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LITTLE GREEN LAKE LIMITED PHOSPHORUS BUDGET

LITTLE GREEN LAKE PROTECTION & REHABILITATION DISTRICT
GREEN LAKE COUNTY, WISCONSIN

May 10, 1999

LPL-537

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EXECUTIVE SUMMARY

This report is intended to quantify the sources of the various nutrient inputs into the lake. This information is necessary to determine high nutrient-loading areas, and to select the management techniques that are most cost-effective and best designed to address these problem areas. The phosphorus budget was used to determine the significance of internal and external loading at Little Green Lake.

Ramaker & Associates, Inc. has prepared a phosphorus budget for the entire watershed. The budget shows that internal recycling contributes the majority of the phosphorus to the lake. The best-fit lake model estimated that 69% of the load is coming from internal recycling. This model also estimates that approximately 25% of the load is coming from land use, 5% from precipitation and 1% from septic tanks.

This Executive Summary is provided for the reader's convenience and should be considered a part of the appended report. Interpretation of this summary should be considered incomplete without reviewing the entire phosphorus budget and associated appendices.

ACKNOWLEDGMENTS

Ramaker & Associates thank the following people who contributed to the development of this limited phosphorus budget: Ms. Jill Geisthardt of the Little Green Lake Protection & Rehabilitation District; Mr. William Rose and Mr. Dale Robertson of the U.S. Geological Survey; Mr. Mark Sesing of the Wisconsin Department of Natural Resources; Mr. John Panuska of the Wisconsin Department of Natural Resources, and Mr. James Hebbe of the Green Lake County Conservation Department.

SECTION 1
INTRODUCTION

The Little Green Lake Protection and Rehabilitation District retained Ramaker & Associates, Inc. to complete a limited phosphorus budget for Little Green Lake in Green Lake County, Wisconsin.

1.1 BACKGROUND

Little Green Lake is a small, relatively shallow water body located just north of the City of Markesan. Little Green Lake is located in Township 15 North, Range 13 East, Sections 29-32, Green Lake County, Wisconsin. The lake is characterized as a seepage lake with two intermittent inlets and one intermittent outlet. It is a small, shallow system that is highly productive as a result of nutrient-enrichment.

A lake management plan was developed in December 1997 in response to concerns raised by many of the more than 240 lake residents regarding the deterioration of Little Green Lake's water quality. According to the Little Green Lake Protection and Rehabilitation District (Lake District), present lake conditions (namely excessive aquatic plant and algae growth) were interfering with desired lake uses and jeopardizing the long-term health of the lake.

In November 1997, the Lake District granted approval to prepare a phosphorus budget by contracting with the engineering consulting firm of Ramaker & Associates, Inc. A $8,100 matching grant, awarded through Wisconsin's Lake Planning Grant Program, was used in conjunction with local revenues to fund the project.

1.2 PURPOSE OF REPORT

The purpose of the phosphorus budget was to evaluate the impacts of internal and external loading. This information is necessary to determine high nutrient-loading areas, and to select the management techniques that are most cost-effective and best designed to address these problem areas.

SECTION 2

ANALYSIS OF EXISTING LAKE & WATERSHED DATA

In order to evaluate the total phosphorus loading, the existing lake and watershed data was evaluated. In addition, the discharge data was adjusted to represent a typical water year.

2.1 LAKE AND WATERSHED DATA

Little Green Lake is part of a 2,111-acre watershed. This watershed includes 1,645 acres of land (Green Lake County Land Conservation Department, Watershed Inventory) and 466-acres of lake surface area [United States Geological Survey (USGS) Data Summary, 1996].

The total unit runoff from the watershed was calculated using the adjusted lake outflow data and dividing it by the lake surface area. Precipitation data was obtained from the National Oceanographic and Atmospheric Administration (NOAA) and is available in Appendix A. The 1998 precipitation data from Dalton, Montello and Ripon, Wisconsin were averaged to come up with 31-inches for the year. Evaporation was estimated using an annual evaporation map showing Green Lake County. The annual evaporation was estimated to be 28.5-inches. However, in some of the computer models the precipitation minus the evaporation was adjusted so the program would calculate the correct hydraulic residence time.

Land use within the watershed of Little Green Lake is 77% agricultural, 15% wooded, 5% residential and 3% roads. Most of the cropland is farmed intensively with row crops such as sweet corn, field corn, peas, soybeans and wheat (Green Lake County Conservation Department, 1994). This type of land use is known to contribute significant quantities of sediment-laden runoff and nutrient loads to receiving water bodies, especially if runoff control measures (known as Best Management Practices or BMPs) are not implemented. Results from a recent watershed inventory study that estimated the amount of sediment and nutrient loading to Little Green Lake are included in Appendix B.

2.2 LAKE TYPE

Little Green Lake has a surface area of 0.728 square miles (466 acres), with 4.2 miles of shoreline. The lake is 26.5 feet at its deepest point near the center, has a mean depth of 10.3 feet, and contains an average of 4,817 acre-feet of water.

Little Green Lake is also described as a shallow water body. Shallow lakes tend to be more productive than deep lakes due to a number of factors. These factors include the large area of bottom sediments relative to the volume of water, more complete wind mixing of the water column, and the large, shallow areas along the lake perimeter that can be colonized by rooted and floating aquatic plants (also known as the littoral zone).

The outlet of Little Green Lake was monitored by the United States Geological Survey (USGS) from October 1997 to September 1998. The USGS measured the annual mean discharge at the outlet and measured a total flow for the year of 368.1 acre-ft. Annual mean discharge at the outlet is the volume of water that exits the system over a one-year time period. The annual discharge is necessary to calculate the lake's flushing rate (average length of time water resides in the lake), or hydraulic retention time. Retention time is important in determining the impact of nutrient inputs. For instance, long retention times result in greater nutrient retention in most lakes. These values are also used to determine the amount of time it will take for the lake to refill with water following a hypolimnetic withdrawal or a water level drawdown. Finally, annual discharge is used as an input variable in a number of lake-modeling applications.

The retention time for Little Green Lake was calculated to be 12.8 years. This residence is long compared to other lakes in Wisconsin and is characteristic of a seepage lake. Groundwater seepage lakes are defined as systems that lack a significant inlet or outlet (Little Green Lake has two intermittent inlets and one intermittent outlet).

2.3 LAKE DATA ADJUSTMENTS

The lake stage measured at the beginning of the study was 5.96 feet (October 1, 1997) and the lake stage measured at the end of the study was 5.48 feet (September 30, 1998). The crest of the Little Green Lake outlet is at an elevation of 5.81 feet. Since the lake level at the end of the study was lower than the beginning, the outflow of the lake was adjusted by –0.15 feet or -69.9 acre-ft to account for the decrease in storage. The Little Green Lake sample data is available in Appendix C.

The outlet of Little Green Lake was monitored by the United States Geological Survey (USGS) from October 1997 to September 1998. In order to determine if the flow observed during the 1998 water year was typical, the long-term average inflow to Green Lake was studied.

The USGS measured the mean discharge at the Green Lake inlet from 1987 through 1998. The Green Lake sample data is available in Appendix D. The average mean discharge between 1988 and 1997 was 36.2 cubic feet per second (cfs). The measured discharge for 1998 was 28.7 cfs. If the 1998 data was to be representative of a normal year, it would need to be increased by 26 percent. Therefore, the Little Green Lake discharge was increased by 26 percent.

SECTION 3

METHODS OF CALCULATING TOTAL PHOSPHORUS CONCENTRATIONS

Total phosphorus concentrations were calculated using the following models: Apparent Settling Velocity Analysis, Seepage Lake Response Model Spreadsheet, Wisconsin Lake Model Spreadsheet and Wisconsin Internal Load Estimator Spreadsheet. The model inputs and analysis are described below.

3.1 APPARENT SETTLING VELOCITY ANALYSIS

The Apparent Settling Velocity Analysis model predicts the apparent settling velocity of phosphorus in the water column of a lake. The apparent settling velocity is an indicator of how quickly phosphorus is removed from the water column. Typically, a higher settling velocity indicates that more phosphorus settles out of the water column. This typically results in lower weed and algae production and clearer water.

This model also predicts the total phosphorus levels after an alum treatment. Aluminum sulfate (alum) is used to lower the lake's phosphorus content by removing the limiting nutrient from the water column and retarding its release from anoxic lake sediments. The model inputs include the following: mean depth of the lake, areal watershed loading, flushing rate and observed in-lake total phosphorus concentration.

This model predicted that the settling velocity of Little Green Lake was 2 meters per year (m/yr). This is a very low settling velocity, which is characteristic of high internal loading. Typically, a natural lake with low internal loading would have a settling velocity between 5 and 20 m/yr.

The model predicted that if there were no internal loading within the lake, total phosphorus concentrations would be between 20 and 35 mg/m^3. Currently, the annual phosphorus concentrations average to be 93 mg/m^3. The results from the Apparent Settling Velocity Analysis are listed in Table 1.

3.2 SEEPAGE LAKE RESPONSE MODEL SPREADSHEET

The Seepage Lake Response Model predicts the in-lake total phosphorus concentration in a lake. The model also can be used to predict the percentage of internal and external loading. The model is calibrated by adjusting the apparent settling velocity and comparing the estimated in-lake total phosphorus concentration to the observed concentration. The model inputs include the following: drainage area, total unit runoff, lake surface area, lake volume, precipitation minus evaporation, external phosphorus input and the annual in-lake phosphorus concentration.

This model can be used to determine the lake concentration if the internal load was minimal. In order to calculate the internal load, a conversion factor of 2.471 (conversion from hectares to acres) was entered in the land use area, so the internal load output would be in kilograms (not kilograms per hectare). By calibrating the model using the in-lake total phosphorus concentrations and an apparent settling velocity of 6.2 m/year, the model estimated an internal load of 750 kg (1653 lbs).

After evaluating several models, the seepage lake model is believed to most accurately reflect Little Green Lake. Since Little Green Lake has a high residence time it acts as a seepage lake. The model predicted that 69 percent of the phosphorus comes from internal loading, 25 percent from land use, 5.2 percent is from precipitation and 1 percent is from septic tank loading. This breakdown is shown on Figure 1. In addition, Figure 2 shows the in-lake total phosphorus levels verses percent phosphorus reductions. By eliminating the internal loading (reducing loading by 69%), the predicted in-lake total phosphorus would be 30 mg/m^3. The results from the Seepage Lake Response Model are listed in Table 2.

3.3 WISCONSIN LAKE MODEL SPREADSHEET

The Wisconsin Lake Model Spreadsheet (WILMS) predicts the spring overturn (SPO) and growing season mean (GSM) in-lake total phosphorus concentrations and estimates the annual nutrient loading. The spreadsheet uses 10 empirical lake response models, which gives the user several options to best fit the lake data. The model inputs include the following: drainage area, total unit runoff, lake surface area, lake volume, precipitation minus evaporation, external phosphorus inputs and the annual in-lake phosphorus concentration.

This model did not best represent Little Green Lake. However, the model was used to get a detailed breakdown of the external loading. Areas 1 through 9 are listed in the model and show the percentage of loading coming from land use. Area 6, Area 9 and Area 4 had the highest external phosphorus contribution. The results from the WILMS model are listed in Table 3.

3.4 WISCONSIN INTERNAL LOAD ESTIMATOR SPREADSHEET

The Wisconsin Internal Load Estimator Spreadsheet (WINTLOAD) is a lake water quality model which estimates the amount of internal phosphorus loading occurring during the time the hypolimnion is anoxic. The spreadsheet uses four methods to estimate the amount of internal loading possible during the period of anoxia.

The WINTLOAD model did not fit Little Green Lake well, possibly because of the long hydraulic residence time. The model estimated an internal load of 39%, which is not consistent with any of the other models and data. The model did estimate an Osgood (1988) Index of 2.3, which means that the lake is polymictic. A polymictic lake is one which destratifies and mixes several times a year. In Wisconsin's deeper lakes, complete mixing of the water column, known as destratification, occurs only during spring and fall turnover. However, since Little Green Lake is polymictic, this destratification occurs intermittently during the weakly stratified summer period. This is typically caused by high winds or rain events. During this destratification the less dense upper zone of water (epilimnion) mixes with the lower zone (hypolimnion) which is anoxic and high in phosphorus. The results from the WINTLOAD model are listed in Table 4.

data supports this?

3.5 IN-LAKE TOTAL PHOSPHORUS DATA

The in-lake total phosphorus measured in the spring will give a rough estimate of the phosphorus load coming from external sources. The external input will be less than or equal to this number. The average total phosphorus for April and May (averaging the top and bottom concentrations) is 57 mg/m^3. Multiplying this concentration by the lake volume gives a phosphorus mass of 340 kg, which is what the WILMS program estimated for the external load. The average total phosphorus for August (averaging the top concentrations) is 183 mg/m^3. Multiplying this concentration by the lake volume gives a phosphorus mass of 1090 kg. The results from the Little Green Lake sampling events are listed in Appendix A.

SECTION 4

RESULTS

The results of the four lake models are summarized below.

4.1 PHOSPHORUS INPUTS FROM PRECIPITATION, GROUNDWATER AND SEPTIC SYSTEMS

The model estimated that 5% of the total phosphorus loading comes from precipitation and 1 % comes from septic systems. Both of these percentages are very low. No groundwater phosphorus concentrations were entered into any of the programs, because no data was available. However, based on the lake water balance information, it is unlikely that the groundwater contribution was significant.

4.2 PHOSPHORUS INPUTS FROM EXTERNAL LOADING

ok

The WILMS model calculated an external load of 340 kg. The 1991 Watershed Inventory predicted a land use load of 285 kg (629 lbs). The average spring total phosphor~~us concentration~~ [illegible] (external input will be less than or equal to this number) was 57 mg/m³. According to Lillie and Mason's (1983) water quality index for Wisconsin lakes, this concentration represents a lake with a "Poor" water quality index.

The current annual lake concentration is 90 mg/m³, with an average summer concentration of 133 mg/m³. The external loading is currently calculated by the Seepage Model to be 25% of the loading to the lake. Figure 1 shows the external total phosphorus inputs as a percent of total load.

4.3 PHOSPHORUS INPUTS FROM INTERNAL LOADING

The Seepage model calculated an internal load of 750 kg. The average total phosphorus for August (averaging the top concentrations) is 183 mg/m³. This number is representative of the internal and external load. According to Lillie and Mason's (1983) water quality index for Wisconsin lakes, this concentration represents a lake with a "Very Poor" water quality index. The external loading is currently calculated by the Seepage Model to be 69% of the loading to the lake. Figure 2 shows the total phosphorus loading breakdown between internal and external sources.

proof? any data?

In conclusion, several of the lake models indicated that internal recycling was a massive contributor of phosphorus to Little Green Lake. After evaluating several models, the seepage lake model best fit Little Green Lake. Little Green Lake has high internal loading because the lake is polymictic and goes anoxic during the summer. During the summer, the bottom portion of the lake (hypolimnion) sends pulses of phosphorus to the top layer of the lake (epilimnion) where it can be used by plants, algae, etc. Figure 3 shows the in-lake total phosphorus concentration verses the percent loading reduction. This plot illustrates that if the internal load were eliminated, in-lake concentrations would still be at the lower eutrophic level.

In addition, the lake has a low apparent settling velocity. The settling velocity term represents how fast total phosphorus is removed from water column. Currently, the apparent settling velocity model estimated a settling velocity of 2 m/year for Little Green Lake. Theoretically, if that velocity were closer to 10 m/year it would represent a lake with minimal internal loading. If the internal loading were eliminated, a predicted settling velocity of 6.2 m/year would fit the observed loading conditions for Little Green Lake. Figure 4 shows the in-lake total phosphorus verses the percent of loading reduction for different seepage velocities.

Discuss w/ Jeff + Paul

SECTION 5

CONCLUSION

where's data?

In conclusion, the majority of Little Green Lake's total phosphorus is coming from internal loading. Internal loading is a significant problem because the lake is polymictic (mixes several times per year). There are several alternatives to reduce the internal loading including the following: aeration, hypolimnetic withdrawal and alum treatments.

destratification

The current condition of the lake is hyper eutrophic. If internal loading was eliminated, the lake would still be lower eutrophic since the lake has a low outflow rate and a high hydraulic retention time. Lakes with high retention times are more susceptible to external loads. Therefore, if the lake residents would like Little Green Lake to be as close to mesotrophic as possible, the external loading should be reduced. Using additional best management practices in the watershed can reduce external loads. Best management practices may include swale buffers, sedimentation ponds and low fertilizer applications around the lake.

SECTION 6

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Fig 1

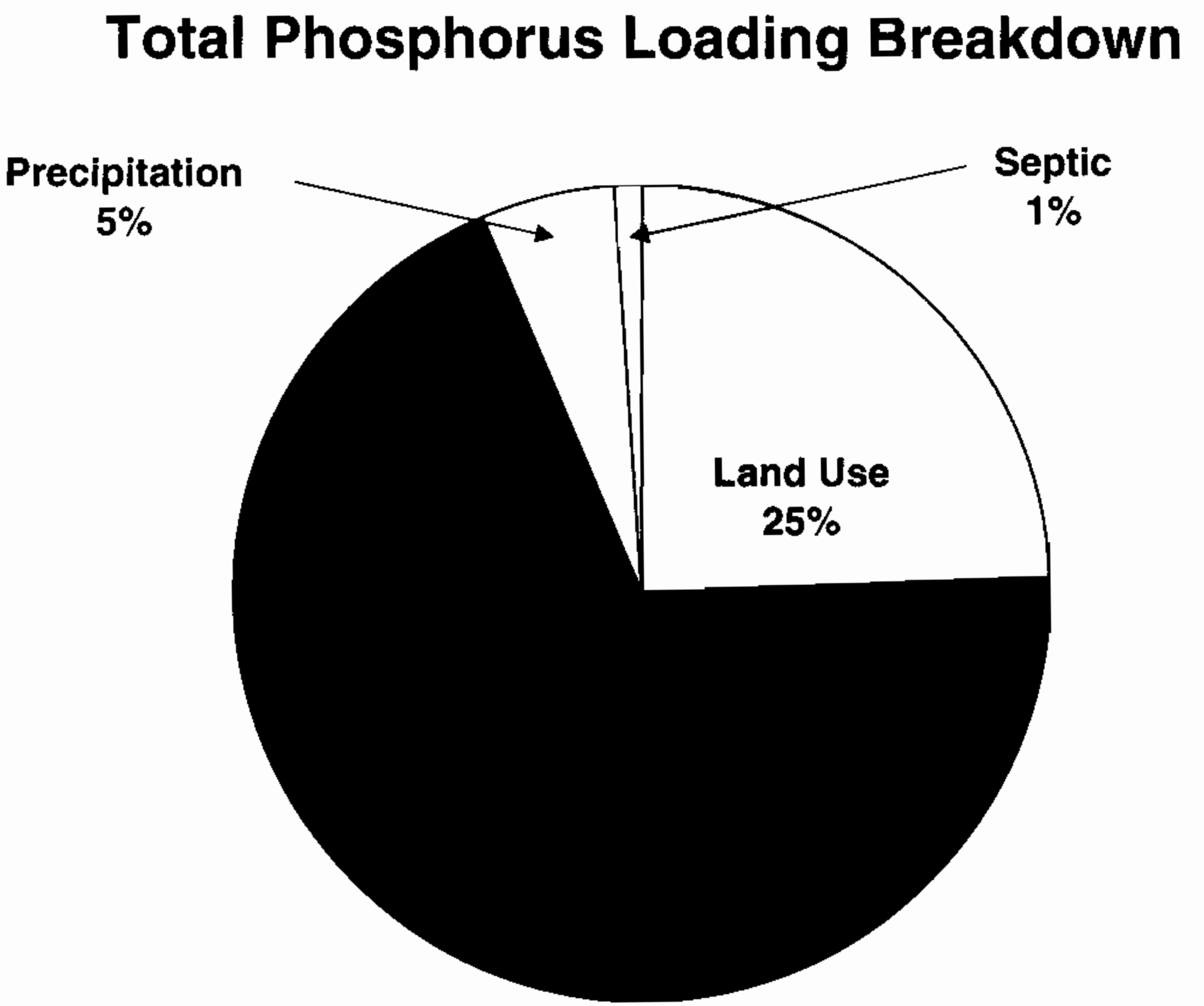
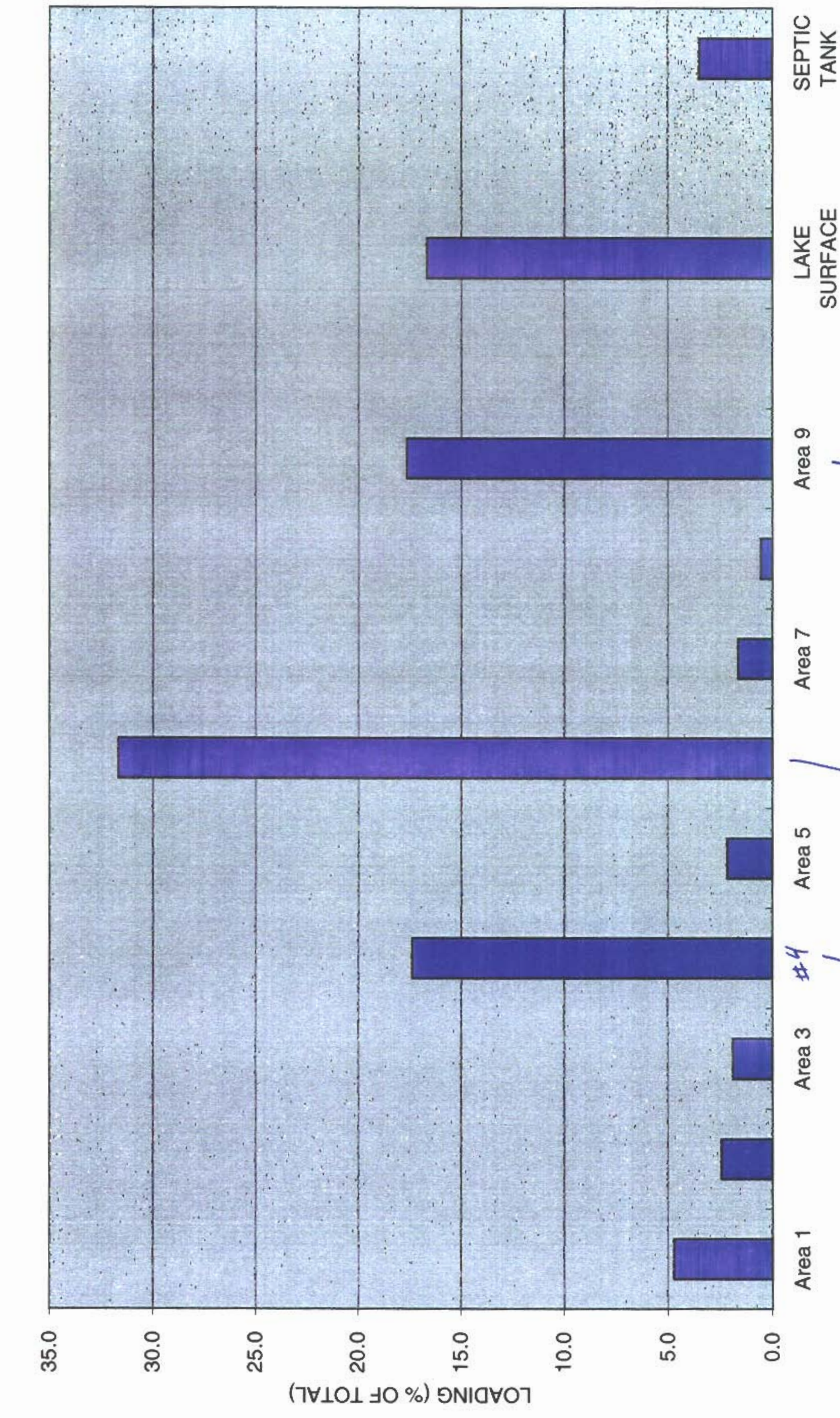

Total Phosphorus Loading Breakdown
Precipitation
5%
Septic
1%
Land Use
25%

Fig 2 P load Breakdown
(external sources)



P INPUTS AS PERCENT OF EXTERNAL LOAD
Little Green Lake

#4 ?

What area is this #6

?

fig 3

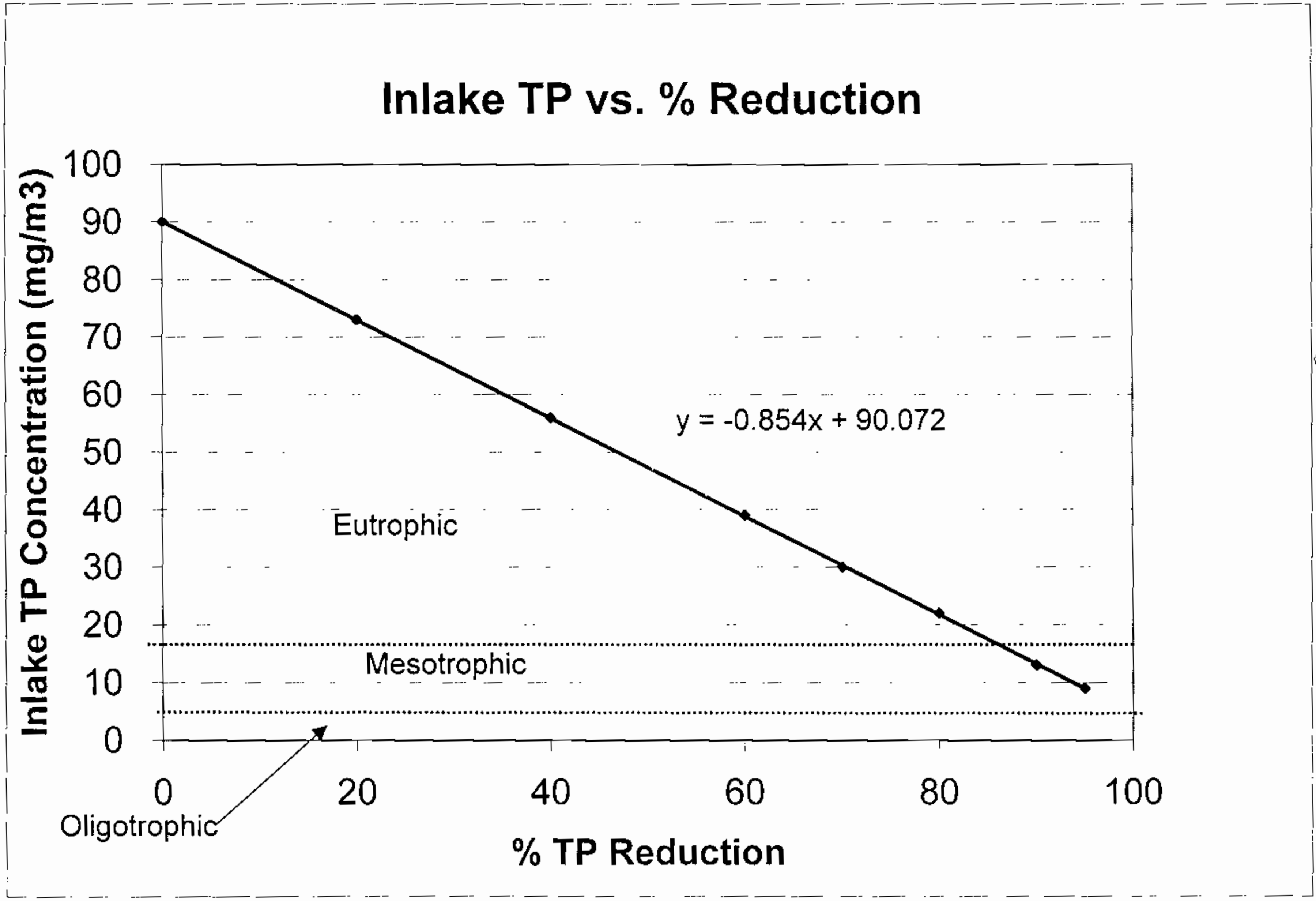
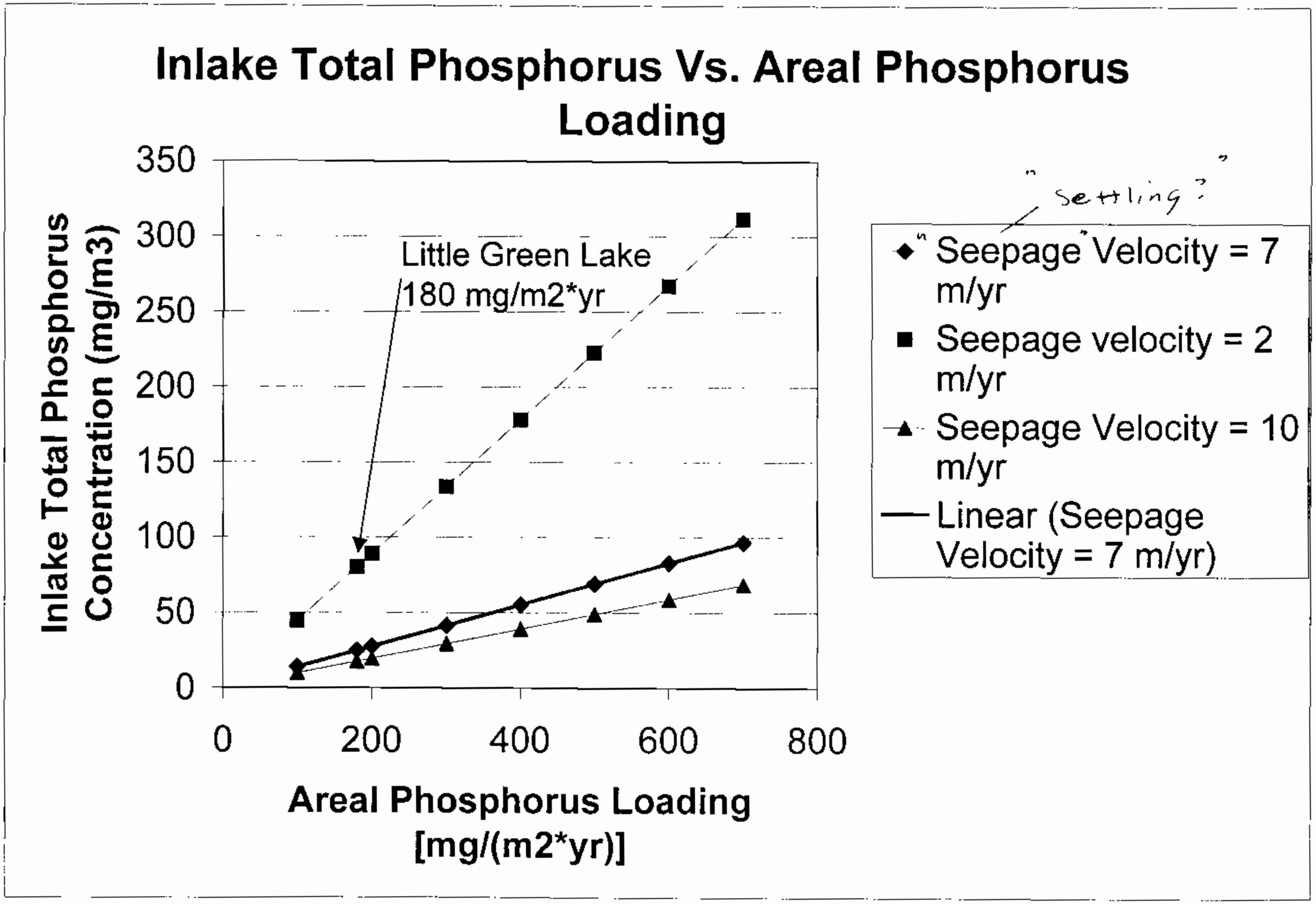
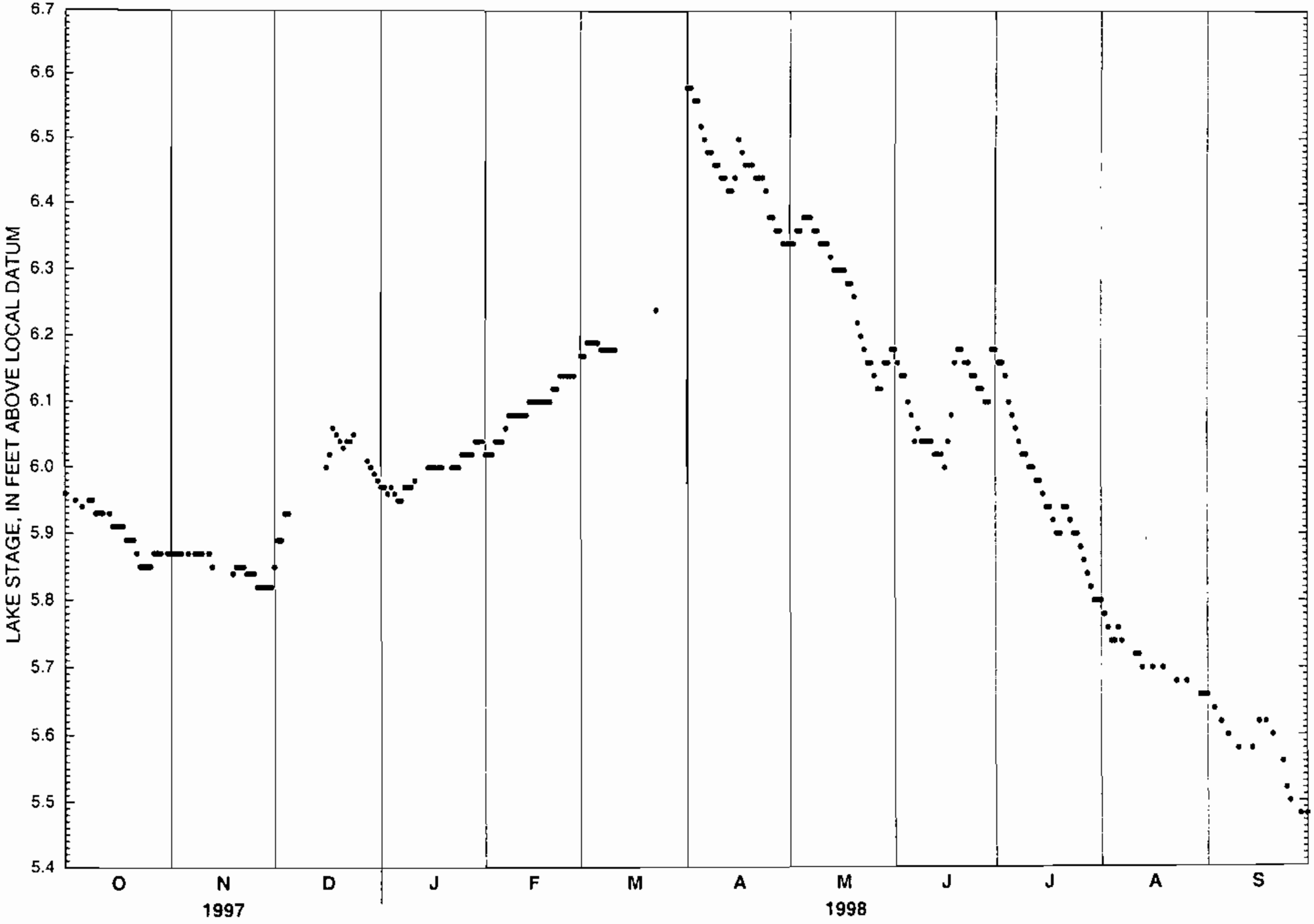

Inlake TP vs. % Reduction
Inlake TP Concentration (mg/m3)
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
% TP Reduction
y = -0.854x + 90.072
Eutrophic
Mesotrophic
Oligotrophic

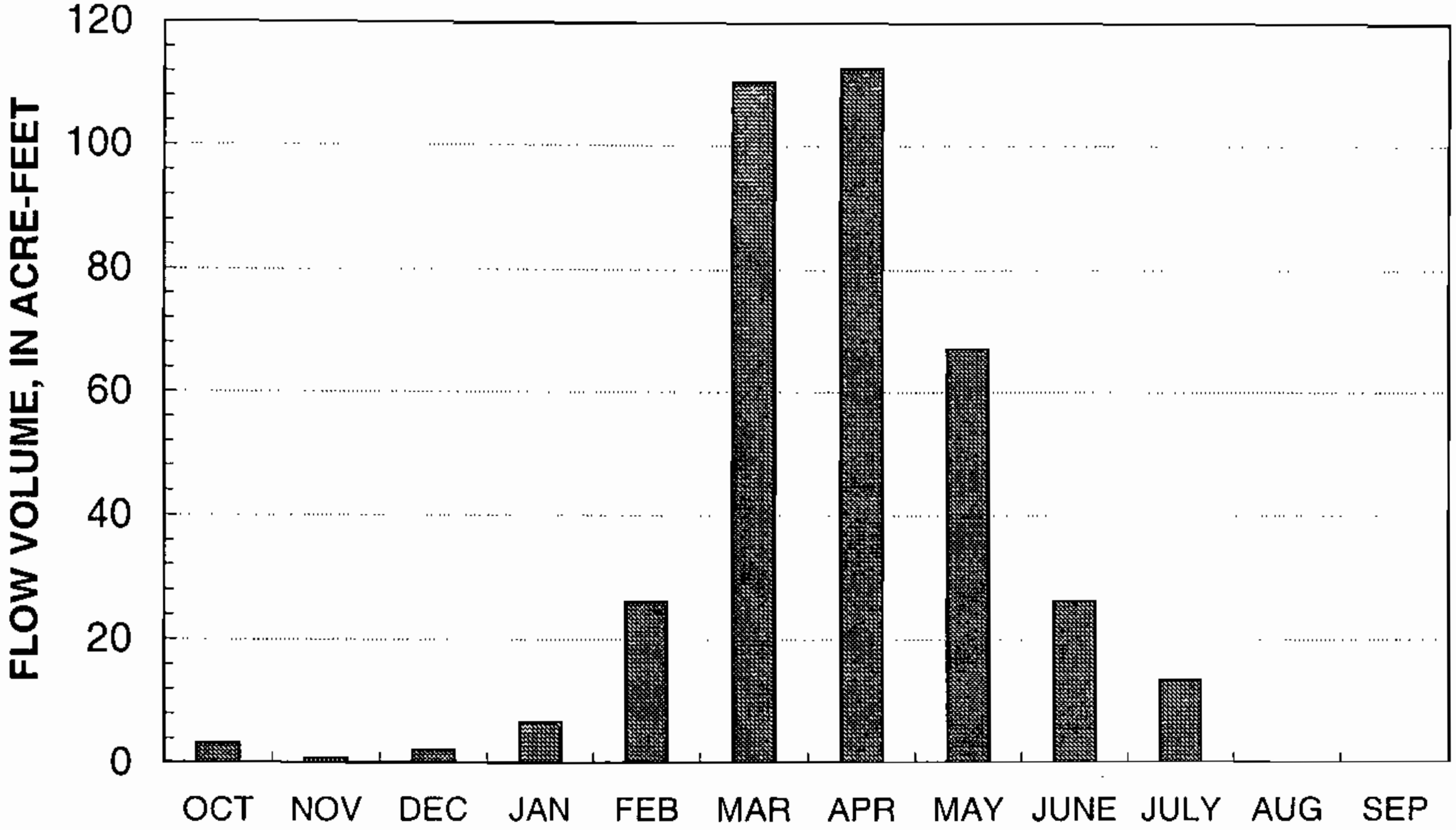
Fig 4


Inlake Total Phosphorus Vs. Areal Phosphorus Loading
Inlake Total Phosphorus Concentration (mg/m3)
350
300
250
200
150
100
50
0
0
200
400
600
800
Areal Phosphorus Loading [mg/(m2*yr)]
Little Green Lake
180 mg/m2*yr
"settling?"
◆ Seepage Velocity = 7 m/yr
■ Seepage velocity = 2 m/yr
▲ Seepage Velocity = 10 m/yr
— Linear (Seepage Velocity = 7 m/yr)

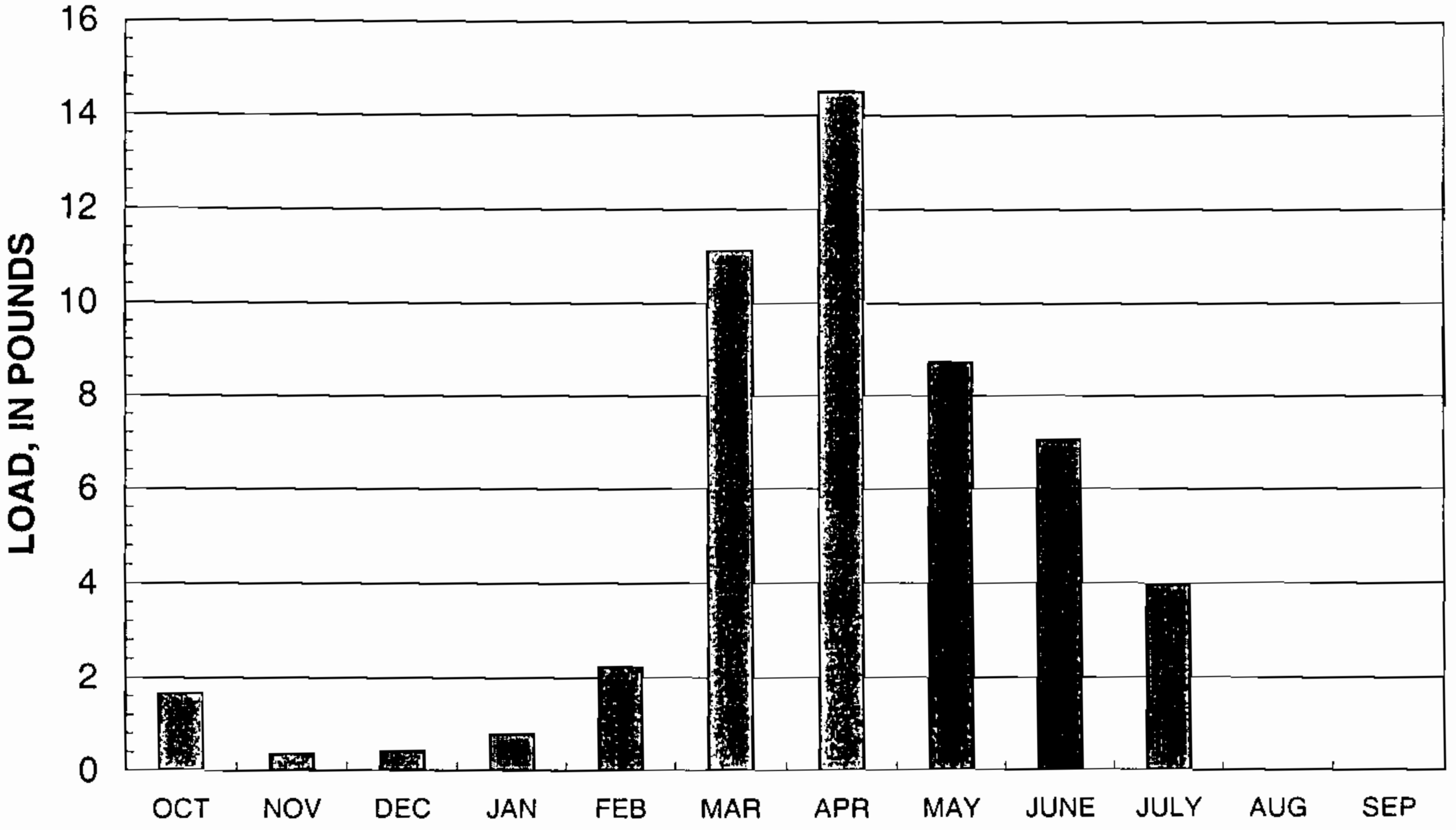


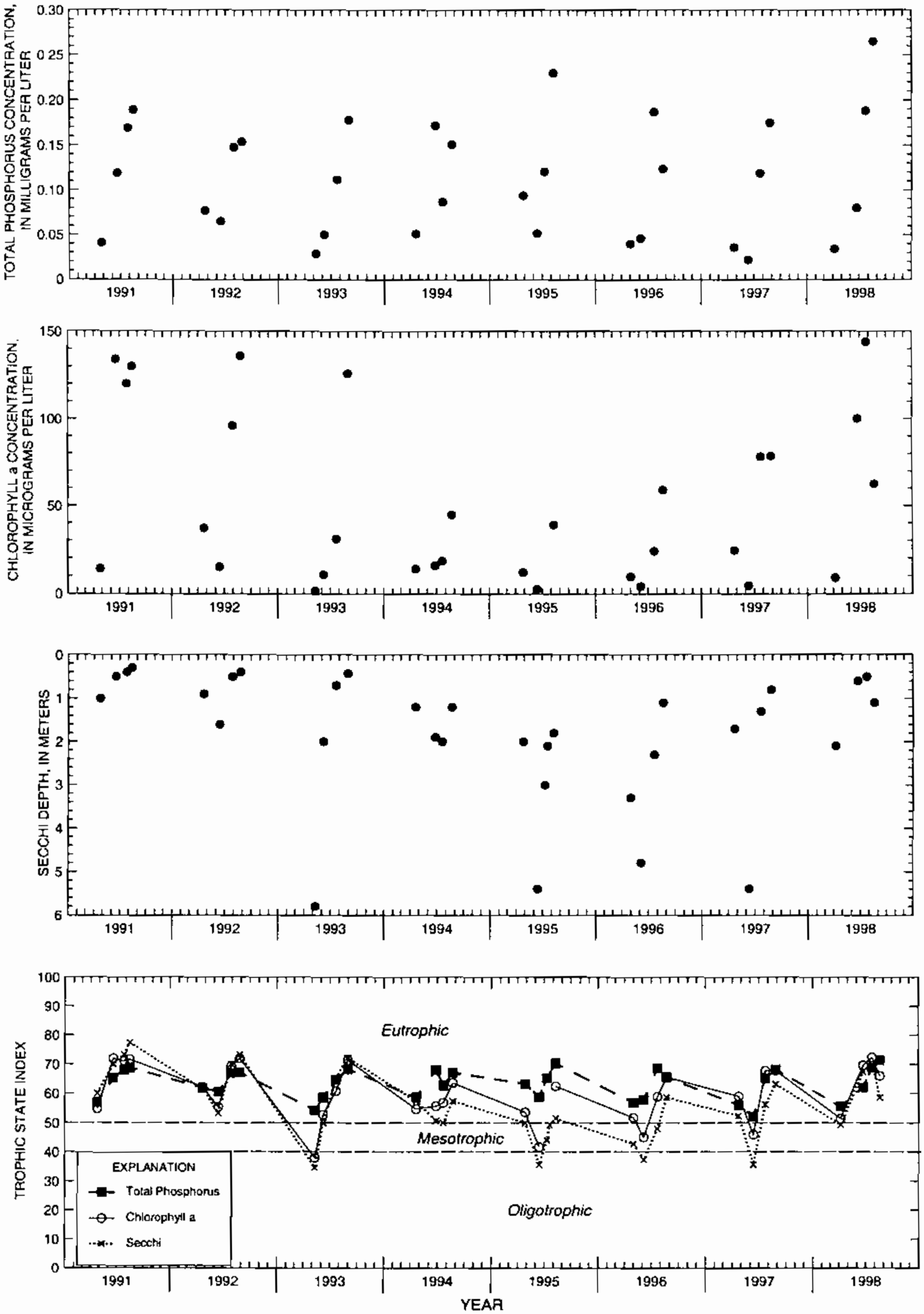
Daily lake stage at Little Green Lake near Markesan, Wisconsin, October 1997 through September 1998.

MONTHLY FLOW FROM LITTLE GREEN LAKE, OCT. 1997 - SEP. 1998



MONTHLY PHOSPHORUS DISCHARGED THROUGH OUTLET
FROM LITTLE GREEN LAKE, OCT. 1997 - SEP. 1998





Surface total phosphorus, chlorophyll a concentrations, Secchi depths, and TSI data for Little Green Lake near Markesan, Wisconsin.

04073000 LITTLE GREEN LAKE NEAR MARKESAN, WI

LOCATION.--Lat 43°44'04", long 88°58'23" in NW1/4 NE1/4 sec.32,T.15N.,R.13E., Green Lake County, Hydrologic Unit 04030201, near lake outlet, and 2 mi north of Markesan.

DRAINAGE AREA.-- 3 35 mi.^{2}

PERIOD OF RECORD.--August 1936 to September 1964, 1978, 1991 to current year. Amount of data available for each year is variable, ranging from 4 to about 200 stage values per year.

GAGE.--Nonrecording staff gage. Datum of gage is 90.00 ft above Public Service Commission datum and 921.65 ft above sea level.

REMARKS.--Lake level is influenced by lake outlet structure.

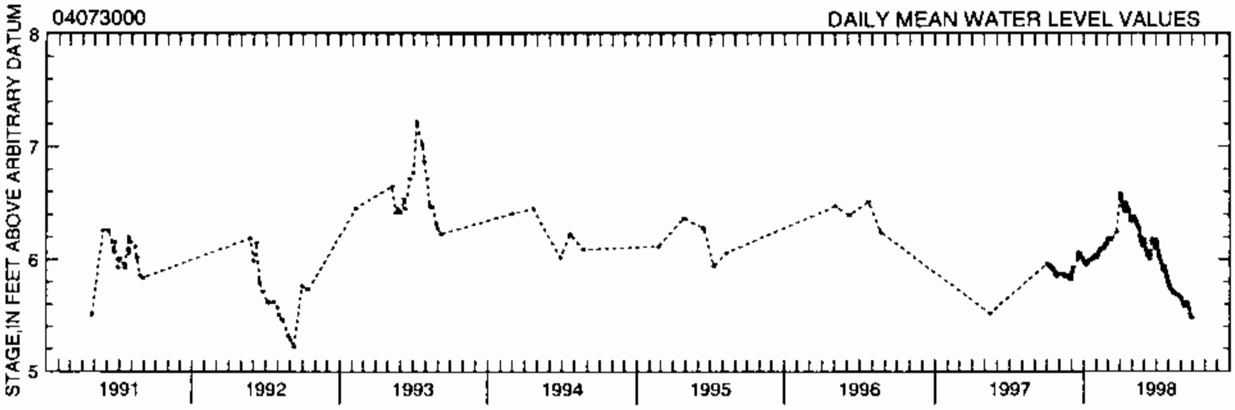
EXTREMES FOR PERIOD OF RECORD.--Maximum observed gage height, 7.36 ft, July 23, 24, 1960: minimum observed, 4.02 ft, Dec. 25-31, 1958.

EXTREMES FOR CURRENT YEAR.--Maximum observed gage height, 6.58 ft, Apr. 1-2; minimum observed, 5.48 Sept. 28 and 30.

GAGE HEIGHT, FEET, WATER YEAR OCTOBER 1997 TO SEPTEMBER 1998

DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	5.96	5.87	5.85	5.97	6.02	6.17	6.58	6.34	6.18	6.18	5.80	5.66
2	---	5.87	5.89	5.97	6.02	6.17	6.58	6.34	6.16	6.16	5.78	---
3	---	5.87	5.89	5.96	6.02	6.19	6.56	6.36	6.14	6.16	5.76	5.64
4	5.95	5.87	5.93	5.97	6.04	6.19	6.56	6.36	6.14	6.14	5.74	---
5	---	---	5.93	5.96	6.04	6.19	6.52	6.38	6.10	6.10	5.74	5.62
6	5.94	5.87	---	5.95	6.04	6.19	6.50	6.38	6.08	6.08	5.76	---
7	---	---	---	5.95	6.06	6.18	6.48	6.38	6.04	6.06	5.74	5.60
8	5.95	5.87	---	5.97	6.08	6.18	6.48	6.36	6.06	6.04	---	---
9	5.95	5.87	---	5.97	6.08	6.18	6.46	6.36	6.04	6.02	---	---
10	5.93	5.87	---	5.97	6.08	6.18	6.46	6.34	6.04	6.02	---	5.58
11	5.93	---	---	5.98	6.08	6.18	6.44	6.34	6.04	6.00	5.72	---
12	5.93	5.87	---	---	6.08	---	6.44	6.34	6.04	6.00	5.72	---
13	---	5.85	---	---	6.08	---	6.42	6.32	6.02	5.98	5.70	---
14	5.93	---	---	---	6.10	---	6.42	6.30	6.02	5.98	---	5.58
15	5.91	---	---	6.00	6.10	---	6.44	6.30	6.02	5.96	---	---
16	5.91	---	6.0	6.00	6.10	---	6.50	6.30	6.00	5.94	5.70	5.62
17	5.91	---	6.02	6.00	6.10	---	6.48	6.30	6.04	5.94	---	---
18	5.91	---	6.06	6.00	6.10	---	6.46	6.28	6.08	5.92	---	5.62
19	5.89	5.84	6.05	6.00	6.10	---	6.46	6.28	6.16	5.90	5.70	---
20	5.89	5.85	6.04	---	6.10	---	6.46	6.26	6.18	5.90	---	5.60
21	5.89	5.85	6.03	---	6.12	---	6.44	6.22	6.18	5.94	---	---
22	5.87	5.85	6.04	6.00	6.12	---	6.44	6.20	6.16	5.94	---	---
23	5.85	5.84	6.04	6.00	6.14	6.24	6.44	6.18	6.16	5.92	5.68	5.56
24	5.85	5.84	6.05	6.00	6.14	---	6.42	6.16	6.14	5.90	---	5.52
25	5.85	5.84	---	6.02	6.14	---	6.38	6.16	6.14	5.90	---	5.50
26	5.85	5.82	---	6.02	6.14	---	6.38	6.14	6.12	5.88	5.68	---
27	5.87	5.82	---	6.02	6.14	---	6.36	6.12	6.12	5.86	---	---
28	5.87	5.82	6.01	6.02	---	---	6.36	6.12	6.10	5.84	---	5.48
29	5.87	5.82	6.00	6.04	---	---	6.34	6.16	6.10	5.82	---	---
30	---	5.82	5.99	6.04	---	---	6.34	6.16	6.18	5.80	5.66	5.48
31	5.87	---	5.98	6.04	---	---	---	6.18	---	5.80	5.66	---
MEAN	---	---	---	---	---	---	6.45	6.27	6.10	5.97	---	---
MAX	---	---	---	---	---	---	6.58	6.38	6.18	6.18	---	---
MIN	---	---	---	---	---	---	6.34	6.12	6.00	5.80	---	---



434412088590700 LITTLE GREEN LAKE, AT CENTER, NEAR MARKESAN, WI

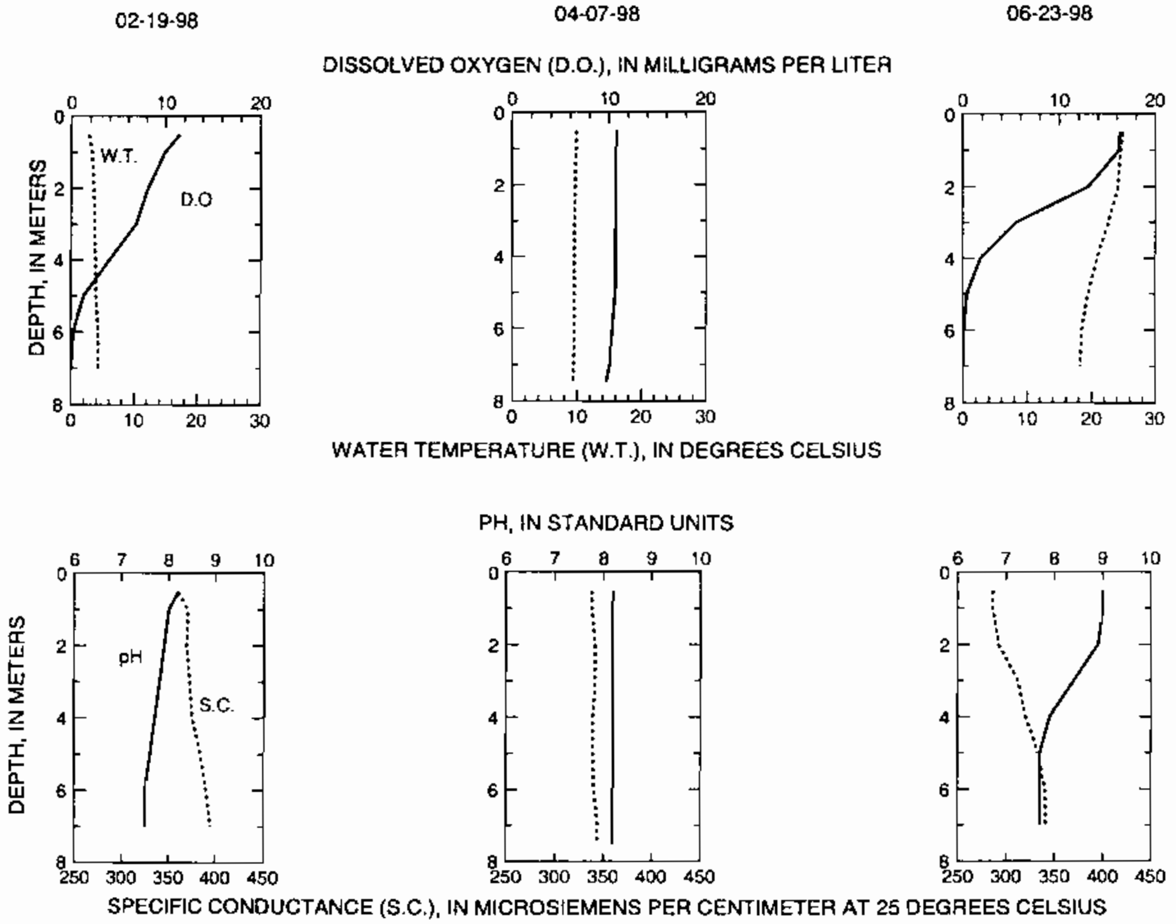
LOCATION.--Lat 43°44'12", long 88°59'07", in SW 1/4 SW 1/4 sec.29, T.15 N., R.13 E., Green Lake County, Hydrologic Unit 04030201, 2 mi north of Markesan.

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

REMARKS.--Lake sampled near center at the deep hole. Water-quality analyses done by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, FEBRUARY 19 TO JUNE 23, 1998
(Milligrams per liter unless otherwise indicated)

	Feb. 19		Apr. 07		June 23	
Lake stage (ft)	4.96		6.48		6.16	
Secchi-depth (meters)	---		2.1		0.6	
Chlorophyll a, phytoplankton (µg/L)	---		8.90		100	
Depth of sample (m)	0.5	7.0	0.5	7.5	0.5	7.0
Water temperature (°C)	2.7	4.3	9.9	9.4	24.9	18.2
Specific conductance (µS/cm)	359	395	338	344	286	341
pH (units)	8.2	7.5	8.2	8.2	9.0	7.7
Dissolved oxygen	11.5	0.0	10.7	9.7	>16.3	0.1
Phosphorus, total (as P)	0.032	0.062	0.034	0.035	0.08	0.167
Phosphorus, ortho, dissolved (as P)	---	---	<0.002	---	---	---
Nitrogen, NO2 + NO3, diss (as N)	---	---	0.018	---	---	---
Nitrogen, ammonia, dissolved (as N)	---	---	<0.013	---	---	---
Nitrogen, amm. + org., total (as N)	---	---	0.50	---	---	---
Nitrogen, total (as N)	---	---	0.52	---	---	---
Color (Pt-Co. scale)	---	---	10	---	---	---
Turbidity (NTU)	---	---	2.2	---	---	---
Hardness, as CaCO3	---	---	160	---	---	---
Calcium, dissolved (Ca)	---	---	31	---	---	---
Magnesium, dissolved (Mg)	---	---	21	---	---	---
Sodium, dissolved (Na)	---	---	7.3	---	---	---
Potassium, dissolved (K)	---	---	3.7	---	---	---
Alkalinity, as CaCO3	---	---	153	---	---	---
Sulfate, dissolved (SO4)	---	---	6.0	---	---	---
Chloride, dissolved (Cl)	---	---	15	---	---	---
Silica, dissolved (SiO2)	---	---	1.3	---	---	---
Solids, dissolved, at 180°C	---	---	196	---	---	---
Iron, dissolved (Fe) µg/L	---	---	<10	---	---	---
Manganese, dissolved (Mn) µg/L	---	---	<0.40	---	---	---



WATER-QUALITY DATA, JULY 24 TO AUGUST 20,1998

(Milligrams per liter unless otherwise indicated)

	July 24				Aug. 20				
Lake stage (ft)	5.90				5.68				
Secchi-depth (meters)	0.5				1.1				
Chlorophyll a, phytoplankton (µg/L)	144				62.5				
Depth of sample (m)	0.5	4.0	5.0	7.0	0.5	4.0	6.0	6.5	7.5
Water temperature (°C)	24.6	24.6	23.5	20.2	23.9	23.7	23.3	22.9	22.0
Specific Conductance (µS/cm)	279	280	320	379	293	296	316	324	370
pH (units)	8.8	8.7	7.8	7.1	8.6	8.6	8.1	7.9	7.2
Dissolved oxygen	7.7	6.0	0.4	0.2	5.4	4.9	0.4	0.3	0.3
Phosphorus, total (as P)	0.188	0.185	0.364	0.733	0.265	0.287	0.480	0.528	1.320

07-24-98

08-20-98