Saugatuck (March 8, 1976)	04119300 Grand River at Eastmanville (March 7, 1979)
Discharge (in ft^3/s)	4,390	3,620	19,400	7,000	12,500
Silica (SiO_2)	7.0	5.0	5.3	6.2	5.4
Calcium (Ca)	14	24	46	44	48
Magnesium (Mg)	5.4	9.4	11	14	14
Sodium (Na)	2.3	.8	5.6	10	22
Potassium (K)	.9	.7	2.7	2.3	3.7
Bicarbonate (HCO_3)	54	118	146	180	170
Sulfate (SO_4)	7.5	6.4	33	35	45
Chloride (Cl)	3.1	1.8	13	17	39
Fluoride (F)	.1	.0	.1	.2	.1
Nitrogen (N)					
Ammonia (NH_4)	.01	.00	.24	--	.95
Nitrate plus Nitrite (NO_2+NO_3)	.11	.11	1.8	1.1	2.2
Organic (as N)	.87	.29	.65	--	.95
Total (as N)	.99	.40	2.7	1.9	3.6
Phosphorus (P)					
Dissolved (as P)	.02	.00	.06	--	.07
Total (as P)	.02	.06	.15	.12	--
Hardness (as $CaCO_3$)	57	99	160	170	180
Dissolved Solids					
Residue	113	123	215	245	289
Sum	67	106	189	217	261
Suspended Sediment	10	70	123	27	60

Table 14.--Chemical characteristics of water during high flow conditions of water-quality stations--Continued

{Unless otherwise indicated, results are in milligrams per liter}

Substance or property	04122030 Muskegon River near Bridgeton (April 6, 1976)	04126520 Manistee River at Manistee (September 14, 1977)	04132052 Cheboygan River at Cheboygan (April 8, 1976)	04135000 Thunder Bay River near Alpena (April 17, 1980)	04137500 Au Sable River near Au Sable (April 19, 1978)
Discharge (in ft^3/s)	6,010	6,720	3,700	1,700	4,420
Silica (SiO_2)	4.9	7.0	6.6	4.8	7.6
Calcium (Ca)	27	56	40	39	40
Magnesium (Mg)	7.5	14	11	8.9	10
Sodium (Na)	4.4	19	2.2	3.1	4.0
Potassium (K)	1.2	1.7	.9	1.3	.9
Bicarbonate (HCO_3)	112	186	170	150	170
Sulfate (SO_4)	11	14	11	16	14
Chloride (Cl)	9.7	53	3.6	5.4	5.3
Fluoride (F)	.1	2	.1	.0	.1
Nitrogen (N)					
Ammonia (NH_4)	--	--	--	.01	.07
Nitrate plus Nitrite (NO_2+NO_3)	.29	.10	.12	.16	.16
Organic (as N)	--	--	--	.48	.20
Total (as N)	.72	.40	.37	.65	.43
Phosphorus (P)					
Dissolved (as P)	--	--	--	.01	.00
Total (as P)	.04	.02	.01	.02	.00
Hardness (as $CaCO_3$)	98	200	150	130	140
Dissolved Solids					
Residue	133	265	172	188	166
Sum	121	257	159	153	166
Suspended Sediment	57	9	5	8	5

Substance or property	04142000 Rifle River near Sterling (March 10, 1977)	04157000 Saginaw River at Saginaw (March 12, 1976)	04159010 Pigeon River near Caseville (April 6, 1978)	04165500 Clinton River at Mt. Clemens (February 19, 1976)	04176500 River Raisin near Monroe (March 22, 1982)
Discharge (in ft^3/s)	870	32,800	506	5,110	6,960
Silica (SiO_2)	5.6	5.0	4.9	5.3	5.3
Calcium (Ca)	41	40	84	48	47
Magnesium (Mg)	9.7	12	21	12	11
Sodium (Na)	8.2	10	6.6	22	6.0
Potassium (K)	3.1	2.4	3.7	3.6	3.4
Bicarbonate (HCO_3)	150	152	230	152	146
Sulfate (SO_4)	30	31	64	39	35
Chloride (Cl)	14	22	30	43	16
Fluoride (F)	.1	.2	.2	.0	.2
Nitrogen (N)					
Ammonia (NH_4)	--	--	.11	--	.12
Nitrate plus Nitrite (NO_2+NO_3)	.58	1.4	6.3	1.8	2.2
Organic (as N)	--	--	1.2	--	.65
Total (as N)	2.0	2.1	7.6	2.4	3.0
Phosphorus (P)					
Dissolved (as P)	--	--	.06	--	.10
Total (as P)	.16	.11	.12	.16	.18
Hardness (as $CaCO_3$)	140	150	300	170	160
Dissolved Solids					
Residue	194	235	380	264	232
Sum	186	197	328	248	196
Suspended Sediment	45	25	27	52	50

☆ U.S. GOVERNMENT PRINTING OFFICE: 1984 755-029