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COMMISSION

Yields of Nitrogen in the Eastern Lake Ontario Region

1968

THE YIELD OF NITROGEN

IN EASTERN

LAKE ONTARIO REGION

by

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ABSTRACT

This report presents the nutrient concentrations and quantities in the waters flowing to Lake Ontario from four basins in the eastern Lake Ontario region. The sources which are believed to be primarily responsible for nutrient levels in these four basins as well as the yearly yields discharged to Lake Ontario are presented. The four basins drain primarily rural (pasture and forest) land. A stepwise regression analysis was used to develop a relationship between concentration yield and land use for this region. An attempt to correlate streamflow and total nitrogen concentration was unsuccessful. Average annual yields of nitrogen were noticed in the range of 1,652-2,721 lbs/mi^2-yr. About 45 to 57 per cent of the annual yields were found to be released during the months of February, March and April. Yields calculated from concentrations of phosphorus found in the same samples indicated a ratio of nitrogen to phosphorus (PO_4) of 8:1. Mathematical equations forecasting concentration levels were developed and were tested statistically. These tests showed no statistical significance.

INTRODUCTION

From recent discussions it is apparent that public and private groups are quite concerned about the increasing evidence that through direct waste discharges and tributary drainage the Great Lakes are becoming excessively enriched with nutrients -- nitrogen and phosphorus. An increase in the primary producers or photo-plankton will usually result in an increase in the zooplankton which provides a better habitat for fish production. However, when this algae growth exceeds the fish food needs, the water becomes undesirable as a source of water supply, as a medium for recreation and other water uses.

Nutrients in surface waters may stem from a variety of sources. Major sources of nitrogen are human and animal wastes, certain industrial wastes and drainage of agriculture, pasture and wooded lands. The yield of nitrogen originating from four selected streams, tributary to Lake Ontario is discussed in this report and forecasting equations based on streamflow and/or other independent variables are developed. The region, which for the purpose of this report is named Eastern Lake Ontario Region, is drained by the Moira, Salmon and Napanee rivers and Wilton Creek (Figure 1). The selected watersheds contain primarily forest and pasture land and have essentially similar socio-economic, physical and climatological features. The nutrient data used for this analysis was obtained by the Ontario Water Resources Commission as part of a regular water quality monitoring program of lakes and streams in the Province of Ontario.

DESCRIPTION OF REGION

The general physiography, population distribution and the location of waste treatment plants and industry in the region are shown in the Figures 1, 2 and 3. A detailed description of the above items in the region has been presented in the paper on phosphorous.[1] However, Table 1 presents the summary dealing with land use, population, industry and waste discharges. Industrial and urban development is small and as this analysis shows, represents an insignificant proportion of the total discharge of nitrogen from the watershed to Lake Ontario. Forest and pasture lands are by far the most predominant land uses in the area of the four watersheds. Napanee is the only municipality served by a water pollution control plant.

METHODS OF ANALYSIS OF NITROGEN DATA

Water quality data were collected at the mouth of all four streams on a monthly or bi-monthly basis during the study period (October 1964 to September 1967). Average daily stream flows were obtained for the days of sampling from hydrologic data collected by the Canada Department of Energy, Mines and Resources. Where stream flow gauges were not located close to the stream sampling point, the nearest stream gauge was selected. On an average about twenty-four samples were collected at each stream during the study period. The samples were collected on random days and therefore represent a random series.

Sample analysis included organic nitrogen or total Kjeldahl and free ammonia, nitrogen and inorganic nitrogen or nitrate and nitrite. All results are expressed as N. In Table 2 the yearly nitrogen yields based on mean annual concentration and mean annual flow is presented. The mean values are based on the number of available samples each year. Figures 4, 5, 6 and 7 show the variation in total nitrogen concentration levels on the sampling days as well as the variation of flows (ft^3/mi^2-day) and yield (lbs/mi^2-day) for the four streams. Actual date of the sample could not be shown because of the small scale, however, the months for the samples are indicated by the values plotted during the month. These figures indicate the relationship between any of the three variables - concentration, flow, and yield.

In Figure 8, the mean monthly yields (yield/mi^2-month) were plotted based on three years of record, for the four streams. Mean monthly yields (lbs/month) were based on the monthly mean concentration and the monthly mean flow (ft^3/day) over the three year study period and then converted to yield/mi^2-month.

Figure 9 shows the range between yearly maximum and minimum concentration for the four streams during the three year study period together with yearly averages. The yearly maximum and minimum yields (lbs/day) have been plotted together in Figure 10.

DISCUSSION

Not much is known about the yield of fertilizing substances to surface waters both from productive and non-productive agriculture, forested and pasture areas. Some important work has been done by some researchers on sources of phosphorous for which reference was made in the earlier paper. However, not much information is available on nitrogen contributions. Sawyer[2] in his report of Madison, Wisconsin (1947) showed the contribution of about 4,500 lbs of nitrogen/mi^2-year from Madison area. Sylvester[3] (1961) showed from the study of two streams draining forested areas of Oregon the mean value of 1,360 lbs/mi^2-year. Neil, Johnson and Owen[4] (1966) showed the mean yield of the four rural streams in order of 3,200 lbs/mi^2-year while the mean from two urban areas was 34,000 lbs/mi^2-year. The yield of four streams in the region investigated here, on an average is 1,967 lbs/mi^2-year which primarily drains the forested and pasture areas.

Neil, Johnson and Owen in 1966 showed a relationship between yield of nitrogen (lbs/mi^2-day) and flows (ft^3/mi^2-day). According to the above authors the relationship was statistically significant and they developed an equation which allowed forecasting nitrogen yield for streams in the same neighbourhood. However, as mentioned in the earlier report[1], this relationship was not based on independent variables. The yield which is multiple of two independent variables (concentration and flow) includes the effect of each variable, therefore any relationship developed between the yield and the individual variable will not be statistically correct.

Figures 4 to 7 show the variation of total nitrogen (mg/l) during the study period. In some months fluctuation is quite apparent. However, no cyclic trend was noticed in the nitrogen concentration curve. In general the rise and fall in concentration did not associate with changes in flow (ft^3/mi^2-day). This was verified by calculating the coefficient of correlation between the two variables. The calculated values of these coefficients, together with the required critical values for coefficient of correlation at 5 per cent level of significance, are shown in Table 3 for all four streams. The non-existence of this relationship indicates that streamflow is not an important factor for forecasting the nitrogen concentrations in these four streams. However, for obvious reasons the curve of yield follows the same pattern as that of flow.

Mean monthly yield (lbs/mi^2-month) of nitrogen, Figure 8, shows the seasonal variation for each watershed. All the four watersheds show great variations in nitrogen yields between periods of high and low stream flows. The seasonal yield of nitrogen from these streams follows generally the same pattern as that found for phosphorous on the same watersheds. During February, March and April the total amount of nitrogen discharge from the four streams ranged between 45-57 per cent while in the case of phosphorous 40 to 50 per cent.

The yield of nitrogen in the four streams was higher than phosphorous. The ratio of nitrogen and phosphorous (N:P) based on the summation of monthly yields is on an average about 8 to 1. Other researchers[4,5] have made similar observations. (Because of the absence of discharges from urban sewage treatment plants there does not seem to be much higher production of nutrients, with the result that the algae growth may not be a serious problem at present.) According to Neil, Johnson and Owen[4] (1966) an N:P ratio of 18 to 1 is required for the production of cladophora. Similarly, Phinney and Peek[5] (1960) found an N:P ratio of 16 to 1 essential for the growth of planktonic species from Klamath Lake.

From these results and the knowledge that land use in the four streams is predominantly forest and grazing it can be apparently concluded that drainage from forest and grazing land does not provide a source of nutrients which would promote excessive algae growth. The seasonal variation of yield may have some effect on the ecological development of lakes which require extensive investigation.

The bar diagrams in Figures 9 and 10 show the maximum, minimum and average values of total nitrogen for the three year study period (1964-67). While the available data do not allow to comment on developing trends at this time, as more data becomes available long term variations of yields and concentration could be predicted.

An attempt was made to correlate the concentration with temperature (C^{o}) of the sample water, the dissolved oxygen (D.O.) (mg/1) in the sample and the flow (ft^{3}/mi^{2}-day). Using the stepwise regression technique the effect of each variable as it was included in the forecasting equation became apparent. However, no significant statistical relationship was found, and the equations are therefore not included in this report.

The equation obtained from the multiple regression analysis relating major land uses to nitrogen yields is shown in the Table 3. The major land uses for this region are forest, horticulture, pasture, grazing land, and urban areas. A significant relationship seems to exist between the nitrogen concentration in the four streams, and the horticulture and urban areas in the four watersheds. However, as there were only four streams, the number of cases for multiple regression analysis for land use were limited to four. In addition, the number of observations were less than the independent variables (different land uses and flow) and therefore after the addition of two independent variations the stepwise regression analysis was terminated. The addition beyond two variables would have given negative values which are meaningless. Although multiple correlation coefficient $R = .992$ calculated seems to be high yet it is below the critical $R_C =$ .997 required at a 5 per cent level of significance. Thus it is concluded that with the data used, no relationship was found between land uses and nitrogen yield and that the established forecasting equation cannot produce reliable results. The same holds true for other equations for the four streams (Table 3).

SUMMARY AND CONCLUSIONS

In this investigation, no statistically significant relationship was found to exist between level of concentration and stream flow. For all the four streams, the coefficient of correlation, which is an indication of the relationship, was very low. The yield however does depend on the fluctuations of flows because the total yield does incorporate within itself the effect of flows (and so is no more random variable to correlate with flows.) Pronounced seasonal variations were noted in the yields of nitrogen from wooded and grazing land areas. About 45 to 57 per cent of the annual yield occurs in February, March and April. Therefore more regular sampling should be done during winter and spring months.

The use of ratio direct or inverse in regression model is full of hazards, therefore is not recommended for use. As more data is available the relation between concentration and land use may be developed, but at present, because of the lack of data, this could not be verified conclusively. However, applying the stepwise regression technique, there is some indication of a relationship with some selected land uses.

The annual yield of nitrogen calculated by summing up monthly yield from the four watersheds is 1580 lbs/mi^2-year for Moira River, 1315 lbs/mi^2-year for Salmon River, 2028 lbs/mi^2-year for Napanee River and 2010 lbs/mi^2-year for Wilton Creek. The high Napanee River yield is probably the result of waste effluents from the Town of Napanee entering the river above the monitoring station. But Wilton Creek seems to be high because of estimated monthly flows. In general the values are less than found by Neil, Johnson and Owen[4] for rural areas. However these are in the same range as found by Sylvester[3] in his study of two streams draining forest areas in Oregon.

The analysis presented here could in general be used on other water quality monitoring data. But in order to obtain statistically significant results, water quality data for longer periods should be available. For the case studied in this report, additional data would be required to increase the reliability of the findings.

TABLE 1. CHARACTERISTICS OF FOUR SELECTED WATERSHEDS IN EASTERN LAKE ONTARIO REGION

Watersheds	Area (sq.mi.)	Estimated Pop. Rural	Urban	Major Land Use (sq.mi.)	No. of Industries	Municipal Treatment Plants	Mean Streamflows (cu. ft./day) During Study Pd.
Moira River	1,040	10,000	3,600	Urban 9.1 Woodland 693 Pasture & Forage Land 261.6	10	3	85102.6
Salmon River	344	10,000	-	Urban 3.68 Woodland 203 Pasture & Forage Land 112.34	0	0	28624.9
Napanee River	300	11,000	7,600	Urban 3 Woodland 165 Pasture & Forage Land 129.7	1	2	24935.0
Wilton Creek	43.4	3,000	-	Urban .5 Woodland 10.9 Pasture & Forage Land 38.1	0	0	3647.4

TABLE 2. MEAN CONCENTRATION LEVEL, MEAN FLOW AND ANNUAL YIELD OF NITROGEN FROM FOUR WATERSHEDS IN THE EASTERN LAKE ONTARIO REGION

	Mean Concentration (mg/l)			Mean Flow (cfs/m^2)			Avg. Annual Yield (lbs/m^2-yr)		
	1964-65	1965-66	1966-67	1964-65	1965-66	1966-67	1964-65	1965-66	1966-67
Moira River	.8	1.194	.81	.7165	1.048	1.077	1129.8	2466.3	1719.3
Salmon River	1.02	1.01	.72	.7994	1.052	1.038	1606.9	2094.2	1472.9
Napanee River	1.46	1.54	1.25	.786	1.073	1.027	2261.7	3256.9	2643.5
Wilton Creek	.93	.74	.94	.7823	1.099	1.037	1433.3	1602.8	1921.1

TABLE 3. COEFFICIENT OF CORRELATION BETWEEN TOT. NITROGEN CONCENTRATION (mg/l), y, AND FLOW (ft^3/m^2-day), x, FOR FOUR WATERSHEDS IN THE EASTERN LAKE ONTARIO REGION

Watershed	Estimating Equation	Computed Correlation Coefficient (r)	Critical Value of r at 5% Level of Significance Req'd
Moira River	$y = .934 - .0497x$	.091	.396
Salmon River	$y = .912 - .083x$	.187	.361
Napanee River	$y = 1.406 - .148x$	.292	.361
Wilton Creek	$y = .739 + .116x$	.216	.404
Whole Region	$y = -.239 + .289x_1 + .745x_2$	.992	.997

where y is Total Nitrogen
x_1 is urban, and
x_2 is Horticulture areas

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(3) Sylvester, R. O. 1961. "Nutrient Content of Drainage Water from Forested, Urban and Agricultural Areas". Algae and Metropolitan Wastes, U. S. Public Health Service, SEC TR, W61-3: 74-79.

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(5) Phinney, H. K. and Peek, C. A. 1960. "Kalamath Lake, An Instance of Natural Enrichment". Algae and Metropolitan Wastes, U. S. Public Health Service, SEC TRW 61-3.

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(1) Chapman, L. J. and D. F. Putman. 1951. "The Physiography of Southern Ontario". Univ. of Toronto Press, Toronto. 284p.

(2) Engelbrecht, R. S. and J. J. Morgan. 1959. "Studies on the Occurrence and Degradation of Condensed Phosphate in Surface Water". Sewage and Industrial Wastes 31: 450-478.

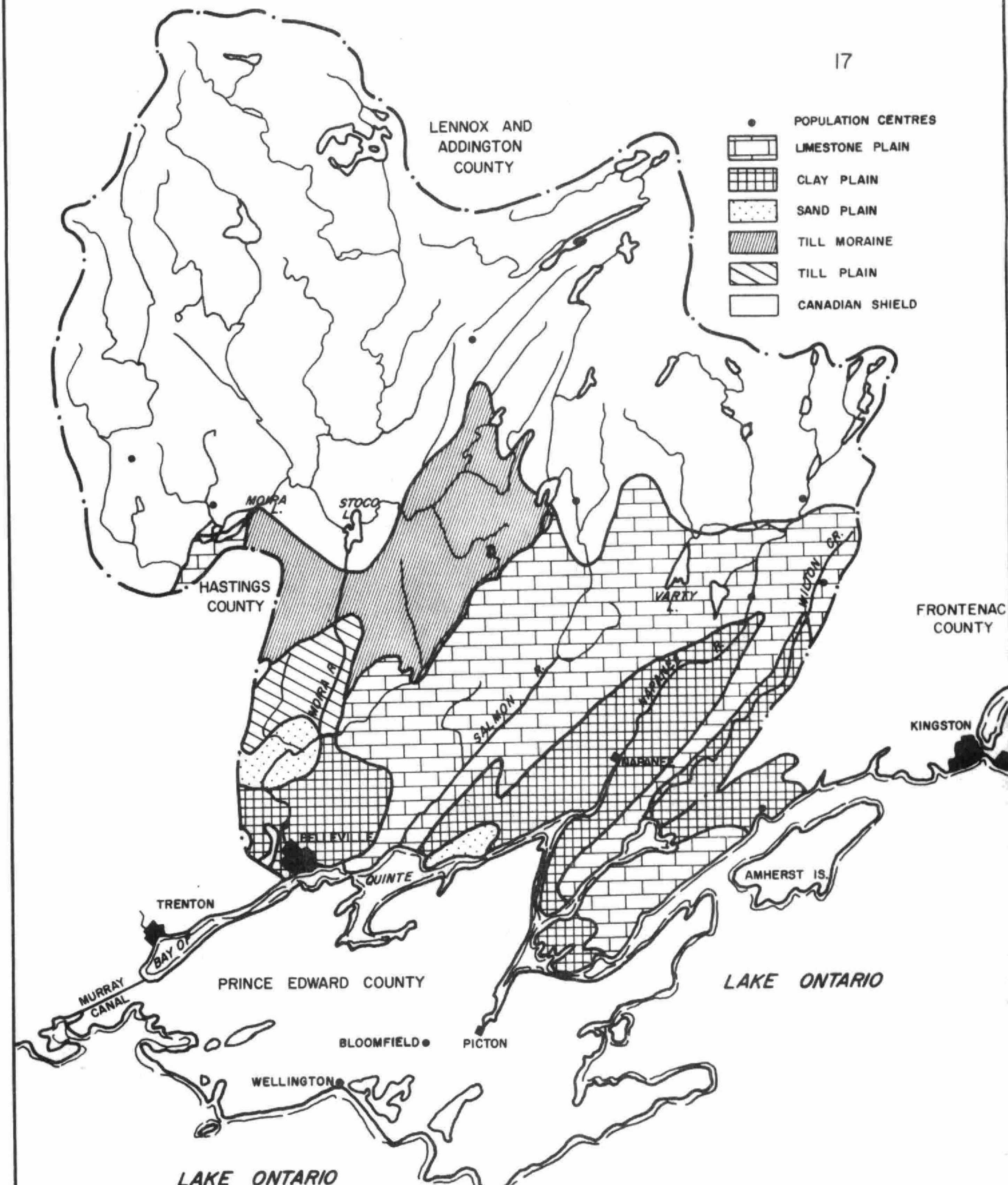

FIG. 1

PHYSIOGRAPHIC REGIONS

8 6 4 2 0 8

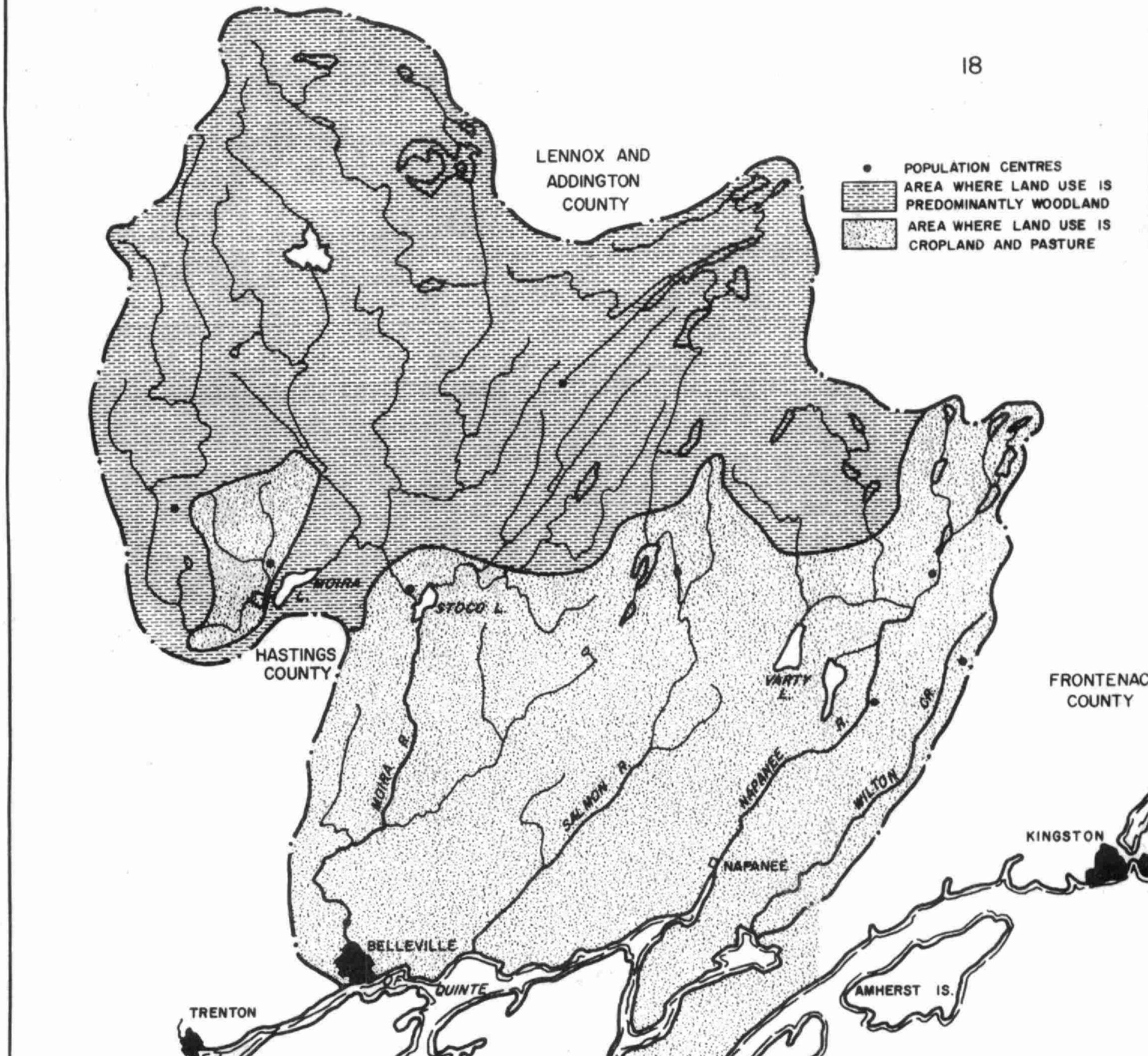

FIG. 2

LAND USE

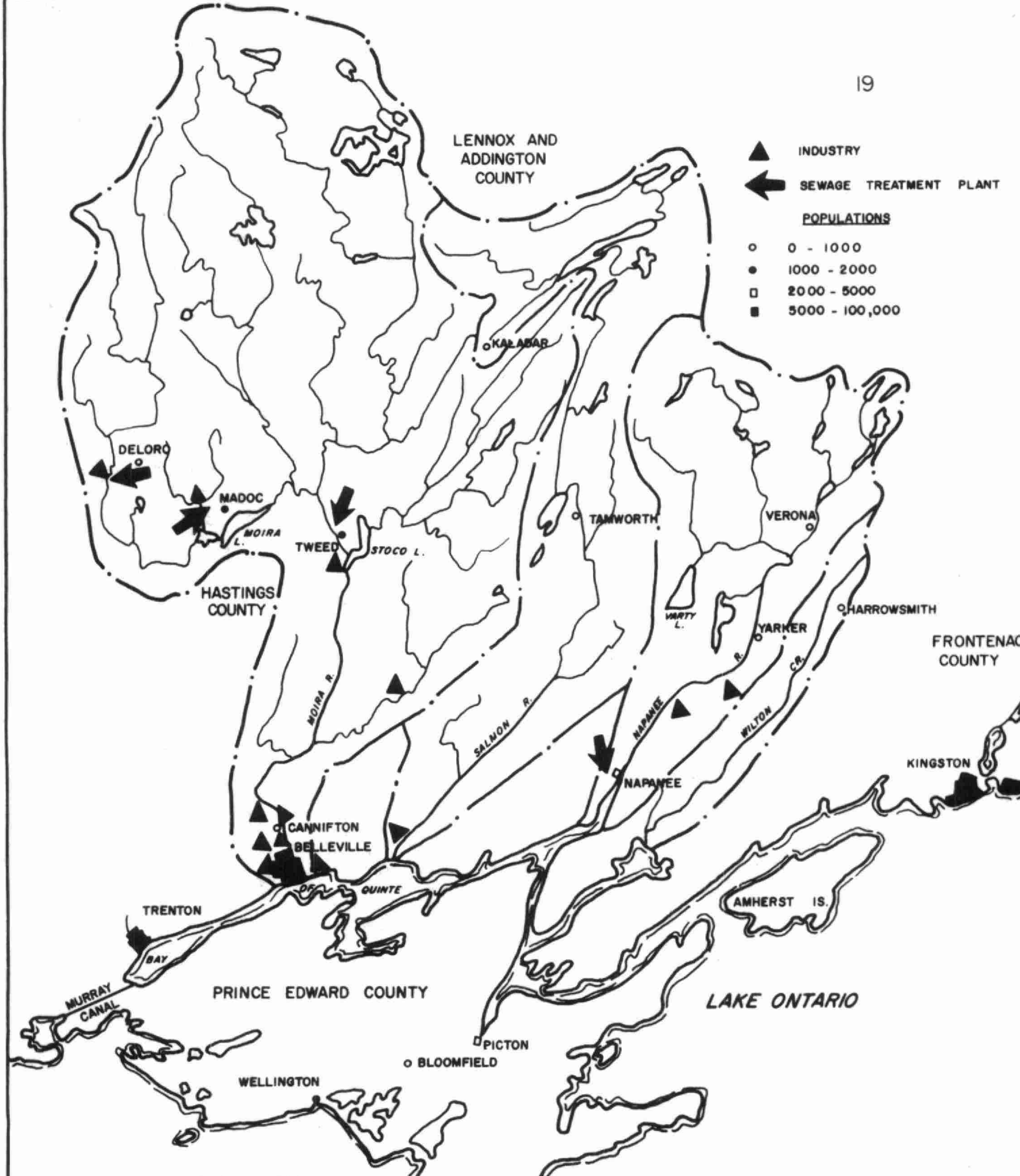

FIG. 3

INDUSTRIES, SEWAGE TREATMENT PLANTS, CENTRES OF POPULATION

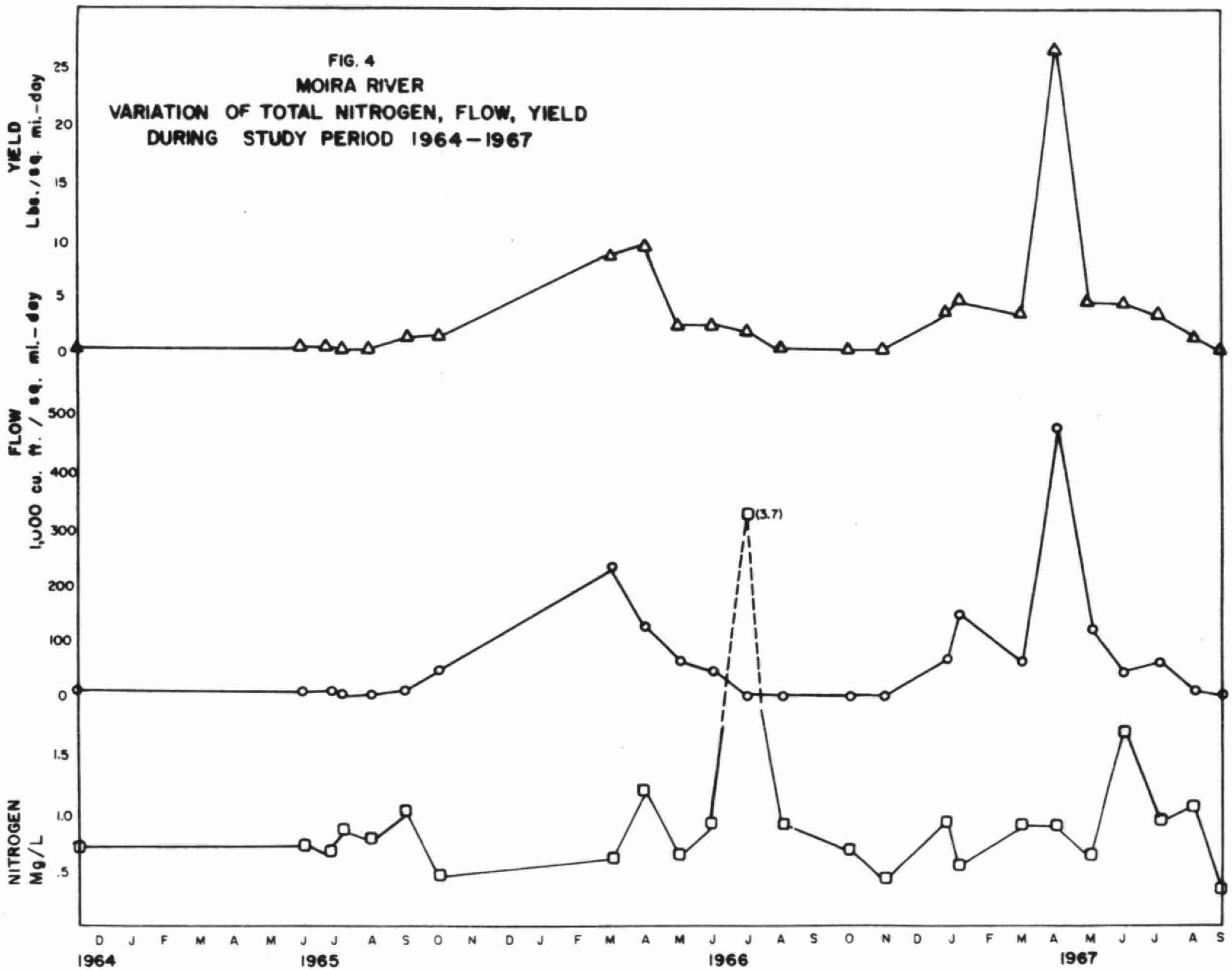
FIG. 4
MOIRA RIVER
VARIATION OF TOTAL NITROGEN, FLOW, YIELD
DURING STUDY PERIOD 1964-1967
YIELD
Lbs./sq. mi.-day
FLOW
1,000 cu. ft. / sq. mi.-day
NITROGEN
Mg/L
(3.7)
1964
1965
1966
1967

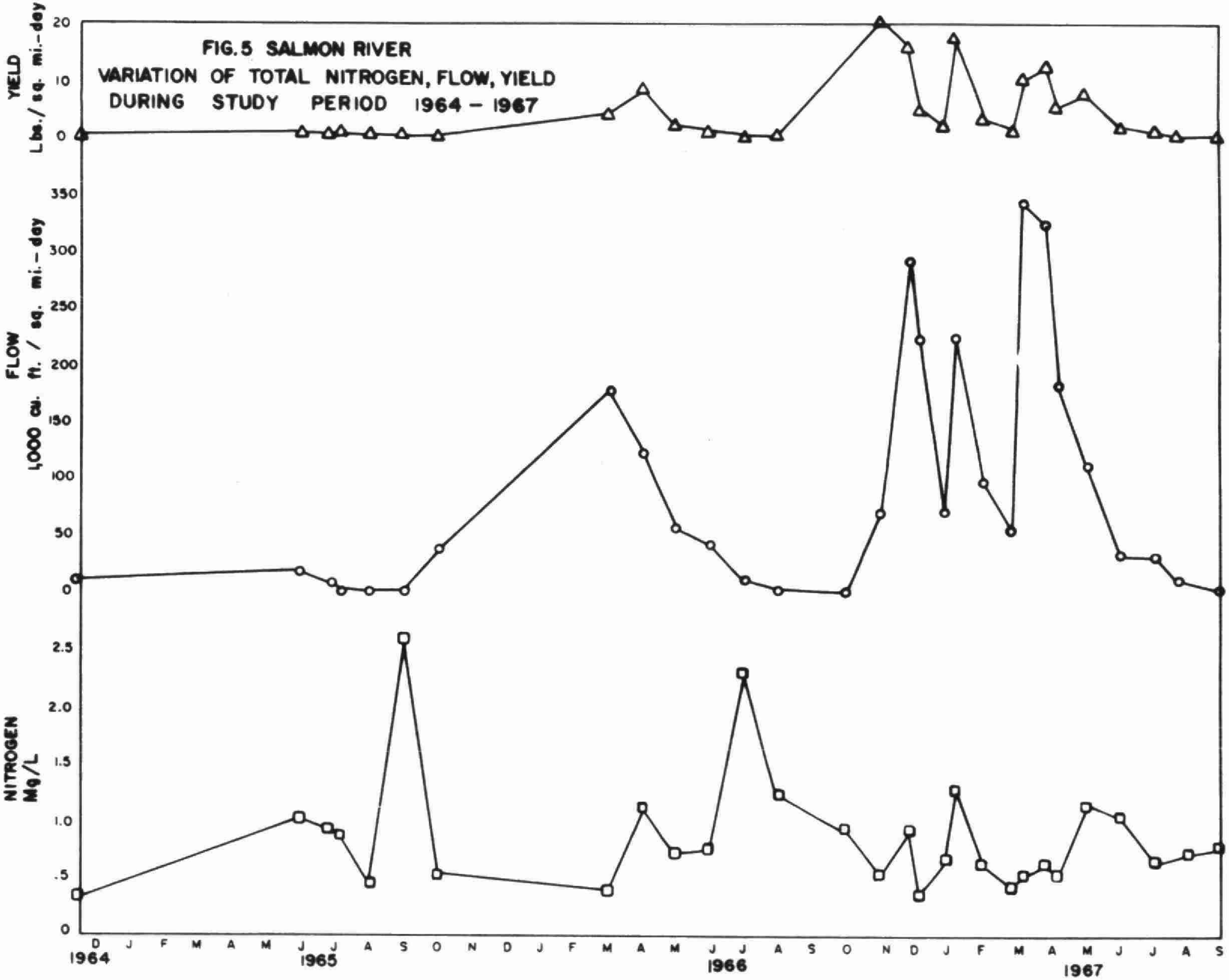
FIG. 5 SALMON RIVER
VARIATION OF TOTAL NITROGEN, FLOW, YIELD DURING STUDY PERIOD 1964 – 1967
YIELD Lbs./sq. mi.-day
FLOW 1,000 cu. ft. / sq. mi.-day
NITROGEN Mg/L
D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
1964
1965
1966
1967

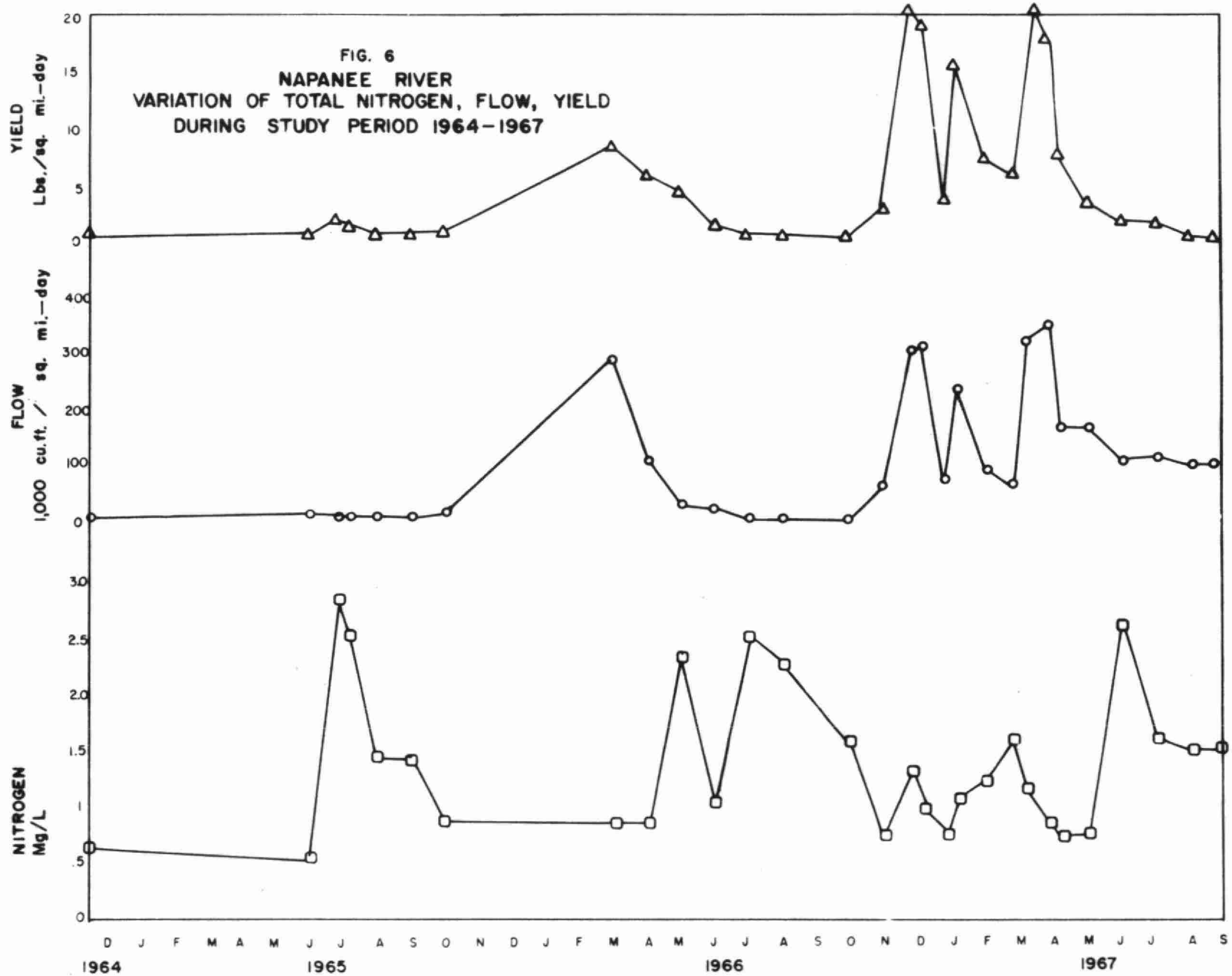
FIG. 6
NAPANEE RIVER
VARIATION OF TOTAL NITROGEN, FLOW, YIELD
DURING STUDY PERIOD 1964-1967
YIELD
Lbs./sq. mi.-day
FLOW
1,000 cu.ft. / sq. mi.-day
NITROGEN
Mg/L
D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
1964
1965
1966
1967

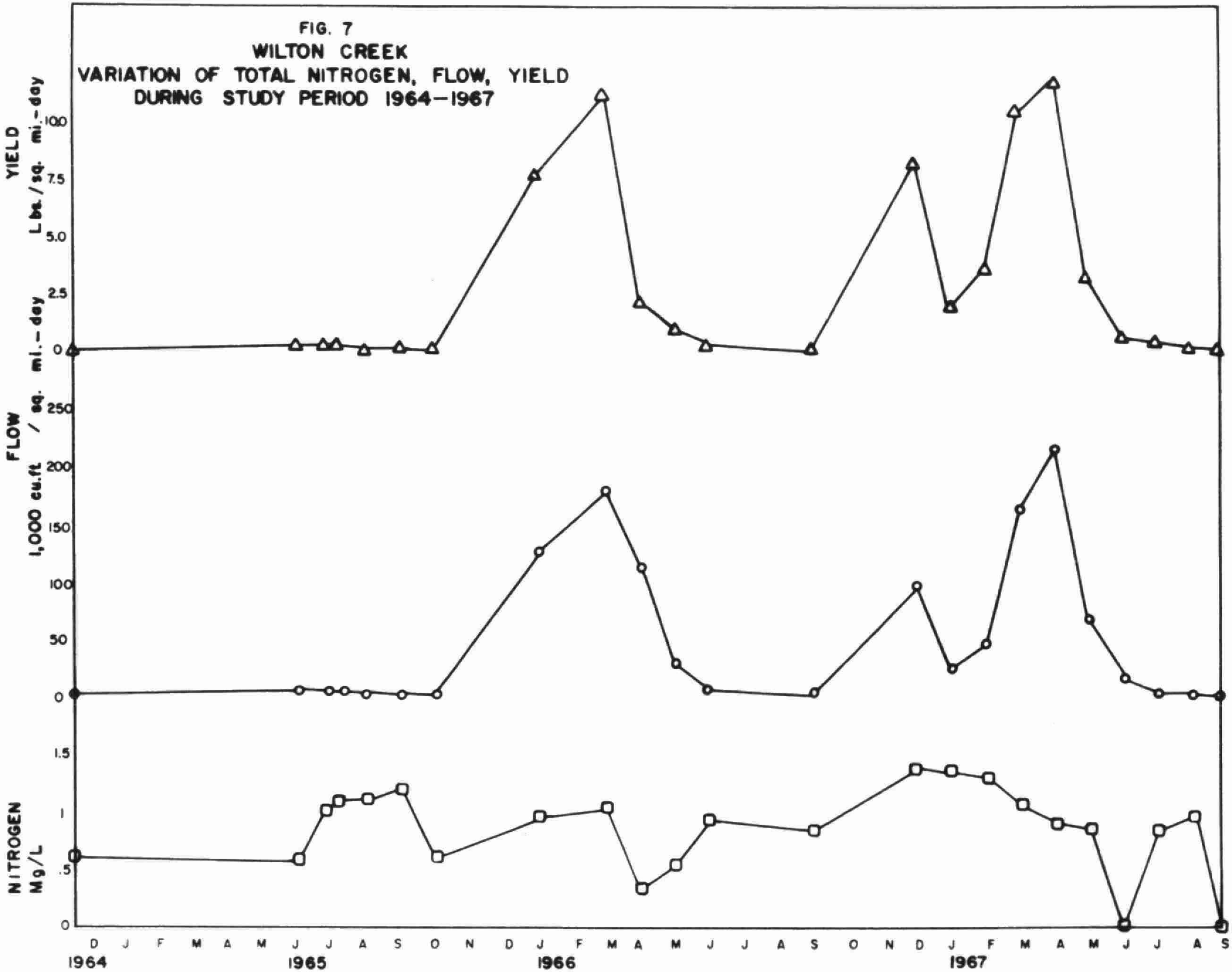

FIG. 7
WILTON CREEK
VARIATION OF TOTAL NITROGEN, FLOW, YIELD
DURING STUDY PERIOD 1964–1967

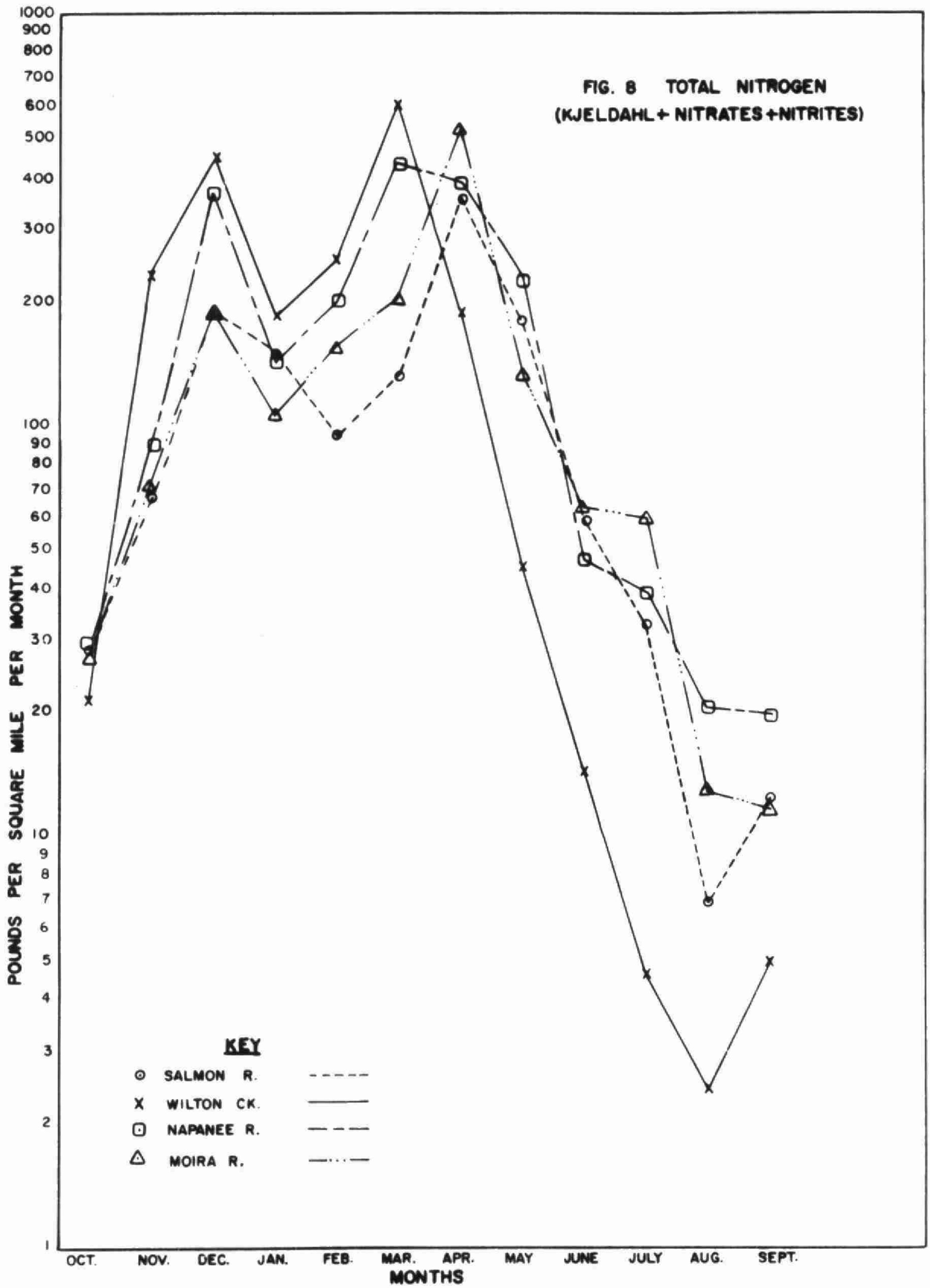
FIG. 8 TOTAL NITROGEN
(KJELDAHL + NITRATES + NITRITES)
POUNDS PER SQUARE MILE PER MONTH
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
MONTHS
KEY
SALMON R.
WILTON CK.
NAPANEE R.
MOIRA R.

FIG. 9

YEARLY MAXIMUM, MINIMUM, AVERAGE CONCENTRATION OF TOTAL NITROGEN 1964 - 67

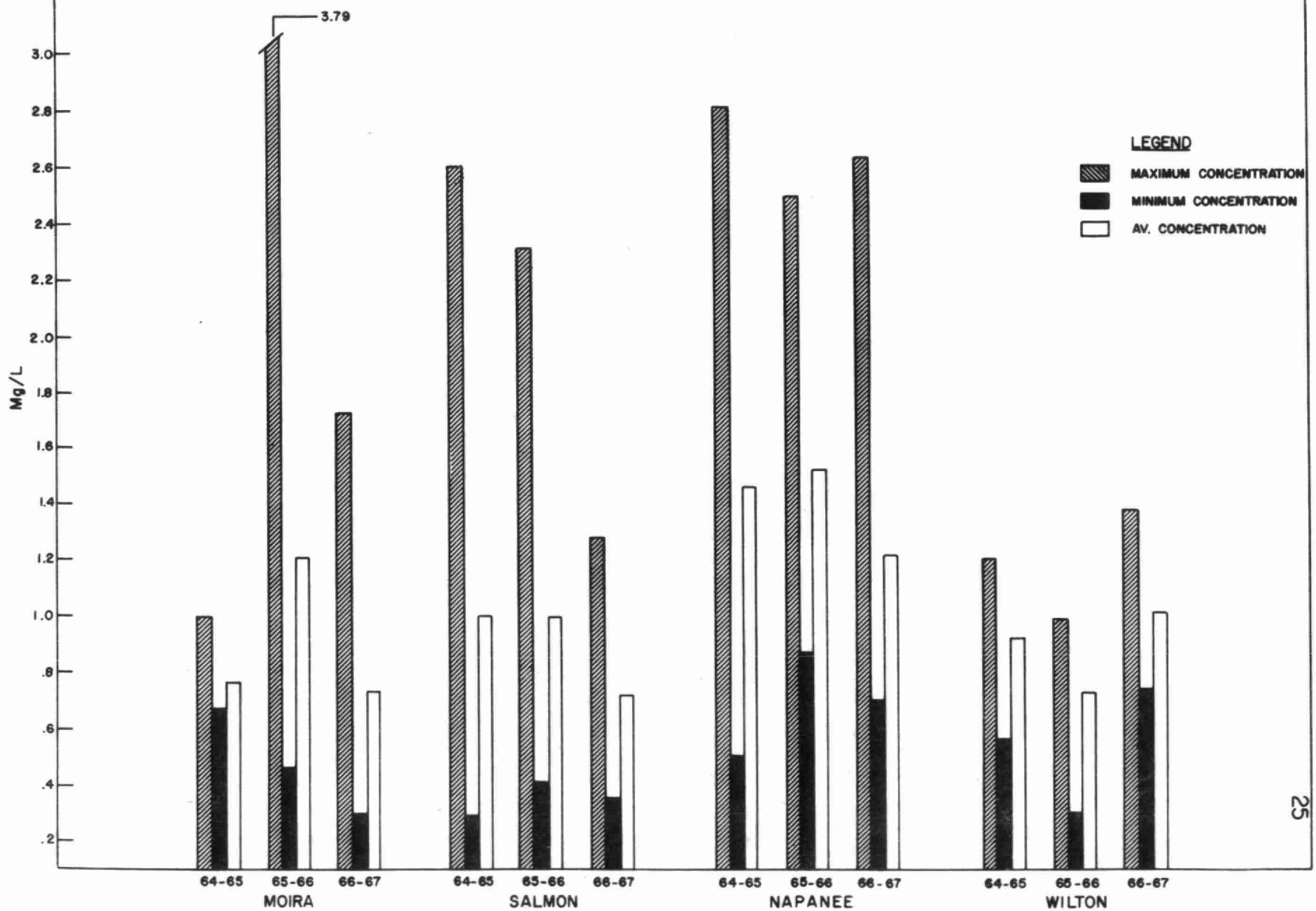

FIG. 10

YEARLY MAXIMUM, MINIMUM YIELD OF TOTAL NITROGEN 1964-67