Little Arbor Vitae Lake near Woodruff, Wisconsin
Water-Quality Data Summary

This summary covers the period October 1991 to September 1996, which is the period of water-quality monitoring of Little Arbor Vitae Lake by the U.S. Geological Survey (USGS). Emphasis in this summary is on data collected during 1996. All data collected during 1996 is included. Data from previous years is included in graphs to illustrate changes or trends.

In reviewing the data, it may be helpful to refer to the methods and explanations of physical and chemical characteristics sections in the USGS annual lake data report "Water-Quality and Lake-Stage Data for Wisconsin Lakes, Water Year 1996" and to Shaw and others (1994) "Understanding Lake Data."

Lake description and sampling locations:

Little Arbor Vitae Lake is classified as a drainage lake, with one inlet and one outlet. The average depth of the lake is 11 feet, and the surface area is 534 acres (0.83 square miles). The water-quality sampling site is located at the deepest point in the lake at a depth of about 30 feet. Lake stage was monitored near the outlet, which is located on the southeastern side of the lake. The locations of the monitoring sites are shown in Figure 1.

Hydrologic conditions during water year 1996:

Annual variability in lake condition often reflects variability in climatic and hydrologic conditions. Air temperature in north central Wisconsin was, on the average, 4.0 °F cooler than normal for the period December 1995 through March 1996; April and May was 5.0 °F cooler than normal; and the period June through August was 0.8 °F cooler than normal (National Oceanic and Atmospheric Administration "Climatological Data--Wisconsin"). Precipitation during water year 1996 was 112 percent of normal precipitation for north central Wisconsin (Pamela Naber-Knox, UW-Extension, Geological and Natural History Survey, written commun., 1996). Watershed runoff in the region of Little Arbor Vitae Lake was between 120 and 140 percent of long-term average runoff (Holmstrom and others, 1997, "Water Resources Data--Wisconsin").

Lake Data for 1996:

The following summarizes some highlights of data given in the tables and shown in the figures.

Lake-stage fluctuations:

Lake stages were measured by Glyn A. Roberts intermittently, and by the USGS on sampling dates. The stages ranged from 7.80 feet on September 2 to 7.96 feet on August 5. This range of fluctuation is similar to the previous 5 years of monitoring. Stage values are listed in table 1.

Lake-depth profiles:

Vertical profiles of water temperature, dissolved oxygen, pH, and specific conductance exhibit a pattern that can be expected for a medium-depth lake. These profiles, which were measured over the deepest point in the lake, are listed in Table 2 and shown in Figure 2. Nearly complete water-column mixing was observed on May 16 at spring turnover sampling. Apparently slight thermal stratification had begun, as indicated by a 3 °C temperature difference between top and bottom water. The lake became thermally stratified through the summer and stratification was maintained better than during most recent summers when the lake has experienced intermittent mixing. In June the lower 7.5 feet of water were anoxic (devoid of oxygen), and by August the lower 15 feet were anoxic. The anoxic zone is unable to support fish. The pH, which ranged between 7.0 and 8.8, is common for northeast Wisconsin lakes and poses no problems for aquatic life.

Chemical constituents:

Analyses of water samples collected on May 16 for selected chemical constituents for chemical characterization of the lake are shown in Figure 2. Samples collected at 1.5 and 28-foot depths show slightly different constituent concentrations, as would be expected under slightly stratified water column conditions. The constituent values for color, chlorophyll a, chloride, calcium, magnesium, pH, alkalinity, total-nitrogen, and total-phosphorus are within regional values for this area as described by Lillie and Mason in "Limnological Characteristics of Wisconsin Lakes," 1983, Technical Bulletin No. 138, Department of Natural Resources.

The ratio of dissolved-nitrogen to dissolved-phosphorus was 25:1, based on the surface concentrations on May 16. This ratio suggests the lake is phosphorus limited, which means algal growth is dependent on the amount of available phosphorus rather than nitrogen.

Three common measures of water quality used as indices are concentrations of near-surface total-phosphorus and chlorophyll a, and Secchi depth. Total-phosphorus concentrations ranged from 0.023 mg/L on June 25 to 0.035 mg/L on May 16, chlorophyll a ranged from 15 µg/L on June 25 and July 26 to

43 µg/L on August 14, and Secchi depths ranged from 1 m on August 14 to 1.7 m on June 25. Surface total-phosphorus and chlorophyll a concentrations, and Secchi depths for the 1991-96 period are shown on Figure 3. No clear year-to-year changes in concentration are apparent in the data for the 6-year period. However, four of the six years exhibited a pattern of increasing surface phosphorus concentration through the summer months. Intermittent mixing of hypolimnetic and epilimnetic waters, which can occur to varying degree from year to year, are the likely cause of this general pattern of phosphorus increase through the summer months.

Total-phosphorus concentration 1.5 feet above the lake bottom at the center site ranged from 0.061 mg/L on May 16 to 0.302 mg/L on July 26. These total-phosphorus concentrations observed during anoxic periods are indicative of moderate phosphorus release from the bottom sediments.

Lake condition:

Water-quality index:

Lillie and Mason (1983) classified all Wisconsin lakes using a random data set collected in the summer (July and August). The index, shown on page 12 of "Water-Quality and Lake-Stage data for Wisconsin Lakes, Water Year 1996," is based on surface total-phosphorus and chlorophyll a concentrations, and Secchi depths. According to the index, surface total-phosphorus concentrations in Little Arbor Vitae Lake indicate "good" water quality, and chlorophyll a concentrations and Secchi depths indicate "poor" water quality.

Lillie and Mason (1983) also provided a means of comparing the condition of Little Arbor Vitae Lake with other lakes in northeastern Wisconsin. The comparison on Table 4 shows the percentage distribution of northeastern Wisconsin lakes within each condition group and the relative position of Little Arbor Vitae Lake.

Trophic status:

Another means of assessing the nutrient, or trophic, status of a lake is to use Carlson's Trophic State Index (TSI). The 1996 TSI data is listed in Table 3. Figure 4 is a graphical illustration of the variation in Trophic State Indices for Little Arbor Vitae Lake during the 6 year study period. The data from 1996 show the lake to be lower eutrophic, or a lake with high nutrient levels.

Table 1. Lake stages for Little Arbor Vitae Lake near Woodruff, Wisconsin, 1996 water year

LOCATION.--Lat 45°54'46" long 89°37'03", in SW 1/4 SE 1/4 sec.28, T.40 N., R.7 E., Vilas County, Hydrologic Unit 07070001, 4 mi northeast of Woodruff.

LAKE-STAGE RECORDS

PERIOD OF RECORD.--February 1991 to current year.

GAGE.--Staff gage read by Glyn A. Roberts.

EXTREMES FOR PERIOD OF RECORD.--Maximum gage height observed, 8.00 ft, Sept. 16, 1994; minimum observed, 7.72 ft, Feb. 28, June 12, 1991, and Oct. 13, 1994.

EXTREMES FOR CURRENT YEAR.--Maximum gage height observed, 7.96 ft, Aug. 5; minimum observed, 7.80 ft, Sept. 2.

GAGE HEIGHT, FEET, WATER YEAR OCTOBER 1995 TO SEPTEMBER 1996

DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	---	---	---	---	---	---	7.92	---	---	---	---
2	7.90	---	---	---	---	---	---	---	---	---	---	7.80
3	---	7.88	---	---	---	---	---	---	---	---	---	---
4	---	---	---	---	---	---	7.88	---	---	7.82	---	---
5	---	---	---	---	---	---	---	---	7.86	---	7.96	7.82
6	---	---	7.84	7.84	---	7.84	---	---	---	---	---	---
7	---	---	---	---	7.83	---	---	7.92	---	7.82	---	---
8	7.90	---	---	---	---	---	---	---	---	---	---	---
9	---	7.86	---	---	---	---	7.87	---	---	---	---	7.82
10	---	---	7.84	---	---	---	---	---	---	7.82	---	---
11	---	---	---	---	---	7.82	---	7.90	7.84	---	---	---
12	---	---	---	7.86	7.84	7.81	---	---	---	---	7.90	7.84
13	---	---	7.86	---	---	---	7.88	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---	---	7.87
15	7.88	---	---	---	---	---	---	---	---	---	---	---
16	---	7.84	---	---	7.84	7.82	---	7.88	---	7.86	---	---
17	---	---	---	7.84	---	---	---	---	7.84	---	---	---
18	---	---	7.84	---	---	---	7.90	---	---	---	7.84	7.84
19	---	---	---	---	---	---	---	---	---	---	---	---
20	7.86	---	---	---	7.84	---	---	7.88	---	---	---	7.84
21	---	---	7.84	---	---	7.84	---	---	---	---	---	---
22	---	---	---	7.84	---	---	---	---	7.84	7.86	7.84	---
23	---	7.84	---	---	---	---	7.90	---	---	---	---	---
24	---	---	---	---	---	---	---	7.88	---	---	---	7.83
25	---	---	---	---	7.84	---	---	---	7.83	---	---	---
26	7.88	---	7.84	---	---	---	---	---	7.84	---	7.84	---
27	---	---	---	---	---	---	---	---	---	---	7.84	---
28	---	---	---	7.84	---	7.86	7.92	---	---	---	---	---
29	---	---	---	---	7.84	---	---	---	---	7.88	---	---
30	---	7.84	---	---	---	---	7.92	---	7.84	---	7.82	7.82
31	7.88	---	7.84	7.83	---	7.86	---	7.88	---	7.86	---	---

Table 2. Lake-depth profiles for Little Arbor Vitae Lake near Woodruff, Wisconsin, 1996 water year

WATER-QUALITY DATA

DATE	SAMPLING DEPTH (FEET) (00003)	TEMPERATURE WATER (DEG C) (00010)	SPECIFIC CONDUCTANCE (US/CM) (00095)	PH WATER WHOLE FIELD (STANDARD UNITS) (00400)	OXYGEN, DISSOLVED (MG/L) (00300)
MAR 1996					
12...	3.00	1.0	125	7.5	7.2
12...	6.00	2.0	122	7.4	5.7
12...	9.00	3.5	122	7.3	2.2
12...	12.0	4.0	125	7.2	1.5
12...	15.0	4.5	129	7.2	0.6
12...	18.0	4.5	135	7.2	0.4
12...	21.0	5.0	147	7.2	0.3
12...	24.0	5.5	211	7.7	0.3
12...	27.0	6.0	253	8.0	0.2
12...	28.0	6.0	258	8.0	0.2
12...	29.5	--	--	--	--
MAY					
16...	1.50	8.5	97	7.6	12.0
16...	3.00	8.5	97	7.6	12.0
16...	6.00	7.5	98	7.6	11.7
16...	9.00	6.5	101	7.6	11.3
16...	12.0	6.5	103	7.5	11.2
16...	15.0	6.5	103	7.5	10.9
16...	18.0	6.0	103	7.4	10.3
16...	21.0	6.0	104	7.4	10.0
16...	24.0	6.0	108	7.3	9.2
16...	27.5	5.5	114	7.2	8.6
16...	29.0	--	--	--	--
JUN					
25...	1.50	20.5	105	8.1	9.7
25...	3.00	20.5	104	8.1	9.7
25...	6.00	19.0	103	8.1	10.5
25...	9.00	18.5	102	8.1	10.2
25...	12.0	18.0	103	8.1	9.8
25...	15.0	17.5	106	7.3	7.7
25...	18.0	15.5	113	7.0	1.1
25...	21.0	14.5	127	7.0	0.5
25...	24.0	13.5	141	7.1	0.2
25...	27.0	13.0	144	7.1	0.2
25...	28.5	--	--	--	--
JUL					
26...	1.50	21.5	109	8.4	9.3
26...	3.00	21.5	107	8.3	9.3
26...	6.00	21.0	107	8.2	9.0
26...	9.00	21.0	106	8.2	8.7
26...	12.0	21.0	107	7.9	8.5
26...	15.0	20.5	109	7.2	5.4
26...	18.0	19.5	115	7.1	2.0
26...	21.0	16.5	158	7.1	0.2
26...	24.0	15.5	176	7.1	0.2
26...	26.5	15.0	185	7.2	0.2
26...	28.0	--	--	--	--
AUG					
14...	1.50	22.5	105	8.7	9.9
14...	3.00	22.5	104	8.7	9.9
14...	6.00	22.5	103	8.8	10.0
14...	9.00	22.5	103	8.8	10.0
14...	12.0	22.5	103	8.7	9.9
14...	15.0	20.5	108	7.6	2.0
14...	18.0	18.5	122	7.3	0.2
14...	21.0	18.0	136	7.2	0.2
14...	24.0	17.5	149	7.2	0.2
14...	27.0	17.0	153	7.3	0.2
14...	30.0	16.5	170	7.4	0.2
14...	31.5	14.0	291	7.7	0.2
14...	33.0	--	--	--	--

Table 3.--Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Little Arbor Vitae Lake, 1996 water year

[- indicates not applicable; -- indicates no data available]

Date	Secchi Disk			Sampling	Total Phosphorus			Chlorophyll a		Dissolved Ortho-phosphate Phosphorus
	Depth (meters)	Depth (feet)	T.S.I.	Depth (feet)	Conc. (mg/L)	Conc. (µg/L)	T.S.I	Conc. (µg/L)	T.S.I.	Conc. (mg/L)
05/16/96	1.5	4.9	54	1.5	0.035	35	56	17	56	0.004
	-	-	-	28	0.061	61	-	-	-	0.009
06/25/96	1.7	5.6	52	1.5	0.023	23	52	15	55	--
	-	-	-	27	--	--	-	-	-	--
07/26/96	1.6	5.2	53	1.5	0.026	26	53	15	55	--
	-	-	-	27	0.302	302	-	-	-	--
08/14/96	1.0	3.3	60	1.5	0.029	29	54	43	63	--
	-	-	-	32	0.160	160	-	-	-	--

Table 4. Regional lake condition and percentage distribution of northeastern lakes

	Parameter		Percentage distribution of lakes in northeast Wisconsin within parameter ranges
	Total Phosphorus (mg/L)		
	<0.010	best condition	22
	0.010-0.020		41
Little Arbor Vitae Lake Values	0.020-0.030		21
	0.030-0.050		12
	>0.050	worst condition	5
	Chlorophyll a (µg/L)		
	0-5	best condition	34
	5-10		38
	10-15		11
Little Arbor Vitae Lake Values	15-30		11
	>30	worst condition	5
	Secchi depth (feet)		
	>19.7	best condition	4
	9.8-19.7		32
	6.6-9.8		22
Little Arbor Vitae Lake Values	3.3-6.6		26
	<3.3	worst condition	16

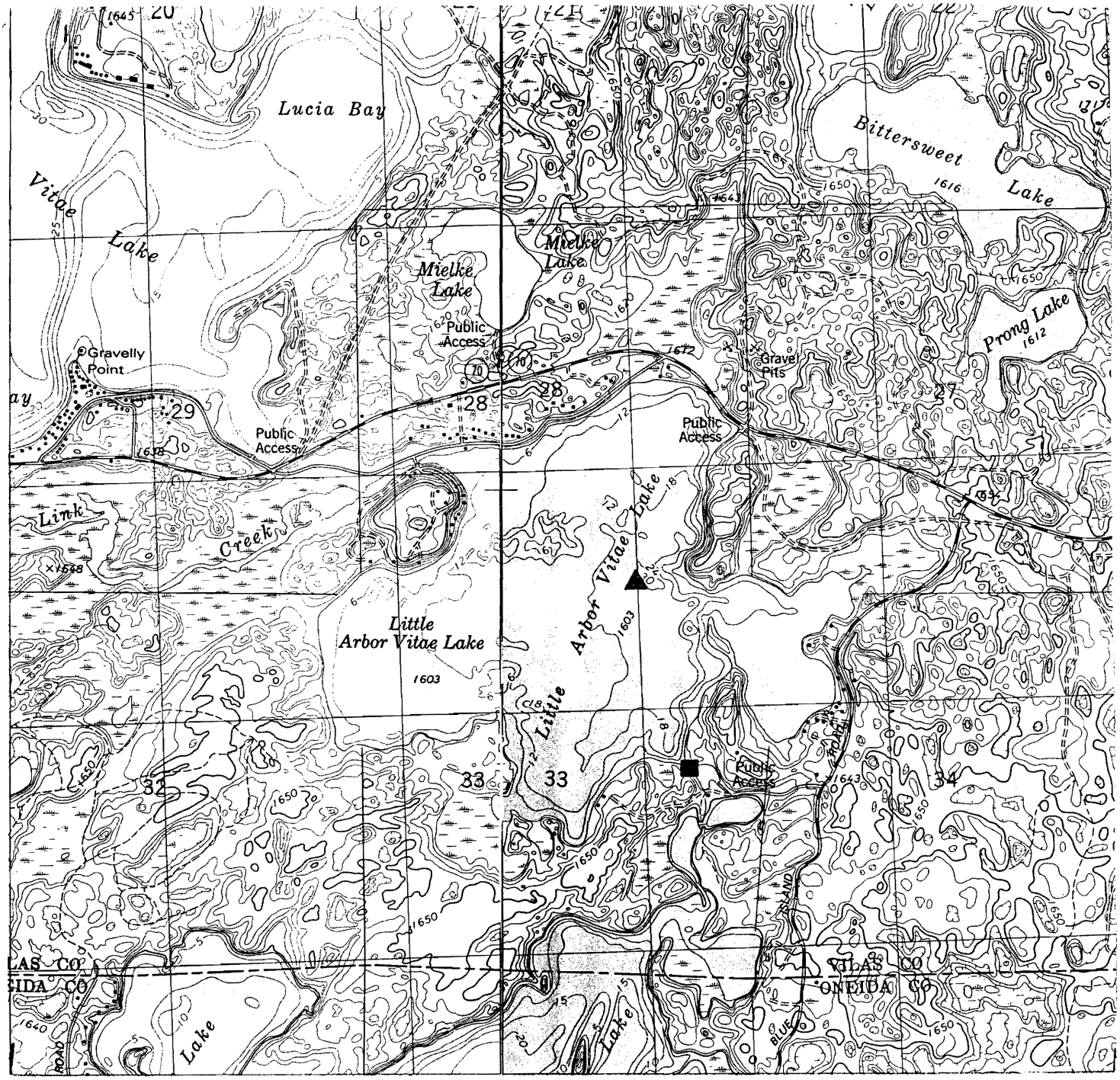

Figure 1. Locations of water-quality and lake-stage monitoring sites on Little Arbor Vitae Lake near Woodruff, Wisconsin.

WATER-QUALITY RECORDS

PERIOD OF RECORD.--February 1991 to current year.

REMARKS.--Lake sampled at the deep hole. Lake ice-covered during March measurements. Water-quality analyses done by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, MARCH 12 TO AUGUST 14, 1996
(Milligrams per liter unless otherwise indicated)

	Mar. 12		May 16		June 25		July 26		Aug. 14	
Depth of sample (ft)	3.0	28	1.5	28	1.5	27	1.5	27	1.5	32
Lake stage (ft)	7.81		7.86		7.83		7.84		7.87	
Specific conductance (µS/cm)	125	258	97	114	105	144	109	185	105	291
pH (units)	7.5	8.0	7.6	7.2	8.1	7.1	8.4	7.2	8.7	7.7
Water temperature (°C)	1.0	6.0	8.5	5.5	20.5	13.0	21.5	15.0	22.5	14.0
Color (Pt-Co. scale)	---	---	15	30	---	---	---	---	---	---
Turbidity (NTU)	---	---	2.0	7.0	---	---	---	---	---	---
Secchi-depth (meters)	---		1.5		1.7		1.6		1.0	
Dissolved oxygen	7.2	0.2	12.0	8.6	9.7	0.2	9.3	0.2	9.9	0.2
Hardness, as CaCO3	---	---	46	54	---	---	---	---	---	---
Calcium, dissolved (Ca)	---	---	13	15	---	---	---	---	---	---
Magnesium, dissolved (Mg)	---	---	3.4	4.0	---	---	---	---	---	---
Sodium, dissolved (Na)	---	---	2.4	2.5	---	---	---	---	---	---
Potassium, dissolved (K)	---	---	0.7	0.9	---	---	---	---	---	---
Alkalinity, as CaCO3	---	---	47	58	---	---	---	---	---	---
Sulfate, dissolved (SO4)	---	---	6.0	7.0	---	---	---	---	---	---
Chloride, dissolved (Cl)	---	---	2.7	2.6	---	---	---	---	---	---
Fluoride, dissolved (F)	---	---	<0.1	0.1	---	---	---	---	---	---
Silica, dissolved (SiO2)	---	---	9.6	12	---	---	---	---	---	---
Solids, dissolved, at 180°C	---	---	72	86	---	---	---	---	---	---
Nitrogen, NO2 + NO3, diss. (as N)	---	---	0.07	0.01	---	---	---	---	---	---
Nitrogen, ammonia, dissolved (as N)	---	---	<0.03	0.43	---	---	---	---	---	---
Nitrogen, organic, total (as N)	---	---	0.50	0.47	---	---	---	---	---	---
Nitrogen, amm. + org., total (as N)	---	---	0.50	0.90	---	---	---	---	---	---
Nitrogen, total (as N)	---	---	0.57	0.91	---	---	---	---	---	---
Phosphorus, total (as P)	---	---	0.035	0.061	0.023	---	0.026	0.302	0.029	0.160
Phosphorus, ortho, dissolved (as P)	---	---	0.004	0.009	---	---	---	---	---	---
Iron, dissolved (Fe) µg/L	---	---	170	630	---	---	---	---	---	---
Manganese, dissolved (Mn) µg/L	---	---	210	480	---	---	---	---	---	---
Chlorophyll a, phytoplankton (µg/L)	---	---	17	---	15	---	15	---	43	---

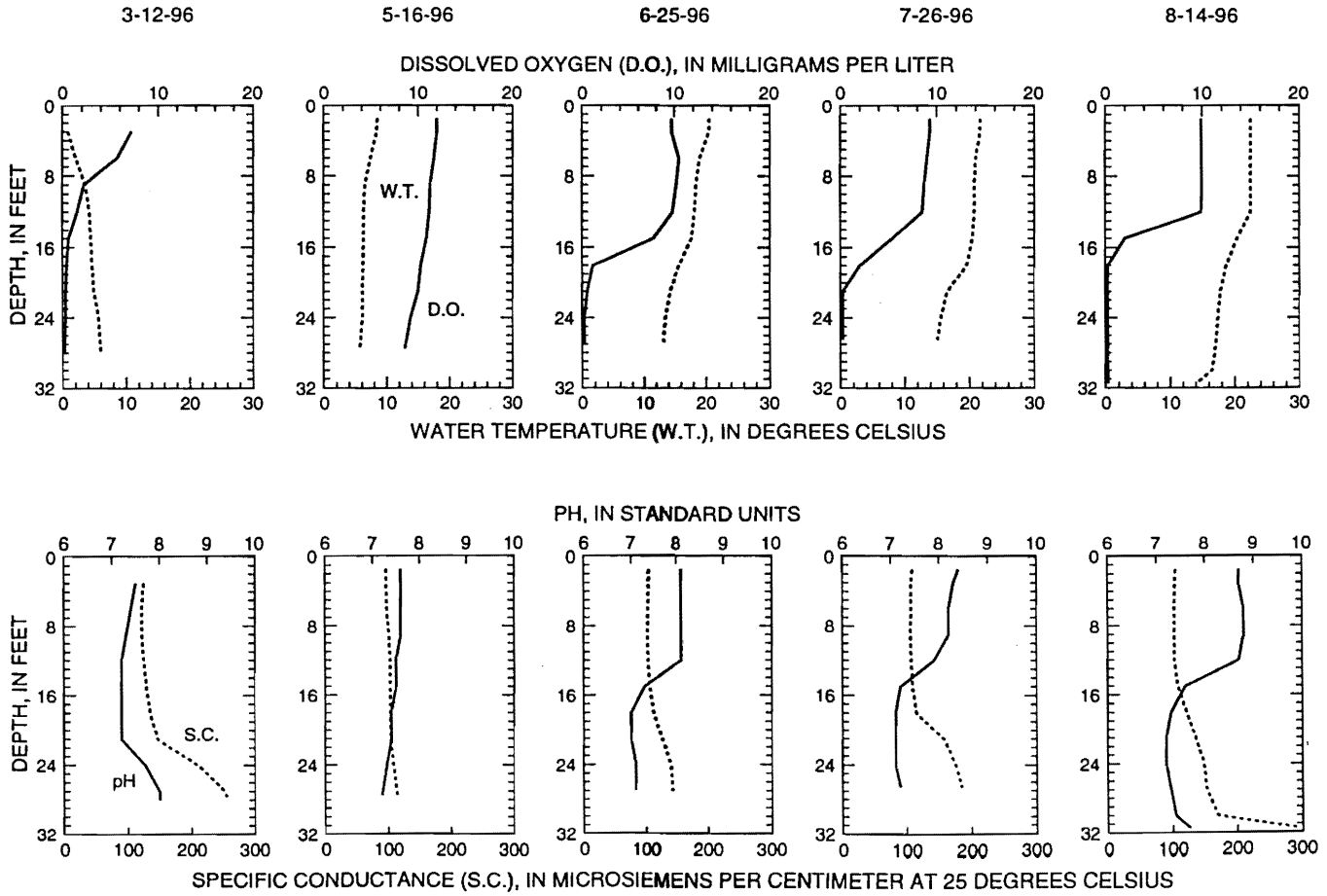

Figure 2. Water-quality data and depth profiles for Little Arbor Vitae Lake near Woodruff, Wisconsin, 1996 water year

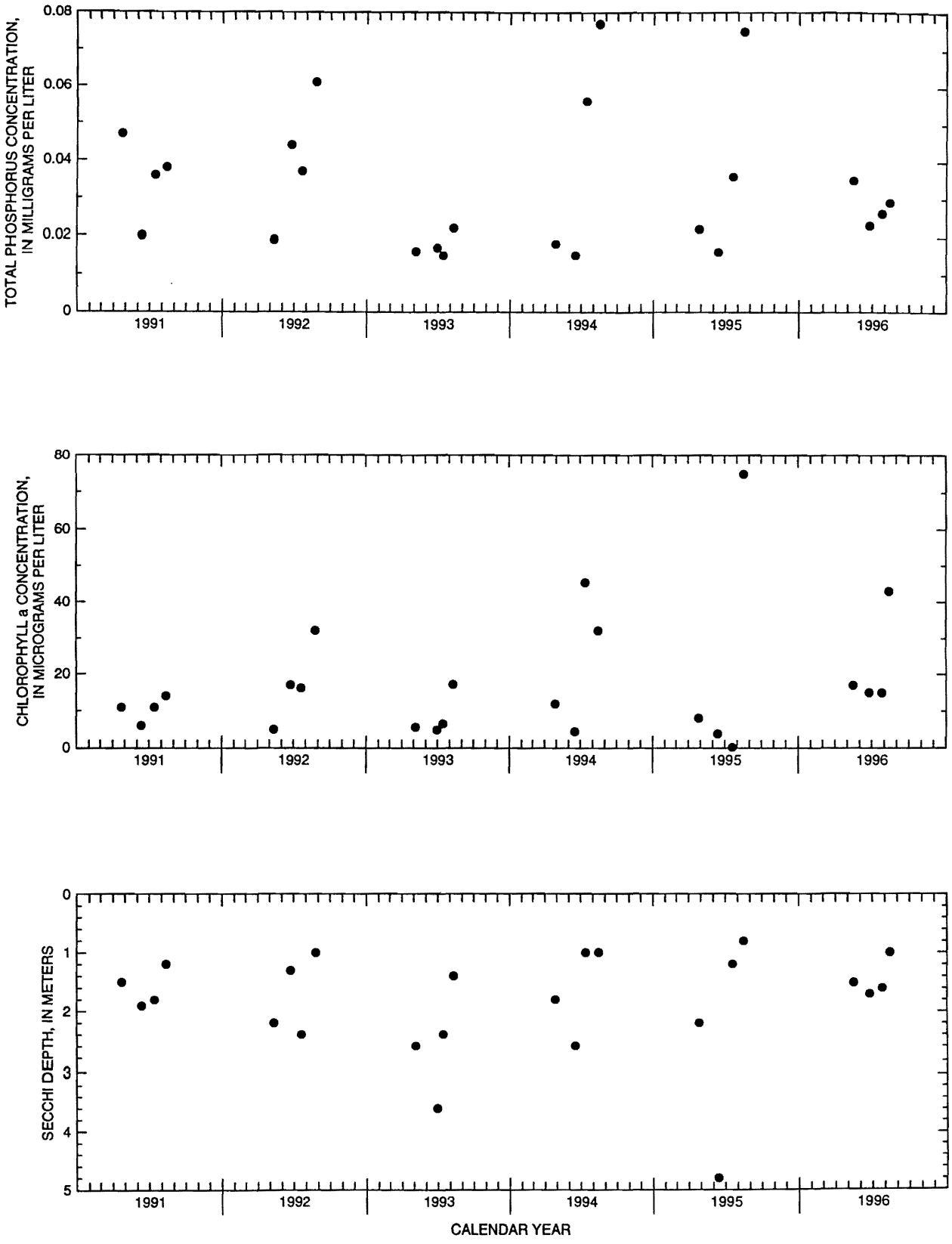

Figure 3. Surface total phosphorus and chlorophyll a concentrations, and Secchi depths for Little Arbor Vitae Lake near Woodruff, Wisconsin.

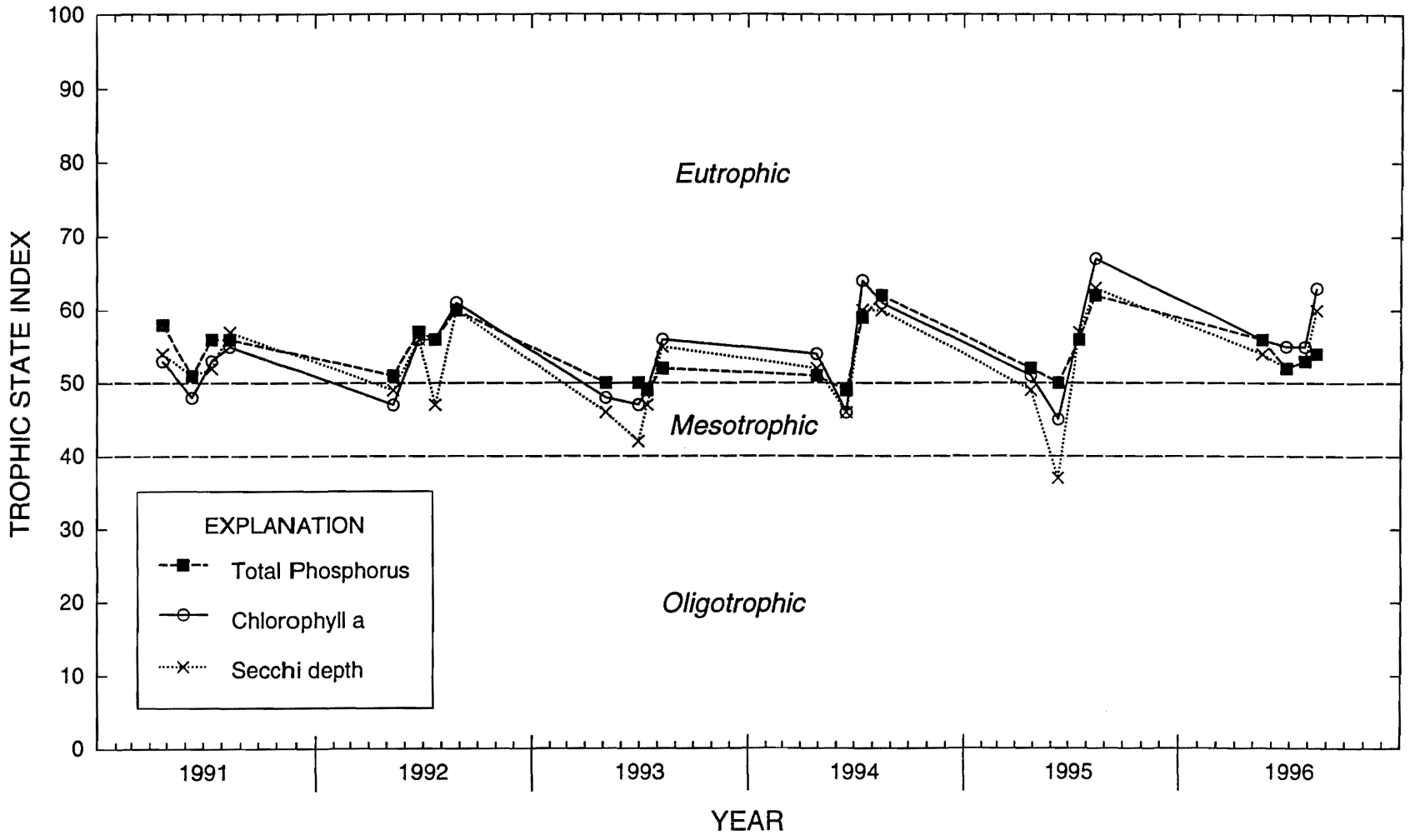

Figure 4. Trophic state indices for Little Arbor Vitae Lake near Woodruff, Wisconsin