

NITROGEN LOADS AND
CONCENTRATIONS IN
FLORIDA STREAMSBy
Larry J. Slack and Donald A. GoolsbyPrepared in cooperation with the
BUREAU OF WATER RESOURCES MANAGEMENT
FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION
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INTRODUCTION

Nitrogen is a fundamental component of all biological systems and, like phosphorus, carbon, and numerous other elements, is a nutrient that is essential for the growth of both terrestrial and aquatic plants. Inorganic nitrogen compounds in high concentration in water can stimulate undesirable plant growth, including algal blooms, increase the rate of eutrophication of lakes, and result in a general deterioration in water quality. Knowledge of the occurrence and distribution of nitrogen compounds is essential so that water management and regulatory agencies can understand the water-quality aspects of Florida streams. This report pictorially presents information on the generalized distribution, nature, and significance of nitrogen concentrations and the loads of nitrogen discharged annually by major Florida streams.

SOURCES AND SIGNIFICANCE OF NITROGEN FORMS

The nitrogen cycle (fig. 1) is a complex biochemical phenomenon in a constant state of interaction. About 34,500 tons of atmospheric nitrogen exist over each acre of land surface throughout the world (Task Group Report, 1967). The upper 0.5 foot of most soils in the United States contains an average of about 1.5 tons of total nitrogen per acre (Task Group Report, 1967). Atmospheric nitrogen (primarily N₂) and terrestrial nitrogen (primarily stable organic nitrogen or complex compounds) are major natural sources of the nitrogen in surface water.

Nitrate (NO₃⁻) is usually the form of inorganic nitrogen most prevalent in uncontaminated water because it is the end product of the aerobic decomposition of organic nitrogen. Concentrations of nitrate are seldom high in natural surface waters because it is constantly being converted to organic nitrogen by photosynthesis. Nitrate may occur in high concentrations in contaminated water that has undergone self-purification or aerobic treatment processes. High concentrations of nitrate may also result from excessive water containing high concentrations of nitrate nitrogen, the Environmental Protection Agency (National Academy of Sciences and National Academy of Engineering, 1973) recommends that the nitrate (expressed as nitrogen) concentration in public water supply sources not exceed 10 mg/l (milligrams per liter).

Ammonia nitrogen refers to the total of NH₄⁺, NH₃, and NH₂⁺. Most ammonia occurs as the ion NH₄⁺. Ammonia is produced by the decomposition of organic nitrogen compounds and by nitrogen fixation.

Ammonia (in the form of ammonium salts) is a major component of nitrogen fertilizer, but owing to the rapid conversion of ammonia to nitrate, little of the applied ammonia remains in its original form. The presence of more than 0.1 mg/l of ammonia in water sometimes is an indication of organic pollution (Rudolph, 1931). Although an ammonia concentration of 0.3 mg/l causes a noticeable drop in the oxygen content of the blood of fish, a concentration of 1.5 mg/l is not harmful to most varieties of fish (McKee and Wolf, 1963). According to Brezonik (1972), algae derive most of their nitrogen from ammonia, often in spite of higher nitrate concentrations in the water.

Domestic wastes usually contain about 8 to 12 pounds of total nitrogen per capita per year (Task Group Report, 1967). In general, about 20-50 percent of the total nitrogen in domestic waste is removed by treatment and about half of the organic nitrogen in domestic wastes can be enzymatically hydrolyzed to ammonia by the time the wastes leave the treatment plant. Based on a removal of about 30 percent of the total nitrogen and an average waste flow of 100 gallons per day per capita, treatment-plant effluent would contain 18-28 mg/l total nitrogen.

The Environmental Protection Agency (National Academy of Sciences and National Academy of Engineering, 1973) recommended that ammonia nitrogen in public water supply sources not exceed 0.5 mg/l "because ammonia may be indicative of pollution and because of its significant effect on chlorination."

Nitrite (NO₂⁻) is an unstable intermediate product generally formed by the action of bacteria upon ammonia and organic nitrogen and is readily oxidized to nitrate. Nitrite is also an intermediate form in the ammonification of nitrate. Nitrite in water sometimes indicates organic contamination. The Environmental Protection Agency recommended limit for nitrite nitrogen for public supply sources is 1.0 mg/l (National Academy of Sciences and National Academy of Engineering, 1973).

Organic nitrogen includes all nitrogenous organic compounds, chiefly amino acids, polypeptides, and proteins. Because of the natural inflow of nitrogenous products by overland flow and normal biological activity, organic nitrogen is present in all surface waters. Concentrations of organic nitrogen often are high in municipal and industrial effluents. Organic nitrogen generally is not pathologically significant, but is important in aquatic biological activity because of its potential as a source of nitrogen for both plant and animal life. Organic nitrogen is sometimes an indicator of pollution also.

Total nitrogen is the sum of the four individual nitrogen species. Its value is important because of the cycling and interrelations among the various species of nitrogen. A knowledge of total nitrogen concentrations is necessary for making mass balance studies, for determining nitrogen loads discharged by streams, and in understanding the sources of nitrogen. According to McKee and Wolf (1963), the enormous growth of plants in streams and lakes, so common where the water bodies have become contaminated, does not occur where the total nitrogen concentration is below 0.6 mg/l.

METHODS OF ANALYSIS

Approximately 4,000 nitrogen analyses from 204 stations were used in the preparation of this report. These data were collected by the U.S. Geological Survey in cooperation with numerous state, local, and federal agencies. Most data used in this report were collected between October 1971 and May 1975. For a few sites the data-collection period extended back to October 1968. Total nitrogen loads were computed for 86 stations where streamflow data were available. Loads were computed from the following relationship:

$$\text{Total Nitrogen Load (ton/yr)} = \frac{\text{Average Concentration (mg/l)} \times \text{Average Annual Flow (ft}^3\text{/s)} \times 0.0027 \times 365}{\text{No. of days/yr}}$$

As a check on the validity of this approach, annual loads for a few selected stations were also computed from a linear regression analysis for streamflow versus total nitrogen loads. Results from the two approaches compared favorably (table 1). Basin loads were prorated on the basis of drainage area size.

NITROGEN CONCENTRATIONS

The distribution and concentration of total nitrogen in Florida surface waters is shown on the large map. The interpretations in this atlas are based on data for the 204 stations mentioned in the previous section and the interpretive reports listed in the Selected References. As data are limited over much of the state, regional concentration patterns are of necessity generalized and local variations may be expected.

The concentrations of total nitrogen are generally lowest in northwest Florida streams and highest in central and southern Florida. This is due, at least in part, to differences in total nitrogen concentrations in bulk precipitation in the two areas. Average concentrations of total nitrogen in rainwater and bulk precipitation at various locations are compared in table 2. The average concentration of total nitrogen in south Florida is 0.90 mg/l (Joyner, 1974). This exceeds the average concentration of total nitrogen in most of the surface waters of northwest Florida. Brezonik (1972) points out that total nitrogen concentrations in rainfall exhibit such large temporal and areal variability as to render mean values meaningless for simple predictive models. Waller (1975), reports that for the conservation areas of south Florida, bulk precipitation was the single largest source of total nitrogen. It contributed 78 percent of the total nitrogen that entered those areas.

Streams with the highest total nitrogen concentrations are those that receive industrial waste (such as Elevenmile, Swift, and Hunter Creeks and the Fenholloway River (numbers 30, 31, 32, and 33, respectively, on the map), those that receive drainage from heavily fertilized areas (such as Magnolia Creek (34)), or those that receive domestic sewage effluent (such as the Econlockhatchee River (35) and Plantation Road Canal (36)).

Organic nitrogen is the dominant species at practically all the surface-water stations throughout the state. The major exceptions to this are found at the stations described in the previous paragraph. In Magnolia Creek the dominant nitrogen species is nitrate and in the Econlockhatchee River, Plantation Road Canal, Swift and Hunter Creeks the dominant species is ammonia.

The average nitrate-nitrogen concentration is less than 1.0 mg/l at 196 of the 204 stations for which data are utilized for this report. The maximum average nitrate-nitrogen concentration is 4.1 mg/l, on Magnolia Creek (34), which drains an area in which fertilizers are heavily used.

The average nitrite-nitrogen concentration is highest, 0.67 mg/l, at Elevenmile Creek (30), which receives industrial waste. At only 6 of the stations is the average nitrite-nitrogen concentration greater than 0.10 mg/l.

The average ammonia-nitrogen concentration is less than 0.50 mg/l at 190 of the stations. Except for 2 stations within the Everglades, all the stations with ammonia-nitrogen concentrations greater than 0.50 mg/l receive industrial, municipal, or agricultural wastes.

The average organic-nitrogen concentration is less than 1.0 mg/l at 106 of the stations. It is highest, (5.0 mg/l), at Lake Apopka (37).

Concentration of total nitrogen is generally independent of discharge, unlike many chemical constituents which show an inverse relation between concentration and discharge. Moreover, the concentration of total nitrogen does not appear to vary seasonally for all sites, that is, concentrations at some sites may be low in a given season one year, and high for the same season the next year.

NITROGEN LOADS

Total nitrogen load depends more on the volume of water than on the concentration of nitrogen in the water inasmuch as the flow volume fluctuates over a much greater range than does the concentration of nitrogen (table 3, fig. 2). Consequently, the load is greatest for the largest streams in the State.

Total nitrogen loads generally vary directly with drainage area. A plot of nitrogen loads versus drainage area (fig. 3) indicates that 1 ton of nitrogen per square mile per year is a reasonable order of magnitude estimate for nitrogen yields. Stream waters with nitrogen yields greatly exceeding 1 ton per square mile per year usually receive industrial, municipal, or agricultural effluents. The following are notable examples:

- (35) Econlockhatchee River near Chuluota (4.6 tons)
 - (38) St. Johns River near Deland (1.8 tons)
 - (39) Apopka-Beauchar Canal near Astata (2.3 tons)
 - (40) Peace River at Arcadia (2.0 tons)
 - (41) Hillsborough River near Zephyrhills (2.1 tons)
 - (33) Fenholloway River at Foley (5.0 tons)
 - Stream waters with nitrogen yields much less than 1 ton per square mile per year generally have a low mean discharge to drainage area ratio. These include:
 - (44) Aucilla River at Lamont (0.5 ton)
 - (52) Withlacoochee River near Holder (0.42 ton)
 - (43) Oklawaha River at Rodman Dam, near Orange Springs (0.45 ton)
- Approximately 73,000 tons of nitrogen are discharged annually through Florida streams, springs, and canals. Of this amount about 21,000 tons are discharged to the Atlantic Ocean and 52,000 tons to the Gulf of Mexico.

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Table 1.—Comparison of annual nitrogen loads computed by two methods.
(Stations cited are shown on map by numbered solid circles.)

Map number ^a	Station name	Mean discharge (ft ³ /s)	Mean total nitrogen concentration (mg/l)	Nitrogen load (tons per year) (b)	Nitrogen load (tons per year) (c)
40	Peace River at Arcadia	1,212	2.3	2,700	2,300
43	Oklawaha River at Rodman Dam, near Orange Springs	1,210	.84	1,200	970
45	St. Marys River near Macclenny	689	0.76	520	—
46	St. Johns River near Coos	1,094	1.6	1,800	1,800
47	Oklawaha River at Moss Bluff	351	1.7	600	540
48	Fishheating Creek at Palmdale	265	1.5	400	430
49	Kissimmee River at S-60E, near Okeechobee	2,188	1.2	2,500	2,600
50	Snake Creek Canal at S-29, at North Miami Beach	391	1.6	620	620
51	Alafia River at Lithia	377	1.6	580	730
52	Withlacoochee River near Holder	763	.88	510	430
53	Suwannee River at Brandford	6,920	.89	6,100	5,900
54	Sophopy River near Sophopy	187	.70	130	150
55	Apalachicola River at Chattahoochee	22,190	.65	14,500	13,800
56	Chipola River near Altha	1,474	.79	1,100	1,100
57	Escambia River near Century	6,033	.52	3,100	2,900

^a Stations 30-37, 41, 42, 44, and 58 are discussed in text or shown on graph but not listed in this table because insufficient data exist to allow use of the regression method in computing loads.^b Computed from: Average concentration $\times$ Average discharge $\times$ 0.0027 $\times$ 365^c Computed from regression equation: Total N (tons/yr) = $c_1 Q^2 + c_2$, where Q is mean annual discharge, c and c₂ are coefficient and exponent terms derived by the computer for specific load-discharge relations which exist at mean discharge.Table 3.—Nitrogen loads and concentrations for major river basins in Florida.
(Stations cited are shown on map by numbered solid triangles.)

Map No.	River basin	Average discharge* (ft ³ /s)	Nitrogen load (tons per year)	Nitrogen yield (ton/yr/mi ²)	Average concentration (mg/l) based on most downstream station	NO ₃ -N	NH ₄ -N	Org-N	Total N
1	St. Marys	1,460	1,100	0.74	0.03	0.04	0.68	0.76	—
2	Oklawaha	1,210	1,200	.85	.02	.03	.59	.64	—
3	St. Johns	10,500	12,000	1.3	.04	.03	1.1	1.2	—
4	Kissimmee (at S-60E)	2,188	2,500	.85	.10	.06	1.0	1.2	—
5	St. Lucie Canal	1,106	960	.86	.06	.06	.72	.88	—
6	West Palm Beach Canal	435	2,100	—	.16	.10	1.7	2.1	—
7	Hillsboro Canal	339	510	—	.13	.18	1.2	1.5	—
8	North New River Canal	451	770	—	.25	.16	1.3	1.7	—
9	Miami Canal	312	510	—	.14	.28	1.2	1.6	—
10**	Tamiami Canal	1,300	1,800	—	.14	.10	1.5	1.8	—
11	Caloosahatchee Canal	1,722	2,000	—	.15	.04	.99	1.2	—
12	Peace River	2,100	4,800	2.0	.130	.07	.86	2.3	—
13	Myakka	610	940	1.7	.01	.05	1.5	1.6	—
14	Manatee	350	320	.91	.01	.04	.71	.91	—
15	Alafia	470	730	1.7	.67	.25	.54	1.6	—
16	Hillsborough	860	1,400	2.1	.96	.19	.52	1.7	—
17	Withlacoochee	2,100	1,000	.50	.06	.02	.60	.68	—
18	Suwannee	11,000	8,000	.80	.31	.03	.40	.75	—
19	Fenholloway	322	350	5.00	.00	.00	5.1	4.2	—
20	Aucilla	450	470	.49	.01	.03	1.0	1.0	—
21	St. Marks	1,100	500	.76	.24	.02	.23	.49	—
22	Ochlocknee	2,000	2,200	1.00	.42	.09	.82	1.2	—
23	Chipola	2,300	1,800	1.46	.35	.03	.40	.79	—
24	Apalachicola	25,200	17,000	.87	.21	.05	.37	.65	—
25	Chattahoochee	7,100	4,100	.88	.17	.04	.37	.59	—
26	Yellow	3,000	1,300	.95	.07	.03	.31	.41	—
27	Blackwater	1,300	580	.69	.04	.01	.42	.47	—
28	Escambia	6,700	3,400	.80	.10	.04	.37	.52	—
29	Panola	1,700	870	.94	.08	.02	.41	.51	—

*From Water resources data for Florida, Part 1, Surface water records, 1974.

**Refers to aggregate quantity of sheet flow perpendicular to Tamiami Canal as measured at four stations.

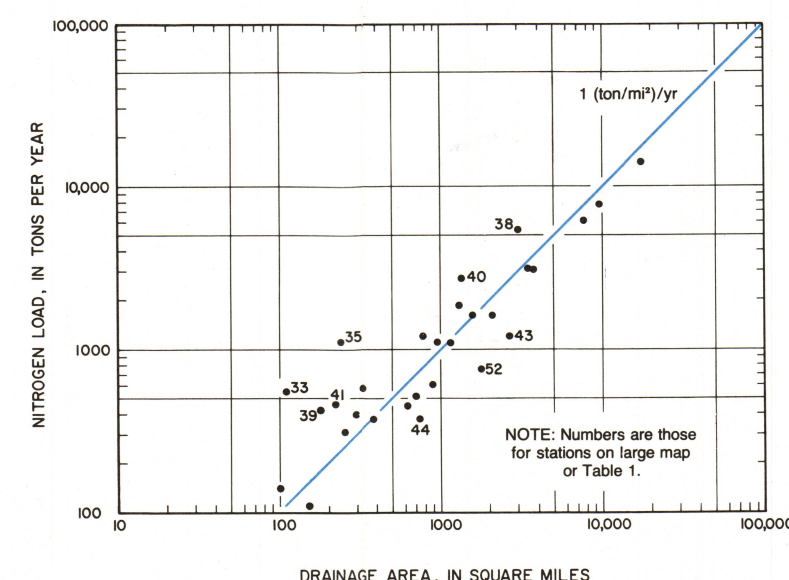


Figure 3.—Relation between yearly total nitrogen load and drainage area for selected stations.

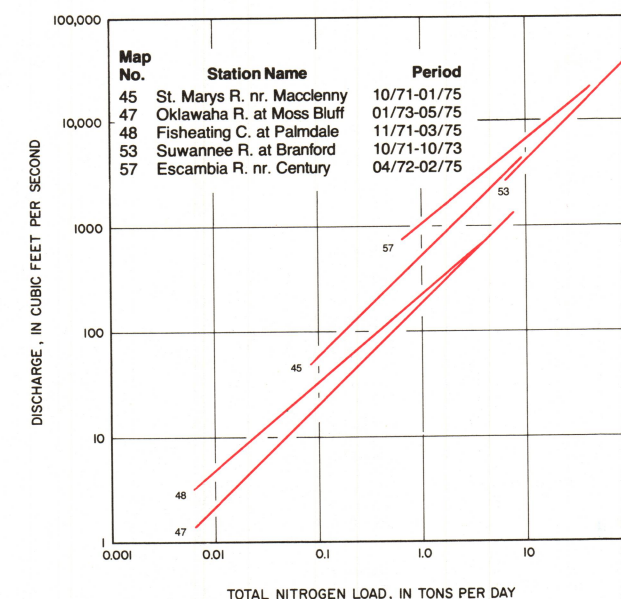


Figure 2.—Relation between total nitrogen load and discharge at selected stations.

EXPLANATION
TOTAL NITROGEN LOAD
(tons per year)

Less than 200	1,000 - 5,000
200 - 500	5,000 - 10,000
500 - 1,000	Greater than 10,000

49 Long-term nitrogen-data stations. Numbers are those referred to in text, Figure 3 or Table 1.
21 Mouth of river basin. Numbers are those referred to on Table 3.

AVERAGE TOTAL NITROGEN CONCENTRATIONS
(milligrams per litre)

Less than 0.60	0.60 - 1.20	1.20 - 2.40	Greater than 2.40
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Figure 1.—A simplified diagram of the nitrogen cycle.

0 10 20 30 40 50 MILES

Graphics by D. F. Tucker and J. A. Tomberlin